

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
Karen Ross, Secretary

2014
Specialty Crop Block Grant Program – Farm Bill (SCBGP-FB)
FINAL REPORT

USDA, AMS Agreement No:
Specialty Crop Agreement No. 14-SCBGP-CA-0006

State of California
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Date Submitted:
March 5, 2018

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CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 1	**Project Title:** Always in Season – Building Community	
Grant Recipient: Buy California Marketing Agreement	**Grant Agreement No.:** SCBG 14001	**Date Submitted:** December 2017
Recipient Contact: Nick Matteis	**Telephone:** (916) 441-5302	**Email:** nmatteis@agamsi.com

Project Summary

California has more than 25 agricultural marketing programs (marketing orders/commissions) engaged in the promotion of specialty crop products. The marketing and promotional efforts of these entities independently compete in a highly diversified media environment for consumer visibility. This project served a need for a promotional "umbrella" to help crosslink independent messaging of these entities to better impact consumer visibility, awareness and increase the competitiveness of California's specialty crop industry.

This project continued the promotional media marketing umbrella, "*California, Always in Season*," which highlighted the year-round growing season in California, its diversity of specialty crops/growing regions, as well as the food experiences that are uniquely Californian. The objective of this media campaign was to position California as the premiere destination for culinary travel as well as to increase the exposure, affinity, and sales of California grown specialty crops. This was achieved through capitalizing on the current momentum of the prior "*California, Always in Season*" promotion, the BCMA public relations and social media campaign, heightened consumer interest in the food supply (where it grows, how it grows and who grows it), and providing the opportunity for California agricultural marketing orders/commissions to independently leverage the media messaging/campaigns.

This project was timely for California's specialty crop industry because it built on the success of the prior "*California, Always in Season*" promotion and fills a needed void in the generic marketing of specialty crop products. The "*California, Always in Season – Building Community*" campaign's goal was to continue to enhance the marketability and competitiveness of specialty crops through the development of markets for all California producers to leverage the work and commitment of a diversity of stakeholders. This was achieved through the objective of expanding CA GROWN participation among specialty crop producers, marketing orders and other stakeholders groups through innovative marketing and promotional activities.

This project built upon the 2013 Specialty Crop Block Grant Program Project 1: *California, Always in Season*. This project complemented the previous project by capitalizing on the successful reach of the content and generating six new content pieces featuring six new specialty crop farmers and their fans. Enhancements include diversification in print media placements to capture both a national audience through Food and Wine Magazine as well as adding a print publication with a western regional audience reach through Sunset magazine. Further enhancement was accomplished with an additional touch point in each Food and Wine and Sunset issue entitled *Fresh Finds* included a call to action to the spread featuring the farmer and specialty crop story. This project also brought a new retail promotions strategy which resulted in positive sales lift.

Project Approach

Six print spreads and six videos were completed and released through run of the project campaign. The six print spreads and six videos featured a California cherry farmer, California wine grape growers, California

prune farmers, a California peach farmer, a California olive farmer and olive oil producers, and a California greenhouse tomato farmer. The cherry, prune and wine grape videos and print spreads captured the northern California region and featured the San Francisco restaurant, Rich Table, where a husband and wife team developed unique recipes using California prunes in asparagus and salsa verde recipe and California cherries in a spaghetti cherry bolognese. The Wente spread and video featured the restaurant on the Wente tasting property that is supplied by a seasonal garden on the property and a recipe developed by the Wente restaurant chef for a California roasted beet salad. The peach, tomato and olive oil videos and print spreads captured the southern California region and featured the Los Angeles restaurant, Animal, where the chef owners developed unique recipe content using Houwelings tomatoes and olive oil in a recipe. The peach print spread and video highlighted a local Fresno California brewery, 559 Brewery, which uses Wawona Ranch peaches in one of their beers. The content was hosted on the Visit California website and all calls to action in the digital and print media buys were designed to drive food and travel interested audience to the campaign content. The video content was also linked on the CA GROWN website. The media buy also executed custom social media content hosted on both Sunset and Food & Wine Magazine platforms which featured the Always in Season content as well as the CA GROWN activation at Sunset Celebration weekend.

Visit CA Always in Season Website Page: http://www.visitcalifornia.com/always-season/

CA GROWN Website Always in Season Link Image: http://www.californiagrown.org/

Samples of the final versions of the second six print spreads are attached (the Wawona Ranch peach story and the Lodi Farms cherry story were published in both Food & Wine and Sunset Magazines):

The (Buy California Marketing Agreement) BCMA project team continued regular weekly blog and social media promotional efforts highlighting specialty crops through content such as: recipe round-ups, farmer stories, *Always in Season* promotional posts, locally grown attractions including farm to fork restaurants and agritourism activities in California.

The project also included five event activations. Two consumer facing events: Sunset Celebration Weekend and Sunset Savor the Central Coast and three trade/stakeholder facing events: Fresno Food Expo, Produce Marketing Association – Fresh Summit, and California Grocers Association Strategic Conference.

The BCMA project team engaged and supported a retail promotion that highlighted the CA GROWN hashtag campaign with Walmart and produced signage for all 233 Walmart Supercenters and 74 Neighborhood markets in California. The POS signage was displayed in the “Locally Grown” produce sections of all of the Walmart stores. Regional management also engaged their employees to participate in the call to action for the hashtag campaign and set a goal for 500 hashtags by December 31, 2014 and the goal was met. The BCMA project team executed an additional retail promotion with Costco Southern California in 30 designated warehouses featuring 20 California specialty crops for a two week period from May 30 to June 11, 2017.

To ensure that Specialty Crop Block Grant funds were used to solely enhance the competitiveness of specialty crops during this reporting period BCMA selected only specialty crops to be featured in the *Always in Season* campaign. Further, BCMA ensured that all social media posts and blogs promoted specialty crops and specialty crop producers. All work provided by contractors was monitored to ensure that Specialty Crop

Block Grant funds were expended on promotion of specialty crops. All event activations included prominent display of California specialty crops.

Visit California provided an in-kind contribution of almost $5 million to build the environment to host the campaign content on their online channels; incorporate the content into their content distribution strategy for the duration of the campaign; inclusion of the campaign content at key influencer and media events and featuring California specialty crops on display at those events.

Goals and Outcomes Achieved

Activities in order to achieve the performance goals included executing 79 media placements which included a combination of print and digital media placements that were designed as native content pieces within each media. These media placements targeted food and travel, California locally grown, farmers market, farm tour brewery, and winery enthusiasts. The social media and blog content targeted a similar audience but added a layer targeting audiences residing near the featured specialty crop farmers featured.

In addition to the content distribution strategy, the BCMA team engaged consumers and stakeholders at five event activations. Two consumer facing events: Sunset Celebration Weekend and Sunset Savor the Central Coast and three trade/stakeholder facing events: Fresno Food Expo, Produce Marketing Association – Fresh Summit, and California Grocers Association Strategic Conference.

The targets and actual accomplishments were as follows:

- Media performance
  - Impression delivery Target: 77,897,743 - Actual: 72,032,090
  - Engagement with custom content Target: 15% rate of engagement, 60,000 visits to food and wine content on VisitCalifornia.com and 40,000 likes on BCMA social media sites - Actuals: 26% rate of engagement, 23,000 visits to food and wine content on VisitCalifornia.com and 62,200 likes on BCMA social media sites.
- Earned media coverage
  - Number of media placements Target: 40 – Actual: 79
  - Impressions Target: 1.74 million – Actual: 4,130,295
- Advertising effectiveness:
  - Increased awareness of California specialty crops among target audience Target: 25% increase from first year – Actual: 41%

The baseline data utilized to show progress toward setting achieved targets was the performance data from 2013 *Always in Season* and is as follows.

- Media performance
  - Impression delivery (benchmark – 58,310,400 Year 1)
  - Engagement with custom content (benchmark – 10% engagement and 50,000 website visits; Year 1)
- Earned media coverage
  - Number of media placements (benchmark – 30; Year 1)
  - Impressions (benchmark – 1,500,000; Year 1)

- Advertising effectiveness:
  - Increased awareness of California specialty crops among target audience 21%

The project completed seven creative executions and 13 unique digital media placements and total of 79 total ad assets/placements run for the *Always in Season* promotion. To date, the promotion achieved an average click through rate of .15% and a total of 69,537,307 impressions delivered, 11,737,307 digital impressions and 57,800,000 print impressions (48 million in Food and Wine Magazine and 9.8 million in Sunset Magazine).

The digital program generated 17,000 clicks and over 23,000 sessions to the www.visitcalifornia.com/always-season/ landing page. Over 83% of all visits to the landing page were sourced from paid media efforts. This resulted in 90% unique visitors to the site, where the average user spent approximately 2:17 consuming content. Food and Wine's daily e-newsletter sponsorships saw over 10% higher open rates (26% vs. 15%), with banner engagement superseding benchmarks as well (.11% vs. 13%).

CA GROWN Social media analytics for the campaign duration are as follows:
BCMA total social media impressions: 2,494,783

FACEBOOK
Total Reach: 1,532,042
Likes: 62.2K
Total Impressions: 2,270,162

TWITTER
Total Impressions: 199.5K
Followers: 3.8K
Retweets: 460
Tweet Likes: 976

INSTAGRAM
Followers: 8.3K
Total Post Likes: 25,121
Total Comments: 822

The total impressions target for this project was: 77 million impressions and the target total media placement goal was: 40 placements.

The Visit California fall 2015 domestic research survey that reported on the *Always in Season* campaign shows that the overall average lift in perception of the state's culinary products is 5.3%. Individual lift was strongest for farm tours, breweries, and farmers markets, though CA GROWN crops saw a 2.4% lift as well.

Those who recall this campaign more closely associate California with all of the culinary products except wineries; the association between California and wineries is so strong that it is difficult to improve.

Associate California with these Culinary Products	No Recall	Always in Season Recall	% Lift
Wineries	4.5	4.5	0.0%
Fine dining	4.0	4.2	5.0%
Local cuisine	3.8	3.9	2.6%
Farmers markets	3.6	3.9	8.3%
Breweries	3.2	3.6	10.5%
Farm tours	2.9	3.2	12.3%
California-grown crops (almonds, grapes, etc.)	4.2	4.3	2.4%
Average	**3.7**	**3.9**	**5.3%**

Source: SMARI

Retail Promotions
The BCMA project team executed a two week promotion with Costco Southern California featuring 20 California specialty crops items in 30 warehouses generating a sales lift of 20-100% for select categories of products and over $2 million in sales.

Beneficiaries

Approximately 350 different specialty crops are grown in the state and each of the growers benefited from the media campaign designed to increase California specialty crop visibility, awareness and overall sales. Specifically, the specialty crop agricultural marketing orders and their approximately 10,000 California specialty crop growers that benefited from this project are as follows: Kiwifruit Administrative Committee; CA Association of Nurseries and Garden Centers; CA Pear Advisory Board; CA Asparagus Commission; CA Avocado Commission; CA Cut Flower Commission; CA Farm Bureau Federation; Agricultural Council of California; Wine Institute, CA Dried Plum Board; CA Fig Advisory Board & CA Fresh Fig Growers Association; American Pistachio Growers; Certified Farmers Markets of Sacramento; Pacific Coast Famers Market Association; California Certified Organic Farmers; California Olive Committee; California Cherry Board.

The approximate number of beneficiaries affected by the project's accomplishments and economic impact of the project is 10,000 specialty crop farmers.

Lessons Learned

Lessons learned through the execution of the project were that securing retail partners that could execute impactful promotions with an ability to report sales metrics took much longer to secure than anticipated. Though the awareness achieved through the first promotion with Walmart the BCMA team did not predetermine a strategy to measure sales associated with the promotion. Learning from that experience the BCMA team, in arranging the promotion with Costco Southern California ensured that there were reportable sales metrics that could show effectiveness of an additional retail promotion spend. The partnership was extremely successful with a significant sales increase number for a two week period lifting sales for select categories anywhere from 20-100%.

The unexpected outcomes of this project came from an anecdotal report from, Houwelings Tomatoes, who was featured in one of the print spreads and videos who reported, “In the last 3-4 years since amplification of CA Grown promotions they have brought on a number of new clients directly related to their ability to supply CA Grown products including: Raley’s, Albetsons, Whole Foods, Sam’s Club, Walmart, Costco, Safeway/Vons, Bristol Farms and Gelson’s.” Additional unexpected outcomes include the feedback and interest the BCMA team learned of at the California Grocers Association Conference of their retail members seeking various levels of support to promote local California products and their need for quality content.

The project did not achieve the total impression target of 77 million impressions for the duration of the campaign, but came very close. Additionally, the target of 60,000 visits to the Visit California website was not met. Though these particular targets were not met, all other performance metrics exceeded targets set and showed exceptional rates of engagement with the content, awareness and significant sales lift. The key learning from the shortcomings in target impressions was that though the project had significant print impressions (over 40 million) the targets for digital impressions being harder to predict could have been a little more modest. With respect to the website visit target, the key learning was that this performance metric did not serve the objectives and goals as well as the above mentioned awareness, engagement and sales metrics and in the future would not be selected as a measure of performance.

Additional Information

See Attachment 1.

USDA Project No.:	Project Title:	
2	California State Fair Extra Virgin Olive Oil Competition	
Grant Recipient: California Exposition & State Fair	**Grant Agreement No.:** SCB14002	**Date Submitted:** December 2017
Recipient Contact: Nancy Koch	**Telephone:** (916) 263-3086	**Email:** nkkoch@calexpo.com

Project Summary

The purpose of the project was to address the need identified in an article published in May of 2013 by the University of California, Davis (UCD) Olive Center regarding "Consumer Attitudes toward Olive Oil." The article suggests a need for clearer information so consumers can better understand the olive oil choices available.

This project created the California State Fair Extra Virgin Olive Oil Competition and market outreach display to educate consumers about oils and California's certification programs during the California State Fair, which is visited by hundreds of thousands annually. The objective was to elevate California's rating in the market through the competition, as regular competitions improve product quality. Consumers in the marketplace in turn select award winning products which would increase sales of California olive oils.

Coupling the competition with a market outreach display at the California State Fair allowed hundreds of thousands of consumers the opportunity to learn about California certifications as well as sample or purchase award winning oils. The outreach display connected farmers to consumers, providing opportunity for direct marketing of their olives while helping Californians reach a better understanding of the importance of California olive oil certifications.

The competition was timely as it supported California olive oil farmers competing in markets where European olive oils held notoriety. The global market lacked standardization in extra virgin olive oil labeling causing confusion for consumers trying to discern quality oils. This project was designed to enlighten consumers about the benefits of California certified extra virgin olive oils without disparaging foreign olive oils on the market.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Review similar competitions to maintain industry standards and participant expectations:
Staff traveled to the Los Angeles County Fair (known worldwide for its olive oil competition), before grant funds were available. Although the trip was part of the funding requested the timing of the competition did not fit within the award period. Understanding the visit would provide critical competition information, the California State Fair opted to absorb the cost of the visit knowing it would pay off in the long run. After the grant award was made known, staff were able to visit the Napa County Fair Olive Oil Competition and an olive oil producer in Lodi to observe and gather additional insight for the new competition and market outreach display. The visits assisted staff tremendously as industry standards were learned and incorporated into the newly created California State Fair Extra Virgin Olive Oil Competition. Staff also met with the executive director for the California Olive Oil Council (COOC) and the UCD Olive Center to discuss sensory

evaluation processes for discerning quality oils ensuring the new competition aligned with industry standards. At the suggestion of the council staff attended the California Olive Oil Convention to advertise the new competition and develop contact list of California Olive Oil Producers. Attending the convention proved quite beneficial in creating rapport and furthering communication with olive oil producers.

Contact California olive oil industry:
The project manager was in communication with multiple organizations that supported the Olive Oil industry such as the COOC, a sensory organization, and individuals within the Olive Oil Cooperative Extension. Communication threads regarding the competition and market outreach display opportunities at the California State Fair included invitations, newsletters, and media releases. Those that marked having interest in olive oil within the newsletter were included in mass communications.

Develop, author and publish competition materials/ Competition handbook:
During Year 1 staff worked on creating a competition handbook that had the capability of expanding as the competition grew. Each year the handbook is updated with additional division and classes that were approved by expert judges. These annual updates proved beneficial as added categories reflected industry's growth and experimentation. These expansions increased the size of the competition and provided additional product lines available for tasting at the market outreach display during the California State Fair. Visitors to the State Fair were provided opportunity to learn and taste the latest and greatest oils grown in California, making them market savvy consumers.

The first California State Fair Extra Virgin Olive Oil Competition included 7 divisions, with each division supporting 8 classes for a total of 60 possible awards. In 2017 the California State Fair competition included 8 divisions, with each supporting 8 classes, additionally the "Best of…." categories added increased the number of possible awards available to 73. Understanding the importance of keeping current with the times the California State Fair intends to continue adding new award categories deemed appropriate by experts, assisting the competition and the California olive oil market with continued growth. The first year of the competition, 100 handbooks were printed and sent out to industry professionals, by the third year in operation 215 handbooks were distributed; demonstrating the growth and interest in the competition. Supporting environmentally friendly options the handbook is and will continue to be made available electronically. Link to current competition handbook: http://www.castatefair.org/wp-content/uploads/2015/01/Olive-Oil.pdf

Compile contact list of California olive oil representatives:
After visiting the COOC Convention in the early beginnings of the project staff collected 100 contacts of those in the industry attending the convention. With persistent and diligent communications staff has annually grown the original contact list to over 300. This current list of contacts includes 294 olive oil producers and exhibitors and 45 olive oil competition judges or advisory members. Also included are 9 media outlets that cover stories in association with the California State Fair.

Develop outreach materials/ publications:
In Year 1 of the grant, the competition handbook was published and a tri-fold brochure was created. Six hundred copies of the brochure were printed and mailed to 108 olive oil representatives to be distributed to growers and producers of olive oil. Link to brochure; http://www.castatefair.org/wp-content/uploads/2015/01/Olive-Oil-Brochure.pdf

As outreach materials proved to be a great way to attract industry interest to both the competition and the State Fair olive oil market outreach display, by Year 3 of the grant, outreach materials had been expanded to include invitational letters and five electronic newsletters that reached over 300 olive oil industry professionals. Newsletters were used to encourage award winners to display and provide tastings of their award winning oils during State Fair in the olive oil market outreach display.

Conduct outreach via, email newsletter, phone, mailings, etc:
Outreach was conducted via phone calls, emails, and mailings. Staff quickly discovered the most effective means of contact for industry professionals was via email. In Year 1 of the grant 136 emails were sent. As emails are easily forwarded to others that share interest in olive oil by Year 3 of the grant, staff sent 425 emails, more than tripling communications in three years' time. Staff continued canvassing interest with phone calls increasing phone communication 25% by Year 3. The use of digital communications proved the most effective in growing contacts and spreading the word about the competition and State Fair market outreach display.

Recruitment of judges:
In Year 1 of the grant, the relationship developed with the COOC proved beneficial in selecting judges from several sensory evaluation panels for the competition. Thirteen judges were recruited for the inaugural California State Fair Extra Virgin Olive Oil Competition. As the competition grew in size and entries, recruitment of judges became the responsibility of the Head Judge. By Year 3 of the competition the Head Judge chose 16 experienced individuals from four sensory panels. An additional panel was added to ensure judging was current with industry trends.

To encourage future interest in olive oil the competition added an apprentice team of judges (four youths) that were invited to learn about the judging process by tasting and scoring oils without impacting the outcome. This addition provided the four youth involved a great opportunity to learn about the industry and the importance of California certifications to help identify quality oils.

Compile competitor information:
Competitor information was collected by staff and used for future communications. The competition saw a 10% increase in competitors between Year 1 and Year 3 yet the number of oils entered was increased by 20%. The purpose of the project; "to elevate California's rating in the market through the competition, as regular competitions improve product quality" was reflected as competitors were vying for awards. The greater marketing story was the increased number of oils entered; furthering the industry with increased award winning California olive oils for consumers in the marketplace.

Hire program staff:
Since most positions were of a seasonal nature, difficulties arose as key project staff would leave for fulltime employment opportunities. During much of the project timeline the Assistant work was completed by various staff and the program manager. Although frustrating for all involved, work tasks were always kept on time and over the three year span of the project the program manager became very familiar with every single aspect of the project. It the future, the assistant work tasks will stay with the project manager for continuity.

Produce reports for judging including score sheets:
The competition adapted the scoring system from the International Olive Oil Council to ensure the inaugural competition would reward oils that represented the highest quality standards. Judges scoring sheets with updated competition categories added are tallied for awards. Program manager oversees scoring sheets and stores them in a secure location for five years, pending any potential protest after each competition. Competition has received kudos from judging panels for its level of professionalism in its scoring and awarding procedures and has not received any protest to date.

Purchase and stock inventory of competition judging equipment:
All supplies necessary to support the competition were purchased in Year 1 of the grant. As judging Extra Virgin Olive Oil involves sensory evaluation, a specialty tasting glass is used. By Year 3 of the grant, it was evident that due to breakage during handling additional glasses and dishwasher racks were needed, and purchased. Additionally, carts used in judging were problematic as oils fell during transport or handling while looking for labels. These additional supplies were purchased in Year 3 to aid and support continued competitions.

Coordinate for announcement of results at Capitol or other high profile event:
As the project supports farmers and producers of California olive oil, the California State Fair has annually invited the Secretary of the California Department of Food and Agriculture to attend its "Best of California" award announcement event. The event takes place on the steps of the Capitol where the California State Fair promotes California award winning Extra Virgin Olive Oil. This high visibility event helps bring attention to California and its role in the feeding the world with quality agricultural products.

Coordinate with Friends of the California State Fair (FOF) for volunteers for entry delivery:
Annually the project manager communicated with the FOF (volunteer organization) to coordinate dates volunteers are needed to assist with the competition. Some of the positions filled by the volunteers included competition runners, pourers and judging assistants. Volunteers play an important part in helping with competitions, and those with previous experience are invaluable.

Install software for judging event using ShoWorks:
ShoWorks is a digital program that allows competitors to access judging, event handbooks, enter and pay for their competition fees, and judges' access to enter award information online. Annually the ShoWorks program is updated to reflect categories represented, registration information, and current competition handbooks. Contact list are created from competitor information from ShoWorks entries, helping further communication.

Event preparations for entry delivery, catering, etc:
Project manager annually communicated and placed work order and developed contract with catering organization. Catering ensures all food service conforms to judging event regulations. Judges are only provided palate cleansers and beverages that are approved for sensory evaluations practices for Extra Virgin Olive Oil. Contracts for judges are annually secured by project manager based on head judge's recruitment.

Hold entry delivery event, inventory intake, judging day:
Within three years of competitions staff has taken in and inventoried over 1,500 bottles of Extra Virgin Olive Oil ranges in size from 10 to 24 ounce (approx. 200 gallons). All entries were logged in and stored in a

secured environment prior to competition per rules and guidelines. As the competition increased in the number of entries by 20% staff investigated a more efficient means of storing entries on metro rack carts. These racks have a cradled storage rack system which will improve efficiency and reduce the chance of bottle breakage during transport.

Equipment and organization preparations for judging event:
Staff and volunteers are used to move in and set up judging equipment and supplies for the competition (tasting glasses, scoring cards, olives and administrative support materials). Some of the preparation activities involve de-scenting the areas within close proximity to the room where the competition is held to avoid possible sensory contamination during judging.

Judging event:
The inaugural competition included 12 judges and a head judge that were recognized taste panelists from all over California. By Year 3 of the grant the competition included 16 judges and four apprentice judges (youth) that tasted and evaluated 170 olive oils from 66 different producers. At completion of Year 3's competition 133 oils from 56 different producers received medal awards. The competition witnessed how seasonal influences on olive oil production impacted the number of producers that opt to participate in the competition. When olives suffered in production many producers choose to sell their entire crop to a larger producer rather than bottling and selling their oils individually.

Double check scoring calculations:
Promoting the competition's integrity final scoring calculations are re-checked by clerks and audited for accuracy by project manager the day following the competition. As mentioned previously all scoring cards are kept in a secure location for five years, in case of protest.

Create results report:
The judging award results report is created by the project manager. Once awards have been announced, links to competition results are included in newsletters to link those interested in purchasing award winning oils directly from the producer. Following is an example:
http://www.castatefair.org/wp-content/uploads/2017/03/2017-Extra-Virgin-Olive-Oil-Competition-Judging-Results-with-Hyperlinks.pdf

Media event announcement of Best of Show winner(s):
Media releases are sent out before event so media organizations can plan to attend. By Year 3 of the grant 2,418 media contacts were notified of the event on the steps of the Capitol, where the best olive oil would be publically recognized.

Press release:
Annually the winners of the California State Fair Extra Virgin Olive Oil Competition are announced and press releases are shared with media organizations. In Year 1 of the grant, the press release was shared with 1,977 media contacts, by Year 3 of the grant that number was increased to 2,766 representing a 40% increase in media awareness of the competition and State Fair outreach display; helping promote interest in California Extra Virgin Olive Oil.

Research educational exhibit materials, design exhibit:
In Year 1 of the grant, staff put in over 900 hours of time researching, planning and designing the market outreach display for the State Fair. Some of that time involved staff visiting a well-known olive oil producing facility in Lodi to gather information and materials for the display to educate the public about California Extra Virgin Olive Oil. Annually staff would revisit and update the design and information presented within the outreach display to ensure it reflected current industry standards and offered interest to State Fair visitors.

Develop product tasting components of exhibit:
To reiterate the projects objective of elevating California's rating in the market through the competition, award winning oil producers were invited to participate in a market outreach display during the State Fair. Award winning olive oil was made available for fair visitors to taste and purchase if so desired. This component of the project provided consumers with the opportunity to learn about California olive oils directly from the producer. By Year 2 of the grant 14 producers of award winning products saw the value of direct marketing their products by participating in the market outreach display.

Schedule olive oil farmer appearances:
Staff contacted award winning oil producers to coordinate daily tasting events in the State Fair market outreach display. This display provided olive oil producers the opportunity to share their products with State Fair visitors with educational tastings as well as having award winning oils available for purchase.
In Year 1 of the grant 6,450 samples of Extra Virgin Olive Oil were given out. It was calculated that tastings averaged 112 samples per hour. For the producers that participated in the display this equated out to a sales average of $123 per hour or the equivalent of 6 bottles of olive oil sold per hour. The market outreach display became a popular stop for fair visitors. Visitation and interest in olive oil at the outreach display increased in Year 2 as 24,939 Extra Virgin Olive Oil samples were given out. Some producers underestimated the amount of sales they prepared for at the California State Fair and ran out of their popular oil product lines

Develop exhibit guest survey:
An exhibit guest survey comprised of six questions that could determine project outcomes was created using an online survey. The online survey was made available to fair visitors that visited the market outreach booth during the State Fair. Producers and assistants communicating with fair visitors in the display would encourage them to take the survey which consisted of six questions. Fair visitors were directed to three user friendly tablets to assist in collecting the responses to the questions. The survey provided the fair with the results of all surveys taken. This process allowed visitors to take their time in answering the questions. Intermittent technical issues with the tablets occurred which caused concern. However in the end as survey responses were reviewed the project easily met and exceeded its expected measurable outcome benchmark.

Construct exhibit:
In Year 1 of the grant the exhibit was constructed to support the various components of the display. Within it was educational signage that provided guests with information about California olive oil, video of the manufacturing process, tasting counters where visitors could talk directly to producers, displays of equipment and award winning olive oils that could be purchased. One popular iconic feature in the display was a nine foot tall olive oil bottle made of 440 individual olive oil bottles stacked on a constructed frame.

Refurbish exhibit/refreshed and updated:
Annually throughout the grant the market outreach display (exhibit) was updated and refreshed with current information to showcase the award winning oils.

Press release/media Olive oil at State Fair:
Press releases and media advisories that are sent out to promote the olive oil competition also include information for the public to come visit the market outreach display during the State Fair. These media releases help drive interest in the State Fair display and California's olive oil industry in general. By Year 3 of the grant, releases promoting the competition and the State Fair market outreach display were sent to 20 different media outlets that are a clearing house of information for a sundry of media organizations.

State Fair:
The project manager and staff oversaw the State Fair market outreach display to ensure it was cleaned, prepped, and maintained daily for the 17 days of the California State fair. Displays and tasting counters were dusted, cleaned and redressed as needed. Outreach and tasting materials are restocked to ensure any and all visitors to the display had the opportunity to taste award winning oils. Culinary interns and educational coordinator assisted producers participating in the display with pouring and tastings, in addition to directing visitors to the survey tablets.

Compile and analyze guest survey and create report:
Surveys results were provided by the organization that created the online survey. Results are compiled in easy to read pie charts with comments broken out and written out separately. Using the number of tastings recorded divided by three (average number of oils available for tasting) it is estimated that the display was able to capture survey information from 7-8% of the visitors. Of these participants in the survey over 20% were inclined to leave a comment which provided valuable insight and direction for future display activities. This information coupled with comments received repeatedly shared with producers and staff assisting in tastings, lead to the creation of the new education center to be showcased during the 2017 California State Fair. The center is designed to provide the visitor with a more in-depth educational experience regarding sensory evaluations which are a large part of the judging process for olive oils.

Report finding to industry leaders and collaborate on program and exhibit refinement:
Annually after the close of the California State Fair, the head judge, sensory consultant, project director, project manager and other key personnel would meet to discuss the competition and market outreach display. Findings from the surveys taken during the State Fair are shared and program refinement is discussed to ensure public interest in California olive oil continues to rise. Findings from survey and visitor comments during Year 2 led to the planning, design and creation of the education center showcased at the 2017 California State Fair promoting the California olive oil industry beyond the life of the grant.

Make revisions to competition outreach, judging process and exhibit based on industry feedback:
Project director and manager annually use feedback provided by the head judge, sensory consultant, and the producers that participated in the competition to plan and revise competition to keep it current with the industry. During this time additional competition categories and classes are considered with determination made for following year. This revision process provides an opportunity to get word out to the industry well in advance of the competition; keeping communications open with industry professionals.

Report all findings to grant authority and share olive oil sales figures with industry leaders:
Required reporting provided a platform to share project status and address questions with regards to reaching goals and measurable outcomes.

Sharing the olive oil sales figures with industry leaders was accomplished via many conversations, using phone, email and outreach newsletters that were sent to the contact list reaching over 300 in the industry.

This project solely benefitted the intended specialty crop – California extra virgin olive oil.

The Friends of The California State Fair played an important supportive role in the project. Volunteers from their organization assisted with both the California State Fair Extra Virgin Olive Oil Competition and the market outreach display during the 2015, 2016 and 2017 State Fairs. The COOC was instrumental in helping staff create the competition standards and select the initial panel of judges that would reflect the best of the California olive oil industry, for the inaugural competition.

Goals and Outcomes Achieved

The following project activities achieved the overall objective to elevate California's rating in the market through competition and increase Californians' knowledge of the efforts by California olive oil producers to establish and enforce the highest industry standards:

Create a statewide competition that awards the best certified California Extra Virgin Olive Oil with highest honors:
The competition was designed to increase interest in purchasing certified California olive oils embodying the highest quality standards. Award winners were announced at the steps of the State Capitol. Competition winners touting their awards on product labeling makes it easy for consumers to choose the very best of California when facing a variety of market choices.

Create a market outreach display at the California State Fair to increase Californians' knowledge of the efforts by California olive oil producers to establish and enforce the highest industry standards, and why such standards are important:
The market outreach display was designed to increase awareness by presenting information regarding California's Extra Virgin Olive Oil certifications, how and where oils are produced within California, and provide visitors with tasting or samplings of award winning oils. Visitors enjoyed having one on one interaction and communication with producers that participated in the display. Many visitors purchased award winning oils in the display and took home literature that would connect them to producers' websites, driving future sales. Producers participating in the display enjoyed the opportunity to share their knowledge with consumers and often times were surprised by the amount of sales that occurred in the display. Some producers ran out of oils as they had underestimated the amount of sales they might generate at the California State Fair. Visitors to the display were encouraged to take a survey that would measure their knowledge of extra virgin olive oil both pre and post their visit to the display. This survey provided the project with a measurable component that could determine the project's success in reaching its intended benchmarks.

At the conclusion of activities associated with the market outreach display and determined by visitor surveys, it was anticipated that guests will indicate a % increased that represented the likelihood they would to seek out

and purchase certified oils after visiting the State Fair Extra Virgin Olive Oil Market Outreach Display. The following annual benchmarks were proposed and regular progress was obtained as described below:

Year 1- the benchmark goal was 30% of visitors would likely seek and purchase certified oils after visiting the market outreach display. After surveys were tallied Year 1 actual percentage was 37% exceeding expected outcome measures.

Year 2 - the benchmark goal was 40% of visitors would likely seek and purchase certified oils after visiting the market outreach display. After surveys were tallied Year 2 actual percentage was 35%. Although this appeared to be a 5% deficiency in reaching outcomes measures, during review it was discovered that duplicative affirmative multiple choice answers may have caused the look of a deficiency.

Year 3 - the benchmark goal was 50% of visitors would likely seek and purchase certified oils after visiting the market outreach display. After survey questions were tallied Year 3 actual percentages are as follows: 31.25% - Definitely will would seek and purchase certified oils and 34.62% - Very likely would seek and purchase certified oils.
Exceeding the benchmark goal of 50% with a cumulative percentage of 65.87% of visitors would likely seek and purchase certified oils after visiting the market outreach display.

Successful outcomes related to the projects' competition:
In as short as 3 years' time, a little over 1/6 of the producers of Extra Virgin Olive Oil in the state of California recognized the importance of the competition and choose to participate by submitting their oil entries. Additionally by Year 3 of the grant, over 1/7 of the California's Extra Virgin Olive Oil producers were recognized for their award winning oils.

Successful outcomes related to the projects' Market Outreach display:
Visitation and interest in olive oil at the outreach display increased in Year 2 of the grant as 24,939 state fair visitors sampled certified California extra virgin olive oil. In turn, average sales per hour of extra virgin olive oil in the market outreach display was equivalent to 5.17 bottles or $66.12 in sales per hour. As such the market outreach display proved to be a fairly impressive revenue generator for producers that participated.

The olive oil outreach display has seen an annual increase in direct revenues of olive oil sales ($4,915 in 2015; $17.079.17 in 2016; $19,230.75 in 2017) and samples distributed (6,450 in 2015; 17,316 in 2016; 25,784 in 2017), demonstrating that visitation and interest in olive oil at the outreach display has increased since the project began. These figures represent the project's ability of successful market enhancement.

During the 17 days of the California State Fair 1,010 visitors took part in the Taste of California classroom that provided extended sensory education of olive oil tasting to those interested. These 1,010 newly educated consumers will enter the marketplace with an understanding of the importance of certifications, and California's place in producing quality oils.

Beneficiaries

California Extra Virgin Olive Oil producers benefited whether they participated in the project's competition and market outreach display or not, as attention was drawn to California as an industry leader in producing quality oils.

Those producers that chose to participate in the competition and won an award benefitted by being able to market their oils as an award winning product.

Award winning producers that participated in the Market Outreach Display during the California State Fair benefitted as they had the opportunity to meet and talk with potential consumers in a one on one setting.

The project also created a relationship with the UCD Olive Center proving to be beneficial to both parties as the State Fair received educational support and UCD was able to receive support from the California State Fair for a program at their Olive Center.

The California's olive oil industry will benefit from this project.

400 producers of California Extra Virgin Olive Oil benefited as the project was designed to focus attention on California as an industry leader in producing quality olive oils.
Of these producers, 56 directly benefited from the project as their oils had been identified as award winning during the competition and could be, marketed as such.
Of these producers, up to 14 participated in the market outreach display during the California State Fair where they had opportunity to generate direct sales with by selling award winning oils to fair visitors.

Lessons Learned

During compiling of contacts and outreach activities of the project with the industry, staff found that digital communication proved more beneficial than standard phone communications. Upon review staff believed that digital communication offered the recipient an opportunity to respond on their own terms rather than being interrupted by a phone call, then possibly forgetting what was discussed during the call. Plus digital communications included all the necessary information that the recipient needed and could refer back to at their leisure. Digital communications took the form of one on one emails, email blasts and electronic newsletters.

One positive unexpected outcome of the project was the amount of sales that occurred as a result of the competition and within the Market Outreach Display that occurred during the California State Fair. Initially producers brought oils to sell in the Market Outreach Display as a courtesy to the select few that may be interested in purchasing after their tasting experience. After the first weekend the display was in operation it became quite evident that visitors not only wanted to taste oils but also intended to purchase what they tasted. A few of the producers were surprised by the number of sales they generated, and ran short on their more popular oils. In order to satisfy fair visitors (aka potential consumers) the producers responded by increasing the stock they brought to the market outreach display during their next visit.

The popularity of the market outreach display in conjunction with the creation of a competition of notoriety has demonstrated that the California State Fair still plays a major role in marketing new products, new information and new innovations as it strives to represent the Best of the State of California.

Additional Information

See Attachment 1

The following are images of the California State Fair Extra Virgin Olive Oil Competition:

Market outreach display as the extra virgin olive oil producers are setting up their product tasting for a day full of fair visitors.



Entries are labeled and samples are prepped for judging.



Judges provide sensory evaluation of oils.



Visitors received valuable information and had opportunity to sample oils using newly gained sensory techniques; creating educated consumers.



USDA Project No.:	Project Title:	
3	Enhancing the Marketability of California Persimmons	
Grant Recipient: United States Department of Agriculture, Agricultural Research Service	**Grant Agreement No.:** SCB14003	**Date Submitted:** December 2017
Recipient Contact: Andrew Breksa	**Telephone:** (510) 559-5898	**Email:** andrew.breksa@ars.usda.gov

Project Summary

The objective of this project was to increase the profitability of California persimmons. Persimmons are a crop that most consumers are unfamiliar with. Key factors that have led to the increased profitability and cultivation of other California specialty crops (grapes, pomegranates) have included: (1) consumer awareness of nutritional factors including the presence of health promoting compounds, (2) the year-round availability of minimally processed products (juices, dried fruit, leathers), and (3) consumer familiarity with the culinary uses of the fruit, or simply put, how to eat or serve it. Project staff proposed to gather information on the health promoting compounds found in persimmons (Factor #1), and develop a process for preparing a dried product (Factor #2). The drying process will be scalable to home, cottage, or large-scale use. The project staff produced a marketing document to be used at points of sale (Farmer's Markets, web sites, etc.) that combined this information with how to use persimmons (fresh and dried, Factor #3). By collecting the details needed to increase consumer awareness and familiarity with persimmons, project staff set the groundwork to make the crop more profitable.

This project has the potential to enhance persimmons as a specialty crop by creating a new product format for both non-astringent varieties that are typically eaten raw and fresh (like an apple) and astringent varieties that are either eaten jelly-ripe or dried whole for multiple weeks. A crispy dried persimmon product that could be made in less than a day can increase customers and sales of California persimmons as this research identified health benefits, cultivar suitability, drying methods and protocols, and consumer preference. This project was timely because consumer interest in the nutritional benefits of their foods is growing and the passage of the cottage food bill makes it possible for both large and small-scale persimmon growers to benefit from the sales of a dried product.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

From October 2014 to September 2015, project staff developed the analytical methods for measuring nutritional characteristics and conducted drying experiments to determine the drying conditions to be used in year two of the project. From October 2015 to September 2016, project staff collected persimmon fruit from commercial growers and the United States Department of Agriculture-Agricultural Research Service (USDA-ARS) National Clonal Germplasm Repository (NCGR) located in Davis, California. For most samples, from 100 to 200 fruits were collected. A total of 59 samples of persimmon fruits were obtained, including 47 from the NCGR and 12 from commercial growers. From October 2016 to June 2017, project staff collected samples from the NCGR and a commercial grower located in Tulare County. Persimmon fruits from a total of 48 cultivars were obtained, including 37 from the NCGR and 11 from the commercial grower.

Across both years, a total of 107 samples were collected. In each instance, representative fruits from each cultivar were used for morphological characterization (shape, color, firmness, etc.) and the remainder processed into a dried product or prepared for nutritive analysis (anti-oxidant, carbohydrate, phenolic content, etc.).

Concurrent to the harvesting of the fresh fruit, a trained panel of volunteers evaluated the fresh and dried fruits for taste, aroma, and texture properties. In conjunction with the annual persimmon fruit tasting held at the NCGR in November 2015 and 2016, project staff conducted consumer taste tests in which project staff completed the collection of consumer preference data for dried persimmons prepared from fruit harvested in year 2015. Based on the analysis of the consumer taste test data collected, project staff identified the top cultivars, from the 2015 year harvest, for preparing a dried chip-style product. Additionally, project staff conducted another consumer test taste in March 2017 to collect data for dried fruits prepared from samples harvested in year 2016.

Due to the quantity of samples and the number of analyses, the data analysis is still ongoing. The project staff plans to share the results through oral presentations and publications in peer reviewed journals. The project staff needs to complete the publication of the results for the 2015 harvest year before moving onto the results for 2016. Therefore, the current efforts will focus on the publication of the results from 2015 and then will move onto the results for 2016. The project staff are in the process of finding a journal to publish the 2015 results. The project staff expect the earliest the 2016 results will be published is the spring or summer of 2018. For the manuscript describing the results from the consumer taste panels, data collected in years 2015 and 2016 were combined. This manuscript is currently under review. Additionally, there are two manuscripts in preparation covering results from the 2015 harvest year, one describing the morphological and organoleptic properties of persimmon fruit and the other reports the nutritional content of the fruito

Over the course of the project, project staff conducted multiple outreach activities to share results with specialty crop stakeholders (e.g., growers, food processing industry, scientific community, and general public). These activities included presentations at national meetings, invited presentations with smaller audiences (California Cooperative Extension (UCCE) Master Food Preservers, commercial nursery, University of California, Davis Departmental lecture), and a publication submitted to *Food Science & Nutrition*. Results from the nutritive and sensory characterizations and drying experiments were used to prepare three Point of Sale Flyers. The flyers for Fuyu-type (non-astringent) and Hachiya-type (astringent) persimmons consisted of a front side describing the nutritive and sensory characteristics, and uses for the fruit. The back side consisted of instructions for preparing dried persimmons. It is not recommended to dry variant type persimmons because the dried products are not visually appealing. Thus, for variant persimmons, the flyer focused on familiarizing consumers with these types of persimmons as fresh fruits. The front side described the nutritive and sensory characteristics, and how to select fruit, whereas, the back side explained pictorially the biology behind variant persimmons becoming non-astringent. The Point of Sale Flyers and results from the project are posted on the project's website: https://www.ars.usda.gov/PersimmonCDFA2014Project.html.

This project did not benefit commodities other than California specialty crops, specifically persimmons.

Project partners were key in providing commercial fruits for the study. These fruits were essential to demonstrate that the drying method is applicable to the cultivars that growers are producing and to those cultivars that are new or lesser-known but available from commercial nurseries.

The project partners were L.E. Cooke Co. (Visalia, California), Oak Acre Farms (Live Oak, California), and Mr. O. Bertolero (Santa Rosa, California).

Goals and Outcomes Achieved

The project staff accomplished the goal to (1) identify the cultivars most liked by consumers as a dried persimmon product, (2) identify a drying method applicable to both home and industrial-scales, and (3) to measure the nutritive characteristics of fresh and dried persimmons. The project staff disseminated this information to stakeholders via meetings, conferences, and a journal article. The performance measure was the number of stakeholders who receive the results and information. The benchmark at the beginning of the project was zero and the target was to complete testing of all cultivars within 20 months and disseminate information to 1,000 stakeholders, including growers, processors, scientists, and potential markets/customers. To date, project staff has disseminated results to 420 stakeholders. It is anticipated that the target of 1,000 stakeholders will be met once the project staff submits additional manuscripts and copies of the Point of Sale Flyer are distributed. It is anticipated to be completed by the fall of 2018.

The objective of this project was to increase the profitability of California persimmons. The progress made towards this long term measure was the development of the Point of Sale Flyers.

The project staff have met the goals established for the reporting period, but did not meet the target of 1,000 stakeholders. The project staff did not have sufficient resources to focus on data collection and publication of the results simultaneously. The secondary reason was that project staff did not have sufficient time to distribute the Point of Sale Flyers during the project period because the Point Sale Flyers were completed at the end of June 2017. To date, 100 copies of the flyers have been distributed.

The project staff characterized the nutritional content of over 50 persimmon cultivars, with some samples characterized over multiple years, harvests or locations, develop a method for preparing dried persimmons, evaluated fresh and dried persimmons using a trained sensory panel and conducted consumer taste studies to identify the cultivars most preferred by consumers as a dried product. The results from the studies, including the identities of the most preferred cultivars, were presented at four national meetings: 2016 Institute of Food Technologist (IFT), 2016 Fall American Chemical Society (ACS), 2017 IFT, 2017 Spring ACS, and the UCCE Master Food Preservers' Conference, and will be forthcoming in a publication that was submitted Fall 2017. In place of preparing a single Point of Sale Flyer, staff prepared Point of Sale Flyers for the three types of persimmons (non-astringent, astringent, and variant). Hard copies were printed in preparation to distribution to stakeholders and the flyers are also available for download from the project's website.

Beneficiaries

The beneficiaries of this project are consumers, persimmon growers, the sellers and/or distributors of persimmons, and UCCE Master Food Preservers. Secondary beneficiaries are nurseries that distribute persimmon trees, food processing companies, and the scientific community.

Based on the outreach activities accomplished thus far, it is estimated that the number of beneficiaries exceeds 420 individuals. Results from this project have the potential to substantially increase grower income as consumers elect to purchase persimmon fruit on account of becoming more familiar with the fruit's characteristics (appearance, taste, use, nutritional benefits, and preservation), purchase additional persimmon fruits for drying, and growers meet consumer demand for dried persimmon fruit in the off-season.

Lessons Learned

The lesson learned was to better match the quantity of data generated with the ability to consolidate the results into manuscripts. The original plan was to submit two manuscripts during the reporting period. However, more time was spent than anticipated on data collection and collected more data than planned for. In the future it would be more efficient to scale back the sample set size in order to complete the data collection and manuscript writing within the reporting period.

After reviewing the results, it was determined that the focus for variant type persimmons should be on the fresh fruit and not a dried product because dried variant persimmons were not visibly appealing. The original plan was to prepare a single Point of Sale Flyer for use with all persimmon types. However, this observation and consultations with stakeholders lead to conclude that stakeholders would be better served if Point of Sale Flyers were prepared for each of the three types of persimmons.

The project staff did not meet their target to disseminate information to 1,000 stakeholders. Also not being able to publish a manuscript in second year of the project and releasing the Point of Sale Flyers in the last month of the product contributed to not meeting this target. The lesson learned from this situation is to periodically reevaluate targets when project activities are not met or when they are delayed.

Additional Information

The project's website is found at https://www.ars.usda.gov/PersimmonCDFA2014Project.html. This site includes photos from the project and links to the presentations made at national meetings. The Point of Sale Flyers are also available for download at the website, as well as a mechanism to request hard copies of the Point of Sale Flyers.

The paper titled "Synthesis of Descriptive Sensory Attributes and Hedonic Rankings of Dried Persimmon (Diospyros kaki sp.)" was published in Food Science & Nutrition journal.
http://onlinelibrary.wiley.com/doi/10.1002/fsn3.537/full

USDA Project No.:	Project Title:	
4	Profiles in Stewardship	
Grant Recipient: American Farmland Trust	**Grant Agreement No.:** SCB14004	**Date Submitted:** December 2017
Recipient Contact: Edward Thompson	**Telephone:** (202) 309-1162	**Email:** ethompson@farmland.org

Project Summary

California specialty crop growers face mounting pressures to improve their environmental stewardship. These pressures come from increasing regulatory requirements, increasing consumer (wholesalers, retailers, and the public) demand for better environmental performance and accountability, and increased degradation and scarcity of the resource base. These pressures often result in increasing the costs of farm management.

Many specialty crop growers have successfully navigated the challenges described and can serve to communicate to other growers, consumers and policy makers, effective strategies - Beneficial Management Practices (BMP) that have worked for them to meet these challenges. However, these stewardship leaders are not being recognized as effectively as they could be.

The project objective was to educate consumers, policy makers and other specialty crop growers as to how and why specialty crop growers who are stewardship leaders adopt BMPs that enhance the environment and benefit their bottom line. This project directly addressed; connecting farmers to consumers by highlighting sustainable production practices, train growers on environmental stewardship skills and expand sustainable production practices to ensure viability of California specialty crop growers by investing in the next generation.

The project's purpose was to compile a portfolio of 100 case studies (profiles) of specialty crop growers who are environmental stewardship leaders in adopting BMPs. These 100 new profiles would add to American Farmland Trust's (AFT's) existing portfolio of profiles. The profiles would be used as education and marketing tools to other growers, consumers and policy makers, demonstrating that specialty crop growers provide food and horticultural products along with valuable ecosystem services. The profiles should also encourage other growers to more rapidly adopt BMPs to improve environmental and economic performance. Follow-ups will be conducted to assess the use and effectiveness of the profiles.

Specialty crop growers are constantly having to respond to changing environmental, technological, regulatory, and market conditions to remain competitive. They do so by seeking information from various sources including their peers. They also are increasingly providing information, either voluntarily or by demand of buyers and/or regulators on their environmental performance.

This project provided a new, direct source of information to other growers and to consumers and policy makers on how specialty crop growers are innovating to improve their environmental performance. By focusing attention on who these growers relied on for advice and assistance, this project can improve the delivery of technical and financial assistance to specialty crop growers who are seeking to adopt BMPs to improve economic and environmental performance. The profiles show the importance of bringing together those who deliver such services to collaborate on how to better provide these services in a more timely, more

efficient, more coordinated, and easier to use system. Grower access to relevant information is key to improving their economic and environmental performance. All specialty crop growers, but especially beginning growers, need and want easy access to technical and financial assistance tailored to their needs. Growers who have had profiles prepared also have a new marketing tool to provide education and outreach to consumers. Policy makers and regulators have a new trusted source of information from which to gain a better understanding of how specialty crop growers innovate and implement new BMPs to improve environmental and economic performance.

Improved delivery of technical and financial assistance will result in more rapid and wide-spread deployment of BMPs and will allow specialty crop growers to better adapt to a changing climate, comply with environmental regulations and meet buyer sustainability demands.

The project did not directly build on a previously funded Specialty Crop Block Grant Program (SCBGP) project. However, under a previous 2010 SCBGP 10: *Assessing Growers' Needs to Accelerate Adoption of Beneficial Management Practices in Specialty Crops*, AFT surveyed specialty crop growers regarding their behavior when adopting new BMPs. The work identified motivations, barriers and system improvements to specialty crop grower adoption of BMPs. See: http://bit.ly/2u5cdX8

This project responds to some of the findings from that report – that growers often rely on peers for information when adopting BMPs, and that recognition in the marketplace or regulatory environment was a strong motivating factor for BMP adoption.

Project Approach

AFT established a project leadership team which met by teleconference in 2015 to review and comment on the project materials, including the case study template, the case study priority matrix, and outreach materials to potential specialty crop grower-cooperators. Members also committed to assist AFT in identifying and recruiting growers to be profiled. AFT then developed a case study template, a case study priority matrix, compiled a list of potential case study subjects (grower-cooperators).

AFT hired and supervised a total of three case study preparers who interviewed growers, obtained photographs, and prepared profiles according to the template. Profiles were prepared from February 2015 through December 2016. This effort resulted in 39 new profiles being prepared and 27 older profiles being updated, for a total of 66 profiles published to a newly developed webpage on AFT's website (http://stewards.farmland.org/) which was made publically available on May 11, 2017 and announced by press release on May 15, 2017 as well as through social media, direct email or telephone notification of the grower cooperators and email to project partners and collaborators. The interactive website includes a searchable database allowing users to find profiles based on geography, crop type and resource conservation practice. The profiles are also listed by farm name. This effort took approximately a year longer than anticipated and resulted in fewer profiles being prepared than first proposed (100) for several reasons including the severe drought in California which made it difficult for growers to be interviewed and complete the necessary steps for a profile.

AFT has used Google Analytics to obtain user statistics on the profile webpages to assess initial impacts of the profiles on subjects and peers. From May 11 through June 30, 2017 (the end date of the project), there were more than 1,500 individual visits to the webpage, resulting in more than 3,600 unique page views.

Returning visitors represent 25% of the visits. Individual grower profiles were viewed most often. The most popular queries were for the *Soil Health* practice (46); the *Water Conservation* practice (39); and the *Nutrient Management* practice (19). The most frequently queried crop/practice combinations were *Nuts/Water Conservation* (34); *Vegetables/Soil Health* (19); and *Vegetables/Pest Management* (12). Individual grower profile views ranged from 285 (1); 80 – 90 (2); 40 – 70 (4); 20 – 39 (19); 10 – 19 (39). AFT continues to highlight individual grower profiles via its Facebook page, Twitter feed and e-newsletter and the project team anticipate the popularity of the website to continue to grow.

The overall scope of the project solely benefitted specialty crops and specialty crop producers. Leadership team members were instructed to focus solely on specialty crop growers, when identifying potential profile subjects. The case study template and priority matrix solely addressed specialty crops. Project partners had clear instructions to focus solely on specialty crop growers when preparing profiles. Therefore, only specialty crop growers were contacted as potential profile subjects. Some diversified growers were contacted, and profiles prepared, but profiles are only prepared on a specific specialty crop they produce. In addition, all grant funds were spent only on grant related activities.

AFT received excellent guidance from project partners during leadership team conference calls and from individual correspondence when designing and implementing the project. AFT received contact information for potential profile subjects. Project partners also helped identify potential grower-cooperators to serve as profile subjects.

Partners are publicizing the profiles and assisting with tracking the effectiveness of the published profiles. The California Association of Resource Conservation Districts (CARCD) is in the process of hosting the profiles on its website, as well as providing a link to the profiles on AFT's website. The California Climate and Agriculture Network (CalCAN) and CARCD invited AFT to present the project at their annual meetings in November 2016 and February 2017. They and others have used individual profiles to further conservation activities through funding increases, improving technical assistance, and peer to peer learning.

Goals and Outcomes Achieved

The project's goal was to compile 100 profiles that represented at least 25 specialty crops and 25 different stewardship practices/approaches. The profiles were to be made widely available. Additionally, the project was to network at least 20 agriculture and conservation websites that would link to the AFT website.

Preparation of case studies (profiles) was completed. A total of 66 Profiles (39 new profiles and 27 older case studies that were updated and revised as profiles) were completed. AFT's website now includes an interactive, searchable page so that visitors can view profiles by grower name or based on crop type, stewardship practice, and location. The page was completed and went live on May 11, 2017. These profiles are now available to growers, technical assistance providers, consumers, policy makers, regulators and the general public on an interactive webpage hosted on the AFT website.

The subject of each profile has been checked against a matrix of crop/practices/regions so that the diversity of specialty crop growers and their stewardship activities is well represented. Tracking against the matrix assures that at least 25 different crops and 25 different stewardship practices are described. Tracking was performed through completion of the profiles. Results can be seen in the attached matrix. The matrix was used as a template for the interactive website and searchable profiles database.

Documentation of the number of websites providing a link to the AFT website to promote the profiles was monitored using web search and social media tracking tools. Personal contact with present and future collaborators was not widely performed since the profiles were published in mid-May, with the project ending in June. A few growers, urban farmers in Yolo County and farmers in the San Joaquin Valley who were profiled for their water conservation practices have contacted AFT to report that they have been approached as a result of people viewing the profiles. Thus far, six websites have posted links to the AFT webpage. The goal was for at least 20 websites to provide a link to the profiles on the AFT website. AFT anticipates that others will provide a link in the near future, since the website just went public in mid-May.

AFT has not conducted follow-up interviews with profile subjects yet due to the delays encountered in preparing the profiles. AFT plans to stay in contact with many of the grower-cooperators to obtain this information after the project period. Results will be tabulated by type and magnitude of benefit, or if no benefit was realized this will be done as each profile is finalized and assessed.

Grower cooperators were supposed to be polled in spring 2017 to determine if there had been any contact by other specialty crop growers inquiring about the stewardship practices described, resulting from the profiles. AFT anticipated that 25% of grower-cooperators would be contacted by other growers. Although this has not yet been done systematically, a few growers, urban farmers in Yolo County and farmers in the San Joaquin Valley who were profiled for their water conservation practices, have contacted AFT to report that they have been approached as a result of people viewing the profiles. AFT will track such contacts informally after the project period.

AFT has no data on those profile subjects who were contacted by other specialty crop growers to determine if they have knowledge of any specialty crop growers that are acting to implement, or have implemented, associated stewardship practices. Therefore results cannot be tabulated and compared to the target of 10 specialty crop growers. Case studies of where profile information was successful in leading to actions to improve technical and financial assistance delivery cannot be documented and presented.

Some results and benefits resulting from the project are long term and cannot be quantified at this time. These include the number of growers who have gained knowledge of stewardship practices from the grower cooperators and of those, who have actually adopted the practices for their own farm. AFT anticipated having more time to follow up with growers to assess this impact, but due to the delays in preparing profiles, this analysis has not occurred. AFT will stay in touch with grower cooperators in the future to see if such benefits are realized. Initial response to the availability of the profiles on the website has been quite robust and favorable.

Profiles are being disseminated through various means. An initial press release went out on May 12, 2017, as well as on AFT and partners' social media feeds. AFT is posting at least one profile per week on its Facebook page and Twitter feed.

Follow-up to determine effectiveness of the profiles campaign has been very limited due to the late public release of the profiles. Thus, it is too early to know if the profiles have resulted in additional BMP adoption by other specialty crop growers.

Prior to the project, AFT had prepared 45 profiles, 27 of which were of specialty crop growers. At the conclusion of the project, 39 additional profiles of specialty crop growers were prepared and the 27 previously prepared profiles were updated. All 66 profiles were posted to a new interactive website that has received more than 1,300 visits since its debut on May 11, 2017. AFT has yet to collect data on farmer to farmer contacts for information on BMPs and intentions to implement them, although several profiled farmers have reached out to project staff to inform them they have been contacted by other growers.

As can be seen from the attached Stewardship Case Studies Matrix, all crops and practices categories are well represented by the case studies. Most geographical regions of the state are also well represented, except for the Imperial Valley. Where there are gaps in the matrix, they were largely anticipated, due to the natural geographic distribution of crops in California and the nexus of practices to the crop type.

A total of 28 collaborators were identified. Fourteen participated on the advisory committee. Ten provided contacts to potential grower-collaborators. Six provided outreach on the availability of the profiles on the AFT website.

More than 1,300 visits to the website have been documented as of June 30, 2017. Each time a grower's profile is posted on the AFT Facebook page or twitter feed, an additional 200 to 300 visits to the website are recorded.

Beneficiaries

AFT has a national presence, while individual Resource Conservation Districts (RCDs) or county Farm Bureaus or Farmers Markets may support local or regional efforts. Individual specialty crop grower organizations may also use this approach. Other specialty crop grower, RCD and other conservation organizations will see the benefit of these profiles and support preparation of additional profiles that may be added to the database. This effort could be adopted by 4-H and FFA chapters for use as learning experiences and ways to promote other local stewardship leaders.

There are approximately 60,000 specialty crop growers in California who farm approximately 5.4 million acres, growing more than 400 different specialty crops with a farm gate value of more than $27 billion. The impact of this project is increased awareness of the environmental stewardship activities being conducted by specialty crop growers throughout California by growers, policy makers and consumers.

The increased awareness of stewardship efforts will result in increased adoption of and support for BMPs by specialty crop growers to enhance the environment, reduce costs, improve compliance with environmental regulations, and meet consumer demands.

Lessons Learned

Overall, conducting this project was a positive experience for AFT. The project team worked with individual specialty crop growers who were obviously very proud of their farming operation. Not only were they proud of the quantity, quality, and diversity of the crops they produce, they were also very proud of their environmental stewardship efforts. They recognize their dependency on the quality of the environmental resources – soil quality, air quality, water quality, biodiversity, water supply, and they understand that protecting and enhancing these resources is part of their responsibility as farmers – for their own benefit, and also for the greater good. The specialty crop growers who volunteered to be profiled were eager to share their

experiences with others to benefit their colleagues, their customers, and the planet. The specialty crop growers recognize that while their own farming operation is unique, they can learn and have learned from others. They are constantly motivated to seek information from various sources. AFT believes the project will continue to provide benefits to specialty crop growers and to their consumers and the environment for years to come.
It was more difficult than expected to identify growers who were willing to spend the time to be profiled. AFT believes a major factor was the protracted drought affecting all growing areas of California. AFT conducted this work during the most severe period of the drought. Many growers were worried about their continued existence and AFT's request for time was viewed as a distraction to them. Additional growers were identified, but the goal of profiling 100 could not be achieved. It took longer than anticipated to follow up with, review, and edit profiles, providing photographs, and release forms for final publication. AFT understands the pressures growers were under resulting from the drought, and is even more grateful to those growers who were willing to be profiled.

AFT believes that deciding to publish the profiles on an interactive website instead of using a PDF or printed document was highly effective and beneficial. The profiles are now available to anyone with an internet connection for free, and it was easy to link to the site from the AFT website and social media. The project team think many more members of the public became aware of the project because of the website than would have been had the project team published them in a PDF. It was also relatively inexpensive to produce and was done quickly. It is now also easy to go back and make changes to any of the content, since it's not a static document. The use of the website, combined with other social media outlets (such as Twitter and Facebook), has resulted in exposure of the profiles beyond the initial expectations of AFT. Profiled growers have been responding favorably to the positive attention.

There have been no unexpected outcomes resulting from the project.

The initial goal of the project was to prepare a total of 100 profiles of specialty crop growers. It was much more difficult than anticipated to find growers willing to spend the time to be interviewed, edit the profile, provide photos, or be photographed for this project. Farming, especially with regards to specialty crops, was often the target of critical press coverage regarding state water use, thus farmers did not want to call attention to themselves, even if they were exemplary stewards of water (and other) resources.

Additional Information

See attachment 1 – Matrix.

USDA Project No.:	Project Title:	
5	Expanding Markets for California Olive Oil	
Grant Recipient: California Olive Oil Council	**Grant Agreement No.:** SCB14005	**Date Submitted:** December 2017
Recipient Contact: Patricia Darragh	**Telephone:** (888) 718-9830	**Email:** oliveoil@cooc.com

Project Summary

The focus of this project was to expand the market for California olive oil in the United States. At the time of the initial project proposal, California, which produced over 99 percent of the olive oil in the United States had only 1-1.5 percent of the market share. While this was an increase from the under one percent figures in the past (2012), the goal was to reach five percent market share by the end of the grant duration (June 30, 2017). Oil olives were California's fastest growing specialty crops. It was essential to increase the market share of California growers for the purpose of growing California olive oil sales to absorb coming production increases. Since the United States represented the second largest consumer of olive oil in the world, this was a formidable task. Imported olive oil producers had very large marketing budgets which would allow them to produce large scale print, radio and television advertisement, which ran nationally.

The grant enabled the California Olive Oil Council (COOC) to reach out to an array of groups including retailers, consumers, culinary professionals and media in an attempt to focus on driving demand nationally for California olive oil. The COOC is a non-profit organization representing more than 90 percent of California's olive oil growers. By increasing the COOC member's knowledge via educational seminars, videos, webinars, collateral, etc. the project team was able to multiply the COOC's efforts by deepening the messaging knowledge amongst members which contributed to their effectiveness in the marketplace.

The industry was at a period where the market share needed to be increased and efforts were being made statewide to focus on promotion and marketing. The industry had the support of a growing network of retailers nationwide as well as with academic institutions such as Fresno State University and the University of California, Davis.

This project built upon the initial success of the 2012 Specialty Crop Block Grant Project 21: *Building Markets for California's Fastest Growing Specialty Crop Industry*. This was done by expanding grower/producer's knowledge base, reaching out to more retailers and building a greater social media following. The 2012 project aimed at increasing the market share of California olive oil to 5 percent by focusing on two regions in the United States, the Mid-Atlantic and California. While the 2012 project built a successful base, the 2014 project created many avenues from the original outreach. Coupled with the increased production of California grown extra virgin olive oil, this complimented a growing demand. Since 2012, there had been widespread media reports on traceability issues as well as outright fraud in the olive oil marketplace stemming almost exclusively from imported oils. This also assisted in providing a greater depth of knowledge amongst consumers of the need for strict standards and product traceability. Further, outreach was also accomplished by updating the COOC website with a new content management system. This created a modern, information based site which greatly expanded overall content and furthered the project team's overall reach.

Project Approach

The project team put tremendous effort to work with retailers as well as distributors which resulted in increased sales. Partners for marketing and education included KeHE Distributors, Williams-Sonoma, We Olive, Market Hall Foods and Oliver's Markets. In most markets, shelf capacity increased by over 40 percent. The COOC was also able to target a cross section of consumers via seminars, Modern Farmer magazine, website content, social media and expansion of the "Meet a Farmer."

Four educational videos were produced which were distributed widely to members, retailers, culinary professionals and consumers. All four videos, "Olive Oil Production in California," "Sensory Evaluation of Extra Virgin Olive Oil," "Shopping for Extra Virgin Olive Oil," and "California Extra Virgin Olive Oil in the Kitchen" were also made available on the COOC website (https://www.cooc.com/videos/). The "Shopping for Extra Virgin Olive Oil" and the "Olive Oil Production in California" videos received the most positive response from consumers. The latter being extremely important for urban and suburban dwellers who did not typically have access to agricultural experiences. Retailers also used the videos for staff training, in-store demonstrations and overall consumer outreach. In April 2016, for the first time ever, a California brand was number one in the olive oil category for supermarket sales nationwide (California Olive Ranch). From January 2014 through January 2017, the market share for California olive oil rose from 1.5 percent to six percent. This was an enormous increase. The United States is considered the second largest consumer of olive oil in the world after the European Union.

All grant funds were used to solely enhance the competitiveness of specialty crops.

Significant collaboration was made through the following: California Grown, Fresno State University, Good Food Awards, American Federation of Chefs, We Olive and Williams Sonoma amongst others.

Goals and Outcomes Achieved

The overall project sought to elaborate and expand upon the success of the 2012 Specialty Crop Block Grant Project 21: *Building Markets for California's Fastest Growing Specialty Crop Industry*. The 2014 project focused on addressing the challenge faced by California growers of increasing the overall awareness level, followed by an increase in demand for extra virgin olive oil. The goals of the project included targeting audiences with emphasis on the farm to table concept. This was accomplished through media and culinary dinners, educating consumers on the preference for premium oil, and providing increased education to the member base. Additionally, via partnerships with Modern Farmer magazine and the production of four educational videos the project team was able to expand the base with heightened awareness of olive oil and tools to assist in increasing demand

This was accomplished in part through a Farm to Table concept emphasizing the use of olive oil as an ingredient. Examples included the COOC exhibit at both the Winter Fancy Foods show (January 2015 and January 2016) and the Summer Fancy Foods shows (June 2015 and June 2016) in New York and San Francisco which provided opportunities to market and educate over 4,000 retailers, distributors and buyers in the specialty food arena. These shows were the largest specialty food shows in the United States. Admission was restricted to buyers, distributors and brokers. The focus at these shows was to communicate to key buyers the value of the COOC seal certification and supporting American agriculture.

Ad campaigns were utilized, including Modern Farmer and partnering with retailers in promotional activities such as We Olive, Good Food Foundation, Kehe Distributors, Fresh Markets, Olive This, Olive That, Oliver's Markets, Williams-Sonoma, Secolari and All Things Olive.

The COOC website content management system was also replaced. The new system allowed for easier updates, an expansion of the site and the ability to load videos. For example, all four educational videos were loaded onto the COOC website. This resulted in an estimated viewing audience of over 5,000 consumers and retailers to date. Members were also able to use the videos for their own websites, training or consumer interactions. The content of the site was also expanded to include more health information, a new nutrition section and an expanded "Meet a Farmer." As part of an ag-tourism promotion, the website also added olive oil tasting rooms throughout the state. Expansion of the website materials also increased the knowledge base of consumers and broadened their overall knowledge of California olive oils. The number of sessions on the website experienced an increase of 150 percent, 160 percent increase in users, and a 120 percent increase in views. Along with the website communication expansion, the COOC added Twitter and Instagram to its social media. By the end of the grant, the project team had reached over 1,700 followers on Facebook. Twitter impressions increased by 250 percent and profile visits had increased 350 percent.

The overall educational curriculum was also expanded and further developed to communicate more effectively with retailers. Educational materials were provided to Cal Poly, Fresno State, as well as Ag in the Classroom. The COOC also provided guidance to the California State Fair in establishing their own statewide olive oil competition. The COOC exhibited at over 35 events and seminars during the period of the funding. Media coverage was vast and included the Los Angeles Times, 60 Minutes, Fresno Bee, Sacramento Bee, and the San Francisco Chronicle.

The market share in the United States grew from 1.5 percent to six percent within the duration of the grant. In April 2017, there were 35 million dollars in olive oil sales in the United States for California olive oils. This was a 62 percent increase over 2014. It was estimated that this increase in sales generated $22 million dollars in additional revenue through job growth, equipment and land sales and related revenue:

Increased sales in California: average 38 percent increase
Increased sales in the Northwest: average 54 percent increase
Increased sales in the Northeast (includes Mid-Atlantic corridor): average 72 percent increase

This was in part driven by events and promotional partnerships but also by the following events: Williams Sonoma (two events) in Portland as well as an event co-sponsored with the Portland Culinary Alliance. Events and training with Town and Country Markets in the Seattle area, visits to multiple retail stores in the northwest, California and the Mid-Atlantic, and American Federation of Chefs event and training in Maryland (chapters from Baltimore, D.C., and Philadelphia) as examples.

Price premiums were met and demand has soared. While the largest producers saw price increases of 8-12 percent over the course of the grant, small-medium producers experienced increases of 25-28 percent. Organic producers saw a premium of another 8-10 % above that.

During the course of the grant, it has been determined that the following audiences were contacted:
Buyers/retailers: 6,000

Culinary professionals: 1,600
Consumers: 2,800
Media: 1,000

As noted above, the outcome was formidable and beyond the expectations for the period of the grant. The funding allowed the COOC to reach a huge audience and also expand overall educational opportunities.

Beneficiaries

The beneficiaries were numerous. First and foremost, the California olive oil farmers benefitted through the expansion of the market for their product. The increase in sales allowed the farmers to reinvest on additional acreage, equipment and hire additional staff. Additionally, consumer and retailers benefited greatly as the grant provided for education and marketing initiatives. Both consumers and retailers became more educated, which allowed the market for California extra virgin olive oil to expand.

The beneficiaries of the funding which resulted in an unparalleled increase in market share were as follows: growers (approximately 400), producers, retailers, distributors, storage facilities, trucking facilities, equipment providers and leasers, providers of related equipment such as bottles, caps, labels, packaging and design companies, and freight forwarders. During the period of the grant funding, the market share in the United States grew from 1.5 percent to six percent of the market. In April 2017, there were 35 million dollars in olive oil sales in the United States for California olive oils. This was a 62 percent increase over 2014. It was estimated that this increase in sales generated $22 million dollars in additional revenue through job growth, equipment and land sales and related revenue

Lessons Learned

The experience was very positive as the industry grew and the efforts of the staff and the programs implemented were successful in meeting and surpassing goals.

The outreach dramatically indicated that consumers and retailers alike were very focused on heathy food for themselves and their families. It was evident that price was less of a factor in selecting good food. This may in part be due to the better economy and more expendable income. Additionally, consumers were much more likely to read food labels and ask probing questions about traceability, pesticide usage and sourcing. It was positive to encounter so many more educated consumers who seemed product savvy and aware.

Additional Information

The website www.cooc.com was upgraded and expanded to include such features as nutrition and “Meet a Farmer.” This continues to expand. Media highlighted the industry in the Fresno Bee, NY Times, Eating Well, Pop Sugar, Los Angeles Times, MarketWatch, Wall Street Journal, Bloomberg News and other media outlets.

USDA Project No.:	Project Title:	
6	California Wines Road Trips: A Marketing Program for Wine Tourism	
Grant Recipient: Wine Institute	**Grant Agreement No.:** SCB14006	**Date Submitted:** December 2017
Recipient Contact: Nancy Light	**Telephone:** (415) 356-7520	**Email:** nlight@wineinstitute.org

Project Summary

Wineries, especially small and medium-sized wineries which represent the majority in the state, depend heavily on tasting room sales, related wine club sign-ups and consumer loyalty to build and sustain their businesses. This project was focused on building value perceptions and loyalty by increasing tourism to California wine regions and wineries. The project promotional, media and event campaign was aimed at educating and promoting the positive qualitative advantages of California wines by growing agricultural and culinary tourism and influencing buying patterns, translating to increased winery and grower returns.

Statistics confirmed the trend of wine consumers, especially younger consumers, having less loyalty to and drinking less local wine were leading to a long-term downward impact on California wine prices and grower returns. Working with regional winery and grower associations and Visit California, the statewide tourism entity, to increase wine tourism from within California and around the United States was both timely and important to the long-term competitiveness of California wine directly as well as generating incremental benefits by drawing visitors to local communities.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

- Implemented publicity, sponsored editorial and social media campaigns around regional tourism itineraries and statewide celebrations for California Wine Month (September) and Down to Earth Month (April) that generated 1.3 billion impressions in print, broadcast and online media outlets with 2.6 billion in circulation through 26 news releases and story placements far exceeding project goals.
  https://www.wineinstitute.org/resources/pressroom/08242015
  http://www.wineinstitute.org/resources/pressroom/08182016
  http://www.wineinstitute.org/resources/pressroom/04022015
  https://www.wineinstitute.org/resources/pressroom/03242016
  http://www.discovercaliforniawines.com/d2e/
- Conducted a comprehensive online survey of 2,000 visitors to California wine country which identified visitor behaviors and perceptions of the California wine visitor experience overall and by region, and shared insights for improving the tourism experience and best tourism practices with 3,000+ vintners and growers as well as regional tourism partners and Visit California.
- Coordinated media, trade and consumer events in Northern California, New York, San Francisco and Los Angeles; participated in annual Visit California receptions in New York, San Francisco and Los Angeles and California Grown events in San Luis Obispo (Savor) and Los Angeles (LA Food and Wine) during the course of the project which garnered participation by 600 top media, 250 wine trade and 14,500 consumers.

- Conducted 10 meetings with regional winery and grower associations from around the state, Visit California and California Grown which were effective in gathering information and building collaborations that enhanced project success.
- Developed series of 15 wine tourism itineraries covering all regions of the state with accompanying maps which were highlighted in publicity, social media postings and websites to highlight the most appealing aspects of the regions and California wine country overall.
- Created a series of maps (15), photo images (75), and videos (12) to promote wine tourism to California wine country for California Wines Facebook, Twitter and new Instagram accounts as well as on the consumer website and YouTube. Daily social media posts of this content and accompanying messages resulted in growth on social media accounts to 19.2 thousand fans on Facebook, 3,616 followers on Twitter and 755 followers on Instagram, a social account that was not included in the proposal but was added due to its growth among wine consumers, especially younger wine consumers. Videos were rolled out on Instagram beginning in September.

The project only benefited winegrapes/wine which are a specialty crop.

Project activities were supported by Visit California, California Grown and regional winery and grower associations representing Amador, Calaveras, El Dorado, Lake County, Livermore Valley, Lodi, Madera, Mendocino, Napa Valley, Paso Robles, Placerville, Sacramento Valley, San Joaquin Valley, San Luis Obispo, Santa Barbara, Santa Clara, Santa Cruz Mountains, Sonoma County and numerous "sub-appellation" groups within counties. These groups contributed ideas, disseminated content on web and social media sites, hosted and responded to media, provided input and review in preparation of information promoted the project in communications vehicles and publicity efforts.

Goals and Outcomes Achieved

The primary activities completed to achieve performance goals were fostering collaboration within the California wine industry and with partners in tourism and specialty crops which augmented project reach and effectiveness; publicity, media outreach and events that engaged targeted members of the wine media and trade as well as consumers to engage them in communicating the special attributes of California wine country and regions; research to provide a benchmark on visitor behaviors, interests and perceptions of the California wine tourism experience statewide and by region and to identify best practices; curating and communicating the best features of California wine regions through images, maps and written materials (news releases, story pitches and social media posts), direct engagement of consumer, trade and media audiences through social media to augment the dissemination of information and sharing and reporting activities to wineries and growers to share information, encourage best practices and invite participation in programs.

- Publicity/editorial coverage: Goal was to develop three news releases sent to 1,000+ media outlets and pitched (outreach) to 300 contacts to generate media coverage of 50 million in circulation for each release or 150 million in circulation total. The actual program accomplishment was 26 news releases on statewide promotions and regional tourism itineraries each distributed to 1,000+ media and pitched to 300+ media which resulted in coverage and story placements in print, broadcast and online media outlets with 2.6 billion in circulation.

- Tourism research: Goal to conduct a survey of visitors to California wine country to collect information on statewide and regional wine tourism, measure impact and identify growth opportunities was accomplished with Destination Analysts survey of 2,000 visitors. Information was shared with 3,000+ vintners and growers as well as regional tourism partners and Visit California and continues to be communicated. https://app.box.com/s/trrq2eb4s4rjl0ph8ppd4mwb5et050ja

- Events: Goal was to host events for Down to Earth Month (three) and California Wine Month (two) and to attend Visit California media receptions in New York, Los Angeles and San Francisco to reach 500 media, 300 wine trade and 500 consumer based on attendance. Project events resulted in total attendance by 600 media, 250 wine trade and 14,500 consumers. Event programs at:
https://app.box.com/s/h39bkort1j2cejan46ctr2aem4z5oxqz
https://app.box.com/s/v72zjuvss1mybbvxivzf1ox8gu3yoxmo

- Collaborations with wine, food and tourism organizations: Goal was to meet with four to six state and regional tourism organizations to gather information and input and build collaborations. Actual accomplishment was 10 meetings over the course of the project with regional winery and grower associations from around the state, Visit California and California Grown which were effective in gathering information and building collaborations that enhanced project success.

- Tourism itineraries: Goal was to develop four to six wine tourism itineraries covering all of California wine regions. Project actual accomplishment was development of 15 wine tourism itineraries covering regions of the state in greater detail with accompanying maps. Find itineraries and other new releases here:
http://www.discovercaliforniawines.com/media-trade/news/

- Videos/Photo Images: Goal was to acquire photos for four to six tourism itineraries and create three videos to cover major wine regions to be posted on social media accounts directed to YouTube and generate 2,000 views per video. Project actual accomplishment was creation of a series of 15 maps, 75 photo images and 12 videos which received 1,900 views each based on social media followers and will receive further exposure with roll out to the California wines Instagram account.
http://www.discovercaliforniawines.com/media-trade/videos/

Project goal was to increase California wine sales by 5% ($1.1 billion) and winegrape grower returns by 5% ($155 million) by the project conclusion as measured by annual reports from wine industry analysts Gomberg, Fredrikson & Associates and the Grape Crush Report. Based on data from BW166 and Wine Communications Group, the partnership that purchased the Gomberg-Fredrikson Report in 2015, the retail value of California wine sales increased 13.5% over the course of the project (9 % in 2015 and 5% in 2016 the most recent year available). California winegrape grower revenues in 2016 were $3.1 billion, an increase of $500 million over 2015 grower returns based on the 2016 crush report, which exceed the project goal of $155 million increase. http://www.wineinstitute.org/resources/pressroom/05012017
https://www.nass.usda.gov/Statistics_by_State/California/Publications/Grape_Crush/Reports/

The third outcome measure was to increase tourism visits to California wineries/regions by 1 million visits by 2017. Wine tourism visits grew by 2.9 million visits from 20.7 million at the start of the project to an

estimated 23.6 billion over the course of the project based on the most recent report on the Economic Impact of California Wine and Winegrapes. http://www.wineinstitute.org/resources/pressroom/08042016

Beneficiaries

The Wine Institute, representing 1,000 California wineries, and the California Association of Winegrape Growers, representing California winegrape growers who farm about 60% of statewide acreage, were the primary organizations supporting the project, but all of California's 4,700 wineries and 5,900 winegrape growers were beneficiaries of project accomplishments.

The economic impact of the project as noted earlier was a 13.5% increase in the estimated retail value of California wine sales in the U.S., valued at $4.4 billion, and an increase in grower returns of 16% valued at $500 million. Tourism related spending based on the increase in visitors grew to $7.2 billion from $2.1 billion at the project outset (based on 2009 numbers which accounts for the large increase.) See details at www.wine-economy.com

Lessons Learned

A positive outcome of the project was the opportunity to deeply mine the offerings of California's wine regions to present them as appealing tourism options. The information gathered with assistance from regional winery and grower associations, regional tourism organizations and individual wineries and presented in the 15 tourism itineraries will have a value beyond the conclusion of the project. In expanding the areas covered from five macro regions to more than 15 regions Wine Institute expanded the results and accomplishments of the project but also the project workload for Wine Institute staff and consultants. However, staff were able to accomplish and exceed the project goals through careful planning and developing processes for streamlining the collection of information, curating images and developing graphics.

An unexpected outcome of the project was a fuller understanding of the importance of wine tourism to California wineries based on direct winery sales through tasting rooms as a business model for many small wineries unable to find distribution through traditional wholesale channels. At the same time, staff learned more about the challenges from local communities concerned about increased tourism in wine regions and became more aware and engaged in this issue.

Additional Information

No additional information.

USDA Project No.:	Project Title:	
7	Market Tours for Small, Ethnic, Beginning Specialty Crop Growers: Creating New Marketing Channels for Buyers and Sellers	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB14007	**Date Submitted:** December 2016
Recipient Contact: Gail Feenstra	**Telephone:** (530) 752-8408	**Email:** gwfeenstra@ucdavis.edu

Project Summary

The market for local, California grown and sustainably produced specialty produce has continued to grow, and this strong demand has created new sales opportunities for specialty crop producers. Distributors and wholesale buyers have increasingly sought out regional producers able to grow, pack, and deliver quality products that meet specifications for proper packing. They seek producers with Good Agricultural Practices (GAPs) certification, labeling, and whom also have a unique and identifiable story that would appeal to a customer base increasingly interested in "knowing the farmer." Meanwhile, small, ethnic and beginning specialty crop growers require technical assistance and support to allow them to capitalize on this expanding market channel. For the farmers, there is a need for increased education around food safety, packaging, labeling, and relationship-building with wholesale buyers.

Demand for local, family-farmed, and sustainably produced products has continued to increase. With proper education and training, small, beginning and ethnic farmers could successfully capture the market share resulting from a consumer shift towards local products. This would allow them to expand and/or diversify their market channels. Programming to connect producers to wholesale buyers at points of sale, followed by resources and farmer-to-farmer workshops, was well-suited to the experiential learning style and needs of this group of specialty crop growers.

This project built upon previously funded 2011 Specialty Crop Block Grant Program Project 1: *Helping Small, Latino, and Hmong Specialty Crop Producers to Profit From New Values Based Marketing Channels*, which connected small farmers to values-based marketing channels through three successful workshops and wholesale market tours. The current project added three additional elements: 1) online marketing tools for farmers interested in wholesale/retail buyers; 2) farmer-to-farmer workshops to build on what was learned on the bus tours; and 3) a state-wide Summit to bring together organizations working with small, beginning, and ethnic growers to strategize and increase the effectiveness of their work.

Project Approach

The overall objective of this project was to link small, beginning and ethnic specialty crop producers to wholesale buyers via "workshop on wheels" bus tours. This project also sought to enhance the farmers' ability to capitalize on their new contacts with buyers by providing technical assistance and additional support through farmer-to-farmer workshops. The project team organized bus tours for growers in four regions of Northern and Southern California, nine farmer-to-farmer workshops, and provided on-line resources for growers. In addition, a statewide Farmer Education and Support Services Summit improved information sharing between organizations as well as increased their effectiveness in connecting farmers to existing

services. All together, these activities increased farmers' sales options, provided essential marketing and food safety skills, and improved their chances for economic viability.

Goals and Outcomes Achieved

Activity: Organize and Conduct Four "Meet the Buyer" Bus Tours
The University of California, Sustainable Agriculture Research and Education Program (UC SAREP) organized bus tours for growers in four regions of Northern and Southern California. A mobile-classroom bus tour format was designed to bring together small-scale growers and a group of established buyers, including wholesalers, restaurants, catering companies and institutional cafeterias. Tours connected growers from the North Coast and Fresno with buyers at San Francisco wholesale markets (February 2015) and growers from San Diego and Los Angeles with buyers at Los Angeles wholesale markets (December 2015). In total the tours had 150 registered participants (128 farmers, 22 support service organization representatives) and visited 14 unique wholesale buyers in California.

Each tour was designed with the University of California Cooperative Extension (UCCE) Farm Advisor serving the tour participants' county. These collaborative efforts resulted in tours designed to match farmer needs. For example, the farmers on the Fresno tour were primarily Hmong and Mien, and one of the tour stops was a restaurant that used moringa, a little-known crop grown by the Southeast Asian farmers. A stop on the North Coast tour included a wholesale buyer that purchased seaweed, a crop also relevant to this group of growers.

Activity: Consultative Follow-up
UC SAREP developed and distributed a one-page resource guide, "Additional Resources on Marketing and Selling Your Produce" (see attachment 1), which included a list of 18 vetted resources. This list was provided to all 150 registered participants from the four tours as well as to the UCCE Farm Advisors to share with their farmer networks. Topics on the resource guide were selected based on farmers' responses to the post-tour evaluation question "What are your top three marketing challenges?" Participants on the February 2015 tours were offered an on-farm marketing consultation; however, only five responded positively. (Two consultations were delivered in-person and three via email.) Due to this limited response, the project team focused efforts on farmer-to-farmer workshops instead, 60% of participants who completed a post-tour evaluation expressed interest in additional training.

Activity: Online Tools/Resources for Farmers
In 2014, UC SAREP created a "Breaking into Wholesale" *(http://asi.ucdavis.edu/programs/sarep/research-initiatives/fs/supply/breaking-into-selling-wholesale)* website page featuring a series of resources to help growers gain an understanding of wholesale requirements, the pros and cons of working with different buyers, strategies for meeting and working with buyers, and more. The site was designed as a one-stop resource with links and information organized by subject area: Marketing, Buyer Introductions, Food Safety, Pack and Grade, Pricing, Delivery, Insurance, and Business Development. The website also highlighted six sample Farmer Profiles, representing the ethnic diversity of California small farmers and demonstrating ways that small famers would present their story in a way that was compelling to buyers.

UC SAREP produced two short videos based on footage and interviews from the December 2015 Los Angeles "Meet the Buyer" tour. The first video, "Selling Wholesale at the Farmers' Market" *(https://www.youtube.com/watch?v=QHz5Cs0LGtM)*, featured a buyer from Heirloom L.A., a successful

catering company, describing how growers could use social media to promote their seasonal crop offerings and unique produce. The video also included a farmers' market manager, who discussed how wholesale buyers used the market as a "hub" for sourcing product from many different small-scale farms. "Selling Produce Depends on Personal Relationships" *(https://www.youtube.com/watch?v=4ZZ1jQLSG_g)*, features a pioneering organic distributor in downtown Los Angeles.

In January 2016, the project conducted a website reorganization to improve navigation and search engine optimization. In March 2016, a "Boost Your Sales!" promotional postcard was created, targeting farmers at the California Small Farms Conference to alert them to the resources available on the website. UC SAREP distributed 500 postcards that directed small farmers to the website where they could learn about breaking into the wholesale market by gaining an understanding of wholesale requirements, find techniques for meeting and working with buyers, and access to market channel trip sheet which helped to explain the pros and cons of working with different buyers.

In September 2016, UC SAREP created a new webpage to highlight the resources and outcomes of the Farmer Education and Support Services Summit: "Convening Farmer Educator Networks" (*http://asi.ucdavis.edu/programs/sarep/research-initiatives/fs/supply/convening-farmer-educator-networks*). The website featured a "Directory of California Farmer Education and Support Services Organizations" (see attachment 2) which compiled programmatic activities, geographic scope and contact information of over 40 different organizations working to educate and support small/medium-scale, beginning and/or underserved farmers in California. Other documents resulting from the Summit were hosted on the webpage, including: 1) an Ecosystem Map of California Farmer Education and Support Services Organizations (see attachment 3), 2) an Ecosystem Chart of California Farmer Education and Support Services Organizations (see attachment 4), and 3) Summary of 15 Priority Focus Areas (see attachment 5). These resources provided valuable tools for farmers and not-for-profit farmer support organizations alike.

Finally, UC Berkeley, one of the project partners, created a training video on food safety that will be dubbed in Hmong and Mien. At the time of this reporting, the video is in the final editing phase and will be uploaded to the UC SAREP "Breaking into Wholesale" website as an additional resource once it is complete.

Activity: Organize Two Farmer-to-Farmer Meetings/Workshops
This project successfully conducted nine workshops, or farmer-to-farmer meetings. Specialty crop producers were provided training and technical assistance around wholesale market readiness. With the exception of one workshop, on marketing and product traceability, the farmer-to-farmer workshops all addressed the topic of food safety since many of the participants identified food safety as a major barrier to accessing new markets on post-tour evaluations.

1) Food Safety Workshop, Fresno – May 20, 2015
2) Marketing & Traceability Workshop, Fresno – July 16, 2015
3) Food Safety Workshop, Berkeley – June 5, 2016
4) Food Safety Workshop, Stockton – June 26, 2016
5) Food Safety Workshop (series), Petaluma – June 6, 13, 20, 27, 2016
6) Food Safety Audit Workshop, Fresno – September 2016

UC SAREP partnered with UCCE Fresno, Fresno Regional Workforce Investment Board (WIB) and the Community Alliance with Family Farmers (CAFF) to put on a Food Safety Workshop in Fresno on May 20, 2015. The CAFF Food Safety Program Manager was invited to present on current and upcoming Food Safety regulations and lead a farm field walk to demonstrate risk areas and to partially simulate an audit. Forty-three people attended the workshop, more than half were Hmong or Mien farmers. A detailed training was given on how to prepare for upcoming regulations, do a self-audit, and a practical demonstration was also given on how to create a cost-effective hand washing station.

Building on the first food safety workshop and on conversations with farmers, UCCE Fresno project partners identified a need for a workshop focusing on traceability. Partnering again with the WIB, UC SAREP helped organize a workshop on traceability on July 16, 2015, and added an emphasis on branding for small farms. In total, 33 people participated in the workshop. The presentation included information on regional, production-oriented branding and farm identity. It also involved a practical discussion about the possibilities and challenges of creating a collective "Hmong Fresno" brand to include on produce boxes. From the prior workshop, the project learned that the workshops were better attended when they offer Continuing Education hours for private applicators with the Department of Pesticide Regulation (DPR). Therefore, the UCCE advisors added a presentation on pesticide labels, biological control and groundwater regulations to create a broad workshop. Farmers were also given details about the feasibility of joining California Grown and considered the possibility of joining, but most did not see the benefit relative to the cost ($1,000; $500 for Farm Bureau members). Following the presentation, there was a roundtable, which included a farmer-to-farmer discussion to identify marketing challenges, exchange ideas and discuss branding.

UC Berkeley project partner organized two on-farm food safety workshops with farmers in Stockton and Berkeley in June 2016. In total, there were 30 participants. Half (50%) of all participants were minority farmers (African American, Latino, Native American and Southeast Asian), and 19 were women (63%). The Berkeley food safety workshop took place on June 5, 2016 at UC Gill Tract Community Farm and had 21 participants. The Stockton food safety workshop took place on June 26, 2016 at Puentes Farm and had nine participants. Following the workshops, templates of the food safety manual, check-sheets and worker training guidelines were shared via email with all the participants. Technical assistance on adapting the documents was provided upon request to five participants via email and phone calls. Two on-farm risk assessments were conducted and feedback provided to each farm about the food safety risks and recommendations on how to mitigate those risks.

UCCE Marin, Mendocino, Napa, Sonoma Counties, conducted a four-part Food Safety Workshop Series that took place every Monday during the month of June in 2016. Thirty participants attended the workshop. The June 6th workshop was delivered by the Policy Director for CAFF and an instructor in the Culinary Arts Department at Santa Rosa Junior College. It provided an overview of food safety including the science of food safety, navigating the Food Safety Modernization Act (FSMA), GAPs, and food safety plans. June 13th workshop covered key food safety themes of workers, equipment, and water with an Extension Specialist from the Department of Plant Sciences, UC Davis. June 20th workshop covered food safety related to soil, livestock, and wildlife. This workshop was taught by the Extension Specialist in Urban Agriculture and Food Safety at the School of Veterinary Medicine, UC Davis, and the Program Manager at the Western Center for Food Safety. June 27th workshop featured a smaller group of wholesale farmers and included a farm visit at a local farm which grew leafy greens for wholesale. The afternoon included an on-site tour,

interactive food safety risk analysis, and an opportunity for participants to discuss plans for implementing food safety measures on their own operations.

UCCE Fresno organized a workshop on September 28, 2016 in Fresno titled "Small Farm Personalized Food Safety Plan Workshop and Mock Audit". Forty-six participants attended the workshop. The content was delivered by representatives of PrimusLab's Local Farmer Program. Topics were based on the Local Farmer curriculum and included pesticide label requirements, pesticide record-keeping, chemical storage requirements, traceability programs, employee hygiene training, harvesting practices, rodent control, water protection, and water testing.

Activity: Collect Follow-up Data
At the end of each of the four bus tours, participants were given a written evaluation survey and asked if the project team could contact them in six months with regard to how the tour had affected their marketing practices. UC SAREP reached out to all those who had answered "yes", either by email, phone and/or in-person, provided contact information was available. Follow-up was conducted in two phases: participants on the Northern California tours received follow up in spring 2016 (February-April), participants on the Southern California tours received follow up in summer 2016 (July-August). Follow-up methodology varied for the different tours, based on farmer demographics. The follow-up strategy was revised after the Northern California tours in order to increase the overall response rate based on what had been learned. Participants on the North Bay tour were contacted by UC SAREP staff via email in February 2016, then received follow-up by phone (up to two attempts were made in March-April 2016) to gather success stories, learn about changes to marketing strategies, and hear about new business created as a result of the tours. Out of the 25 participants who attended the North Coast tour, 10 agreed to be contacted for follow up, but only four responded to the follow-up survey questions via phone or email for a 6.25% response rate.

Most of the Hmong and Mien farmers who participated in the Fresno tour were not English-speaking and most did not give email addresses. UC SAREP conducted a follow-up via a facilitated phone call with UCCE Fresno and a representative farmer responding to the survey questions.

In order to address the low follow-up response rate, UC SAREP changed the process for the San Diego and Los Angeles tours to an online survey distributed via email (sent to 53 tour participants who indicated that follow-up was "okay" and to participants who did not complete an evaluation). Additional follow up calls were instrumental in boosting the overall response rate to 36% of contacted participants responding to the post-tour follow-up.

Activity: Conduct Summit
UC SAREP successfully organized a Farmer Educator and Support Services Summit on September 9, 2016 in Sacramento. The Summit was an opportunity to bring together organizations working with small, beginning, and ethnic farmers in California to strategize how to most effectively serve these growers, what is being done well and identify areas of improvement, and to explore opportunities for these organizations to work together more effectively. In the early planning stages for the Summit, the team found that FarmsReach had already done substantial work in the area of farm support, organizational assessment and networking. In collaborating with FarmsReach to host the Summit, the team was able to build on existing momentum from a 2015 Convening hosted by FarmsReach and Multinational Exchange for Student Agriculture (MESA), thereby using the Summit event to a expand the strategic conversation.

Fifty-nine people registered for the event (out of 160 invited) representing 32 different organizations. The day's agenda began by considering the landscape in which these groups work and exploring areas of overlap and opportunity, then moved to a focused look at collaborative fundraising – what possibilities exist for support organizations to access greater funds by working together. Finally, the group identified priorities for moving this collaborative work forward. The one-day Summit achieved three important objectives: 1) information sharing about each organizations' programming, 2) networking between organizations and 3) prioritizing shared goals to advance the work being done by California support organizations.

Tours and workshops targeted specialty crops producers. Buyers on the tours only discussed their purchasing and sourcing of specialty crops. This project solely benefited the competitiveness of specialty crops.

As detailed above, UCCE project partners in Fresno, North Coast, San Diego, and Los Angeles contributed knowledge about their farmer constituencies and regional buyers, helped with recruitment and outreach for the tours, and disseminated follow-up materials. In addition, UCCE partners played a significant role in organizing farmer-to-farmer workshops to deepen specialty crop growers' knowledge of practices necessary to adopt in order to successfully sell to wholesale market channels. All of the project partners attended the Summit in September and shared their perspectives on the needs of small, beginning and ethnic farmers based on their on-the-ground experience working with these growers.

This project's long term outcome measures will likely continue to be realized into the future as participants of the "Meet the Buyer" tour and farmer-to-farmer workshops continue to adopt and assimilate the information into their farming practices. Sales relationships can take time to develop, therefore the actual impact of this project could not be fully measured within the project timeline. The project team deferred the follow-up surveys for at least six months in order to capture the most realistic impact data and allow sales to develop.

Goal 1: Farmer Tours

a.) At least 50% of farmer tour participants (total 150 in four regions) will expand gross sales by 10% as a result of wholesale/retail market tours. Accomplishment: 150 participants on four bus tours (122 farmers, 28 food advocates). 66% of follow-up survey respondents said they had seen an increase in sales from the previous year. (Farmers were reluctant to say how much their sales had increased.) 64% of those who had seen an increase in sales attributed it to the "Meet the Buyer" tour.

b.) At least 90% of tour participants will make at least one new business contact with whom they plan to follow up to discuss future business. Accomplishment: Respondents to the post-tour evaluation reported an average of five new contacts made during the tour, and 88% said they were likely to follow up with buyers, and/or other farmers after the tour. In follow-up surveys, 41% of respondents said they had reached out to at least one of the wholesale buyers on the tour and 53% of respondents said they had used the strategies they learned on the tour to reach out to other wholesale buyers in their area.

c.) At least 80 tour participants will receive follow-up marketing consultations after their tour and as a result of these, 25% will make at least one positive change in their marketing plans. Accomplishment: All 150 tour participants received a follow-up email with a one-page resource guide, "Additional Resources on Marketing and Selling Your Produce," and an offer for consultation. Only five responded favorably. In the six months+ follow-up survey, farmers were asked if they made any changes to their operations in the last six months as a result of anything they

learned on the tour. 58% of participants answered the question. Changes included: general marketing plan – 73%, marketing channel – 55%, communication strategy with buyers 36%, use of social media to share farm story 27%, branding 9%.

d.) The online marketing tools webpage will receive at least 1,000 hits by project's end. Accomplishment: 1,948 website hits (as of September 2016, increasing from 180 in October 2015 to 599 in April 2016) and 190 unique views of the two education videos.

Goal 2: Farmer-to-Farmer Meetings/Workshops

a.) At least 90 farmers will attend one of two farmer-to-farmer meetings post tours to discuss marketing strategies and the potential for aggregating products. Accomplishment: 182 attended nine follow-up workshops.

b.) At least one of these farmer groups continues after the first meeting. Accomplishment: The July 16, 2015 workshop in Fresno discussed this topic. Interest in continuing to meet as a farmer group was low and farmers did not follow up on this idea.

c.) At least 25 farmers will explore the feasibility of joining California Grown. Accomplishment: 27 growers were given information on California Grown either face-to-face or via email. The growers who attended the tours were very small scale farmers, so California Grown did not make sense financially.

Goal 3: Summit

a.) At least 50 people attend the final summit to discuss how to collaborate effectively with this group of farmers. Accomplishment: 59 people registered for the event (out of 160 invited) and representing 32 different organizations.

b.) At least 500 farmers throughout California will be sent information from the organizations that attended the summit about the summit content. Accomplishment: The Summit resources were sent out to all 160 event invitees to share with their farmer constituencies. These resources were also posted on the FarmsReach listserve, with 3,000 subscribers, and posted on the UC SAREP website.

Baseline data about farmer demographics was collected via evaluations completed by “Meet the Buyer” bus tour participants. 78% of tour survey respondents self-identified as “new/beginning,” 20% identified as “ethnic,” and 33% identified as certified organic farmers (COF). (Note: The Fresno tour evaluation did not have this question, however, the majority of participants and all evaluation respondents were Hmong or Mien small farmers). The majority (over 84%) of participants were small farmers reporting gross sales under $250,000 (55% reported gross sales under $25,000; 22% reported $25,000-$100,000; 7% reported $100,000-$250,000; and 16% reported gross sales over $250,000).

Activities for this project were education and outreach related and, as such, outcome measures focused on increasing connections and relationships where none existed before, therefore baseline data was zero. For example, at least 90% (or 135) tour participants will make at least one new business contact as a result of the tours (baseline: zero, achievement: tour participants reported five new contacts on average and 88% (132) indicated that they were likely to follow-up with these contacts). A new webpage was created which exceeded the target for number of hits (baseline: zero, achievement: 1,948). Ninety farmers will attend at least two workshops (baseline: zero, achievement: 182 farmers attended nine workshops). Fifty people will attend the Summit (a new event) and the resulting information will be sent to 500 farmers (baseline: zero, achievement: fifty-nine attended the event and information was sent to 160 organizations and nearly 3,000 farmers.

Tours: Participants indicated an overall confidence score of four (0-5 scale) for finding new markets. According to the six months+ follow-up survey for the two Southern California tours, there had been five reports of successful sales. Of these, four resulted in ongoing sales relationships and one farmer secured a 250 pound per week contract for his efforts.

Much of the verbal and exit survey feedback indicated that personal interaction with other small and beginning farmers and networking with the "decision makers" at the sites was the most valuable portion of the day. From the 53% of respondents who answered the question about post-tour outreach to other participants, six farmers reported talking or meeting with other farmers to discuss business, marketing, or collaboration opportunities and there were nine independent instances of farmers connecting post-tour.

Farmer-to-Farmer Workshops: Out of 23 participants that filled out the evaluation forms at the food safety workshops in Berkeley and Stockton, 61% indicated they learned a great deal, and 39% said they learned a moderate amount, with 0% indicating that they learned a little or not at all. 100% of those who participated in the longer workshop indicated they learned a great deal. Prior to the workshops, only one person indicated they had done a food safety risk assessment on their farm, and none had a food safety plan in place. At the end of the workshops, 16/23 (70%) indicated that they planned to adopt one or more practices learned at the workshop including a.) water testing, b.) soil testing, c.) creating a food safety plan, d.) assessing food safety risks on their farm, e.) installing a toilet and handwashing station at the farm, training workers in GAPs and/or f.) record keeping.

At the North Bay Food Safety workshop series, 100% of post-workshop survey respondents indicated that they planned to use the information they learned from the workshop. At the Fresno Food Safety Plan and Mock Audit workshop, 16 of the 46 workshop participants completed evaluations and over 80% of them said they were likely to adopt the following GAPs: handwashing stations (94%), rodent control (94%), employee hygiene training (88%), flagging and avoiding animal droppings (88%) and sanitizing equipment (81%).

Summit: As a networking event, the Summit was successful in connecting people; the average number of new contacts made was five. Many respondents wrote that they found great value in "re-establishing" or "refreshing" relationships with preexisting contacts or meeting people face-to-face that they only knew through virtual working relationships. Participants also responded that, on average, they planned to follow up with at least three organizations they spoke to at the Summit for potential collaboration opportunities. Participants reported a 4.35 value rating (on a 1-5 value scale) when asked if they would attend the event again. Participants were also asked to indicate their main takeaway/results from participating in the event and 70% of the short answers responses used the terms: connect, network, collaborate, and partner which demonstrates the value in face-to-face meetings. Other responses that were repeated during the day's event were about gaining understanding about the "landscape" and wanting to do research post-summit with other organizations (39%), challenging existing measurements of success/creating shared metrics (11%), and a need for diversity in the movement (8%).

Outreach: The project team sought out opportunities to highlight the activities and accomplishments of this project with farmers and other organizations by attending several farming conferences. Posters were presented at 1) the California Agriculture and Natural Resources (ANR) Strategic Initiatives conference, 2) the National Small Farm Conference and 3) the Food Distribution Research Society conference, as well as attended 4) the California Small Farms Conference.

Beneficiaries

California specialty crop farmers benefitted from information and technical assistance provided on the bus tours and at workshops, and from resources resulting from the Summit. Wholesale buyers benefitted from increasing relationships to producers who can help them meet their sourcing objectives for regional and/or sustainable products. Non-profit and governmental organizations who provide education and training to small, beginning and underserved farmers benefitted from networking and strategic planning at the Summit. California consumers of specialty crops benefitted from increased farmer knowledge and capacity to supply the state with regional products through wholesale market channels.

Three hundred and thirty-two small, beginning and ethnic specialty crop growers in Northern, Central, and Southern California who attended the bus tours or the workshops. Twenty-two support organizations who attended the tours. Six wholesale buyers who were involved in the tours. Fifty-nine attendees from 32 different farmer support organizations who attended the Farmer Education and Support Services Summit. 160 organizations who received the follow up content from the summit. Three thousand list-serve subscribers who received outreach regarding the key summit outcomes and resources to connect with support organizations and educational opportunities in their region.

Lessons Learned

Success Stories:
The bus tours resulted in the following success stories: one participant from the North Coast tour connected with a buyer to package and distribute seaweed products. Another North Coast participant found buyers for persimmon and apple crops. A Los Angeles grower reported a shift in his production plan from time intensive crops to baby greens after learning about wholesale demand for baby greens and evaluating his farming capacity. Hearing stories about branding and marketing of an Australian citrus variety inspired Southern California participants to develop marketing strategies for their own specialty citrus crops. In Southern California, the behind-the-scenes visit at the farmers market with market manager and a specialty catering company yielded conversations about effective use of social media and Instagram hashtags to connect farmers and restaurants with seasonal produce.

More than merely providing a forum for buyers and farmers to meet and exchange contact information, the tours were providing the farmers with a roadmap for procedures they needed to implement in order to be able to sell through these market channels. The tours also provided an excellent opportunity for farmers to network and learn from each other.

Lessons Learned:
Farmers need additional support to develop “wholesale readiness” and to allow them to take advantage of new connections to wholesale buyers. From post-tour evaluations and conversations with UCCE advisors, the project team learned that although the farmers valued the information and the exposure they gained on the tours, many still had a significant distance to go in order to become “wholesale-ready.” Lack of readiness on the part of the farmers prevented new buyer relationships from becoming immediately actionable.

Exchanging contact information on the bus tours was sometimes not enough to develop a lasting sales relationship. Both buyers and farmers are very busy and in some cases needed more face-time to work out logistical arrangements and figure out how to do business with each other.

For smaller-scale farmers, the wholesale buyers on the tour were located outside of the farmers' immediate sales region, and some buyers required larger volume than the small-scale farmers were producing. The project team received feedback from some of the farmers and a few of the farm advisors that some of the buyers on the 2013-2016 tours were mismatched for the scale of the farmers. The team also heard from one of the farm advisors that the farmers in their region were interested in selling their product more within the county.

In organizing the Farmer Education and Support Services Summit, the team was surprised to learn that several organizations were already involved in the work of networking and convening farmer support organizations for the purpose of improved communication and effectiveness. California Certified Organic Farmers (CCOF) and the Center for Agroecology and Sustainable Food Systems had launched a Farmer Educator Network (FEN) on the Central Coast and FarmsReach and MESA had hosted a convening at EcoFarm in 2015. The project team felt that it was essential to build on, rather than duplicate, these efforts, so the project team partnered with FarmsReach to host the Summit, and used the results of the previous convening as a starting point for this event's agenda and group activities. Collaborating with FarmsReach brought additional resources to the Summit, both in terms of knowledge and capacity, and linked this event to a larger set of strategic planning activities around how farmer support originations can better meet farmers' needs.

It is recommended that future buyer-producer networking activities, identify and include buyers representing a range of scales, some of whom would be more appropriate for smaller-scale growers. To generate a larger increase in sales resulting from these activities, it would also be beneficial to target mid-scale growers for the tours who may be already positioned to taking advantage of new relationships with larger wholesale buyers.

Additional Information

Please see the corresponding attachments for the following information:

1. Additional Resources on Marketing and Selling Your Produce
2. Directory of California Farmer Education & Support Services Organizations
3. Ecosystem Map of California Farmer Education & Support Organizations
4. Ecosystem Chart of California Farmer Education & Support Organizations
5. 15 Priorities from the Farmer Education & Support Services Summit
6. Poster Presentation for national conferences
7. Farmer Education & Support Services Summit Agenda
8. Bay Area tour of San Francisco markets Agenda
9. Fresno tour of San Francisco markets Agenda
10. San Diego tour of Los Angeles markets Agenda
11. Los Angeles tour of Los Angeles markets Agenda
12. ANR News & Information Outreach in Spanish coverage of Los Angeles tour: http://ucanr.edu/sites/Spanish/Noticias/?uid=6585&ds=199 and video: https://www.youtube.com/watch?v=y24Pe5-ZMSY
13. Article "Wholesale Ahead" by UCCE Food Systems Advisor published in Grown in Marin News (Spring 2015) and re-run in the Sonoma Marin Farm Bureau News (not available online): http://growninmarin.org/Grown_In_Marin_News/Archived_Issues/Spring_2015/Support_article

USDA Project No.:	Project Title:	
8	Random Acts of Flowers – Getting Social	
Grant Recipient: California State Floral Association	**Grant Agreement No.:** SCB14008	**Date Submitted:** December 2017
Recipient Contact: Nick Matteis	**Telephone:** (916) 441-5266	**Email:** nick@agamsi.com

Project Summary

Increasingly, consumers have begun to look to blogs and social media for advice on food and lifestyle, with 61 percent of consumers saying that they had made a purchase decision based on a blog post. The time was right to give California flowers a prominent voice on social media. The purpose of this project was to educate and inform consumers about California grown flowers, thereby encouraging them to purchase cut flowers and ask for California flowers from their florist.

At the start of this project, the California grown flower industry was faced with an increasing percentage of flowers sold in the market were being imported from other countries. Research showed that if given a choice, consumer's preferred to purchase California grown flowers. The challenge to the flower industry was making consumers aware of the availability and variety of California grown fresh flowers and to encourage consumers to look for California grown flowers in the marketplace and to ask for them when ordering from a florist.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Activities undertaken during the entire grant period included the creation of a robust social media platform for the California State Floral Association (CSFA) which was used to help educate consumers about flowers and encourage them to purchase flowers grown in California. The social media program earned 68 thousand followers with 10 million impressions during the duration of the grant. The social media platforms continue to be used by CSFA as an asset and communication tool to reach people whom were interested in and likely to purchase flowers.

A new website and blog http://calstatefloral.com/blog/ was created that highlighted the variety and availability of California flowers. The website featured information about farmers, florists, and flowers. The website also hosted a blog with posts that featured California farmers and flowers. Many 'do it yourself' blog posts were posted featuring California flowers including:

- "Same flowers – three different looks"
- "Summer Flower Roundup"
- "Fall Wedding Flower Roundup"
- "4th of July Tables cape"
- "Fall Floral Roundup"
- "May Day Pole Tradition Made Easy"
- "Birthday Fun with Flower Pot Favors"
- "DIY Flower Crowns"
- "Rose Bowl Entertaining Made Easy"
- "This Valentine's Day, say I Love you with Beautiful Flowers"
- "A Suspended Wedding Arch"
- "Summer Wedding Flower Roundup"
- "Decorating your wedding cake with California flowers"
- "Spring Floral Roundup"
- "Memorial Day Wreaths"
- "Think outside the "Vase" this Mother's Day"
- "Spring Flower Crowns"
- "Treat Everyone with Flowers this Valentine's Day"
- "DIY: Vintage Holiday Garland"

Industry blog posts gave consumers insight into the flower industry and featured farmers, florists and wholesalers as well as coverage of consumer-facing events, like the California State Fair in first and second years of the project. Examples included:

- "A peek inside California Flower Grower – Green Valley Floral"
- "Q & A Session with Flower Duet"
- "A Q & A Session with Kay Wolff, AIFD, CCF"
- "A Day in the Life of a Flower Wholesaler"
- "California State Fair: Farm-to-fork Edible Flower Cooking Competition"
- "California State Flower Day"
- "Stop and Smell (and Eat) the Roses on Sunday"
- "Flowers, Florists, and fun at the California State Fair"
- "Random Acts of Flowers"

Six different videos were produced for the CSFA, each one highlighting the beauty and versatility of California grown flowers and were meant to encourage consumers in California to look for and purchase flowers grown in their state. The videos included:

- "Random Acts of Flowers"
- "Meet a California Farmer Passionate about Protea"
- "Flowers, Florists and Fun at the California State Fair"

Three florist and flower videos were also included:

- "Beautiful and Custom #CAGROWN Flower Bouquets"
- "We Love #CAGROWN Flowers!"
- "Enjoy Beautiful #CAGROWN Floral Designs"

The videos earned a combined 1.3 million views across Facebook and YouTube. These videos continued to live on the CSFA website and Facebook pages and with continued shares and views.

One of the issues facing florists was the consumer's limited knowledge regarding the types of California flowers available to them. To educate the consumer on the large variety of flowers available to them, the CSFA created an online database of flowers. Consumers, farmers and florists were able to use and share these flower descriptions to help create a better understanding of the scope and seasonality of the California floral industry. Fifty-two of the most popular flowers in the state were photographed, and descriptions were created and uploaded on the CSFA website. The flowers continued to be shared on the CSFA social media sites as part of a "Flower Friday" educational tool.

To further educate consumers on California grown flowers, CSFA took to the California State Fair in 2015 and 2016 with an educational exhibit and display designed to interact with consumers and encourage them to purchase flowers grown in California. The project team discovered that consumers were very interested in learning more about California flowers through the interactions with the public at the state fair. The exhibits offered visitors a close-up look at how flowers were grown, giving them a better appreciation for flowers and support for the industry. With over half, a million-people attending the state fair over the 17-day run each year, the CSFA was able to reach a large audience of consumers. The team found the activation to be beneficial to increasing overall awareness of California flowers. Video and photography of the California State Fair activation were captured and promoted on social media to reach audiences outside the state fair as well.

The CSFA engaged in several activities to execute and ensure that the Specialty Crop Block Grant funds were utilized to solely enhance the competitiveness of specialty crops. All social media content was precleared by the CSFA team at regular content calendar meetings whereby the team ensured that California flowers were featured on social media and blog posts. All elements of the CSFA California State Fair activation were focused on California flowers.

Significant contribution came from the CA GROWN, and California Cut Flower Commission programs through content sharing on their platforms to help further the project's overall reach.

Goals and Outcomes Achieved

The CSFA website was revised in order to be more consumer friendly. The website was designed by graphic designers and developers, a blogger was secured to create content for the blog, and a social media team created social media content three to four times per week. A photographer was secured to create photography for the website and social media posts, and a videographer was secured to create the video content.

For the California State Fair activation, CSFA staff worked with board members to create the exhibit space and coordinate activations within the space.

The CSFA staff worked with contractors to develop a list of California flowers and then create photography and descriptions for floral database.

Long term, the CSFA and the flower farming community will have access to the digital assets created by the project team, a library of flower descriptions and quality videos that can continually be shared via social media and websites. These assets will help continue to educate and inspire consumers to purchase California flowers.

The goal of the project was to increase sales of California grown flowers by 5% by putting flowers at the forefront of the minds of the consumer and by offering creative usage ideas. While messaging about flowers reached 10 million people, the industry did not experience a 5% increase in sales overall.

In a 2013 omnibus survey conducted among 1,106 adults in 48 states and Washington D.C., indicated that 74% of adults did not know where their flowers came from, and if given an option 58% would purchase California grown flowers versus imported flowers. In 2017, the CSFA conducted a similar survey and discovered that 73% of consumers didn't know where their flowers were grown, and 47.9% said they would prefer to buy California grown flowers. Of the Californians surveyed in 2017, 65% did know where their flowers were grown, and 65% said they would prefer to buy California grown.

The CSFA program reached 8.5 million consumers and earned 1.3 million video views with positive messages about purchasing California grown flowers. The messaging was well received and offered ideas for using store-bought California grown flowers and ideas for working with a florist to creative beautiful arrangements.

Beneficiaries

This project provided promotional benefit to the 250-275 California flower farms and 20,000 floral outlets represented by the California Cut Flower Commission, the CSFA. These groups and operations benefited

from consistent content distribution through online platforms educating California consumers of the availability and uses as well as the importance of purchasing "local" California flowers.

The beneficiaries were the 250-275 California flower farmers, the retail and floral businesses who sold California flowers. The beneficiaries benefited from the nearly 10 million consumer impressions generated throughout the state calling consumer attention to the availability and various uses of California flowers and encouragement to purchase California flowers. The program also generated digital assets i.e. photography of over 60 California flower varieties; video content that can be linked and played as well as blog and 'do it yourself' content that could be distributed to a consumer audience in the future.

Lessons Learned

The first lesson learned was that the budget allocated to the development of an online flower application (app) would not have been sufficient for both the effective development and promotion of the app to encourage significant downloads of the app. The app market landscape at this time was hypercompetitive. Without sufficient promotion it was unlikely that the project would achieve many downloads of the app. Instead, that budget was reallocated to the activation at the California State Fair in 2015. Additionally, the project team decided that the already popular apps (Facebook; Instagram; Pinterest) were a more effective way to distribute the same content that would have been distributed through the proposed floral app. The successful California State Fair activation in 2015 led to the successful activation at the 2016 California State Fair. The second lesson learned was that in order to enhance the promotion of the purchase of California flowers the project needed to invest in an online resource that could educate consumers what California flowers were available at specific times of the year. This led to the development of a visually impactful and user-friendly online California flower database that highlighted and identified 52 of the most popular California flowers available for purchase.

Sales of cut flowers did not increase as expected, but changes in growing acreage and the market may have influenced the outcome. The significant shortcoming in setting the sales goal was identifying how to effectively measure the impact of the program on actual sales of California flowers. Additionally, the execution of the social media, blog and video content distribution, though successful with 10 million impressions generated for the run of the project, did not have a direct transactional relationship with the sales of California flowers. Future promotions of California flowers that aim to increase sales should consider including a retail promotion of California flowers in order to more directly relate the efforts of the project to increased sales of California flowers. This was found to be the most realistic method to have an impact on sales given that there are market dynamics and global economics that often cannot be overcome through a single promotional program. More partnerships with retail and sales outlets should be integral to a promotion program in order to effectively influence sales of California flowers – sales is not marketing, though they are interdependent.

Additional Information

No additional information.

USDA Project No.:	Project Title:	
9	Shade Cloth Benefits for Apples	
Grant Recipient: California Apple Commission	**Grant Agreement No.:** SCB14009	**Date Submitted:** December 2017
Recipient Contact: Todd Sanders	**Telephone:** (559) 225-3000	**Email:** tsanders@calapple.org

Project Summary

The growing regions in California receive an enormous amount of sun and heat which result in better tasting apples, however the sun is also detrimental to the apple coloring. The California Apple Commission (CAC) researched different types of Shade Cloth (SC) and the effects it had on apples grown in California. The project focused on determining the economic viability of applying SCs in California. Improving color and specifically limiting sunburn on California apples will dramatically improve their marketability. The project used 400-500 tons of apples as a sample size each year. Research in SC has demonstrated good results in other areas but this research had not yet been conducted in California. To achieve prime coloring, apples should be grown in a 68°F- 86°F environment. Studies state that SC can reduce temperatures within the orchard up to 12°F. On average, California apples are grown at 90°F. The project's research was set to determine if utilizing SC could improve California apple coloring as well as protect apples from sunburn and hail damage. Furthermore, the project monitored the amount of water that was utilized on the SC orchards and the amount of crop protection products (CPP) used when compared to the control orchards. This brought forward the idea that if the temperature of the orchard was lower, then the grower would use less overhead cooling (water) to maintain the correct temperature. Considering that California is in an extreme drought, if this process works it could be extremely beneficial. The use of SCs has the potential to combat several issues (heat, sunburn, hail, water limitations, and reduced CPP) that hinder California apple industry.

The importance and timeliness of the product was extremely significant for several reasons. First, due to the ongoing drought, growers in California are being forced to be more cautious and prudent with their water usage. In California, apples are grown with overhead cooling (water sprays) to help reduce the temperature in the orchards. Not only is overhead cooling exceptionally costly, but it uses a resource that is extremely limited. Growers in California are quickly turning to crops that use less water and removing crops that use more water. As California enters another possible year of drought, anything that can reduce water usage will benefit not only California apple growers but all Californians. In addition to the reduced water usage, SC reduces the temperature of the orchard which has shown the potential to increase the color and brix of certain varieties. Both the increase in color and brix have demonstrated the ability to increase sales. If there is an increase in sales, that should translate to more money to the grower which in turn would lead to more apple plantings. If all of these variables were found to be valid, the California apple industry would have benefited dramatically.

This project did not build on a previously funded Specialty Crop Block Grant Program project.

Project Approach

The CAC began working alongside several growers, comparing and contrasting four, 10-acre plots from Northern and Southern California. This provided an effective sample size of close to 400-500 tons of apples per year to evaluate. The research included comparing and contrasting growth, color, damage, water usage,

and crop protection tools on apples from each plot. Plots from each growing region utilized SCs and the other plots were grown traditionally as a control group. The plots were located side by side to achieve valid data. The SC group used different SC colors and exposure percentage levels to decipher which would be most beneficial to California growers. This experiment occurred in 2015 and 2016 with the actual harvest occurring during the months of July through October. Economic impact and cost effectiveness of the SCs concluded in December 2016 with final results disseminated in February 2017.

A very specific outcome of the project that the growers have greatly appreciated was the SC structure building process. During the initial year of the project, structure to hold the SC was built in ordinance with Washington State and other growing region standards. This was not practical, as most California growers utilize overhead cooling and "V" trellis systems which is not the industry norm. Additionally, the central valley apple growing regions are extremely windy at times and the new structure had to account for that. The SC structure that was designed, was specific for California and would not have been possible without this project. Below are some of the specific findings of the project:

1) Looking at all apple varieties, the control apples had a more consistent color than that of the treated apples, and received the higher color rating at pack out.

2) Across all varieties, the size of the fruit was consistent, not including the Pink Lady and Granny Smith varieties which showed an increase in diameter at pack out due to the SC.

3) Firmness stayed consistent across the control and SC apples, except for Granny Smith variety which had a lower firmness under the SC.

4) Brix fluctuated more across the treatments. The Gala SC apples were about one point higher than the control apples but the Fuji control apples were about one point higher than the Fuji SC apples.

5) At pack out, the defects seen in the SC apples of the Granny Smith variety were significantly lower. This variety demonstrated lower incidence of bitter pit, cork spot, sun burn, and bruising (93% less than control). Unfortunately, it also demonstrated almost seven times the incidence of scabbing. In the Pink Lady variety, the SC apples showed a lower incidence of sunburn, russeting, growth crack, and San Jose Scale but had a higher occurrence of bruising, bitter pit, insect damage, and wind falls.

This project did not enhance the competitiveness of non-specialty crops.

The project used a third party researcher which remained readily available to both the CAC staff as well as participating growers throughout the term in which involvement in the project occurred. The researcher handled the installation of temperature probes in participating orchards where the fruit was then collected and analyzed within an appropriate time frame. Additionally, the researcher provided the CAC with a thorough report which included a compilation of data that was gathered from the project. This data analysis represents the results of the project at this point in time, despite the setbacks that were faced within the process early on.

The project worked with a supplier that provided the CAC and participating growers with the necessary shade cloth materials for this project. Even with the port closure that occurred early on in the project, the supplier

worked diligently to expedite the materials and even offered to air freight the materials to California to help evade the port closure problems.

Our participating growers have consistently worked alongside the CAC staff and other partners to ensure this project reached completion as effectively as possible.

Goals and Outcomes Achieved

The overall goal for the grant was to provide California growers with an abundance of information regarding the use of SC on California apples.

The measurable outcomes for this research are outlined as follows:

1) Determine if SC will help improve the quality in color, size and damage of apples that are treated verses that of the control:
   - The research found that the initial answer to this question for all four varieties (Granny Smith, Pink Lady, Gala, and Fuji) is inconclusive due to the loss of the first year, which resulted in a limited range of data. In spite of this, within the limited data it was found that across all varieties, the control apples had more consistent color than that of the SC apples, no major differences in size between the control and SC apples (although the Granny Smith and Pink Lady varieties were slightly larger under the SC), Damage and defects were decreased under the SC in both Granny Smith and Pink Lady varieties.

2) Measure water usage and CPP applications and contrast that between controls and treated: the target is to decrease the use of both water and CPP applications.
   - Due to a restricted data range, initial results are statistically limited but the research found that on average water usage was decreased under the SC apples verses the control apples. Soil moisture was increased under the SC apples verses control apples. There was no noticeable difference in CPP applications with the SC apples verses the control apples.

3) A cost/benefit analysis of using SC was preformed to demonstrate the cost and potential savings upon the implementation of the SC.
   - Since the data range is limited, accurate and detailed results are statistically invalid. The overall grower consensus was that another growing season is needed to provide a statistically relevant economic feasibility study. Initial observations indicate that there may be benefits that are economically viable with the Granny Smith variety but not with the other varieties. More data is needed to determine if the SC was viable in California.

The outcome of the project was to determine if the SC was viable in California. Due to the limited data of the initial year, the CAC plans to further their research about SC. This should allow for more data to be collected and provide a more valid statistical outcome. The findings of this project will be distributed to all California apple growers so that any long term SC investments can be contrasted with this research.

Before the start of the project, there was zero information on SC in California. All SC research had been conducted in other growing regions such as Washington State, New Zealand, and Australia. These growing regions have very different conditions, problems, and growing styles than California. Since this project has

concluded, the information provided has proven extremely valuable to the California apple industry. Even though some of the information did not turn out as expected, the research did demonstrate to the California apple industry what SC is capable and incapable of doing. Growers from California now have specific data on SC relating to California which can now be used to make future decisions. The building of multiple SC structures, each with its own unique individual growing challenge, has allowed for multiple years of research to be completed in one season. The California apple industry now has a discernable design on how the SC structure needs to be built in ordinance with California's unique growing trends. Additionally, all SC research will be disseminated to 72 growers within California which will allow for smaller growers to benefit from research that normally would not be economically feasible.

Although not all data were positive outcomes, the observations from this project include:

1) SC did not improve the overall apple yield per acre based on the current available information.
2) CPP usage was not measurably impacted but that could change with the extended data from future research.
3) Water usage decreased when using SC and soil moisture increased when using SC.
4) With red or bicolored apples, the SC detrimentally impacted skin color.
5) With the Gala and Pink Lady varieties the pack out per bin decreased in treated fruit (12% Gala and 27.1% Pink Lady).
6) With the Granny Smith variety the pack out per bin increased by 3.2%.
7) Size was increased in the Granny Smith variety.
8) Postharvest disorders decreased in the Granny Smith variety.

Beneficiaries

The groups that benefited from the project's accomplishments include the apple growers and apple packing sheds, as well as the consumers. If SC improved color and quality, a better apple would have been delivered to the consumer. Unfortunately, the preliminary data thus far has determined that there may not be a tremendous amount of benefit in implementing SC into all apple orchard operations besides the Granny Smith variety.

The beneficiaries of the data collected in this project are 72 apple growers and 8 apple packing sheds. The project determined that SC impacted water usage and cooled the orchard temperatures when full coverage was used. With lower temperatures and a decrease in water usage, more money will return to the grower. Consensus among the participating growers is that another season is needed before the economic feasibility of SC in California apple production can be full assessed. Some initial observations indicate that there may be benefits in the Granny Smith variety production but not in Gala, Pink Lady or Fuji varieties. The project can conclude that the Granny Smith variety has benefited in size and postharvest disorders. Other intentions of this research were to demonstrate improved size, color, brix, and other variables which ultimately would result in the consumers benefiting as much as the growers and packers. With a better apple, the growers and packers would get a better return on their investment and sell more apples at a higher price. Unfortunately, with limited data due to the initial year, concrete conclusions on size, color, and brix are not statistically valid.

Lessons Learned

After completing this project, the project staff learned that a fully covered orchard does significantly better than those with only partial coverage. Water conservation was greater, along with a decreased temperature, in the orchards with greater coverage. There was an average 3°F decrease in temperature but as much as a 6°F decrease in some orchards overall. Across all apple varieties, the control apples had more consistent color than the treated apples, and received more of the highest color rating at pack out. The treated Granny Smith and Pink Lady apples produced larger sizes at pack out. The SC was also useful for protecting the apple orchards from hail in some instances.

Initially, the project was delayed due to unforeseen circumstances, such as the port closure and troubles with finding the correct structure alignment and placement. These delays lead to limited research being conducted during the first year. However, it was not a complete loss as some of the most valuable SC research turned out to be the design and implementation of the SC structure. Ultimately, one very positive lesson of the grant was in the design of the SC structure and the placement of the SC. Both structure design and SC placement was critical to discern the benefits of SC. Once the SC was installed "correctly," valid research was conducted. Additionally, it was initially thought that the SC would benefit all varieties of apples. At the conclusion of the project, it was apparent that some varieties did better under SC while others did not. For example, the Granny Smith variety (2nd largest by volume in California) demonstrated improvement under SC while other varieties, such as Gala, did not fare as well. All this information is valuable to the grower because they can now focus on where SC can help rather than looking for a "catch-all product" that claims to help everything. As one grower put, "Knowing what SC cannot do, is just as valuable as knowing what it can do."

Unexpectedly, the SC research was extremely beneficial in determining the type of structure needed to hold the SC over the orchards. Initially, this was not even considered to be an issue or problem, but due to California's unique overhead cooling apparatuses the SC structure had to be designed from scratch. This caused some setbacks but the project allowed the California apple industry to design the SC structure specifically to a "V" trellis system with overhead cooling.

The project's overall objective was to provide California growers with an abundance of information regarding the use of SC on California apples. The overall goal of the project was achieved as ample information was obtained, but it did not necessarily align with what the CAC originally hoped to achieve.

Additional Information

The California Apple Commission published an Annual Report which includes detailed information regarding the Shade Cloth research. The CAC's Annual Report can be found at the following link: http://www.calapple.org/AnnualReport.

USDA Project No.:	Project Title:	
10	Plant Something! Inspiring Consumers to Plant a Garden with California Nursery plants	
Grant Recipient: California Association of Nurseries and Garden Centers	**Grant Agreement No.:** SCB14010	**Date Submitted:** December 2016
Recipient Contact: Chris Zanobini	**Telephone:** (916) 448-3900	**Email:** chris@agamsi.com

Project Summary

This project addressed the significant contraction experienced by the California nursery industry in recent years. Many producers either consolidated or exited the industry entirely. The primary driver of this downturn was the depressed construction industry during and following the recession coupled with broader economic hardship. The mission of Plant California was to inspire and educate Californians to plant something. By equipping consumers with gardening best practices through fun and informative garden projects and tips, consumers become more excited and confident to plant. The goal of this project was to ultimately increase nursery products sales by increasing consumer demand for plants.

With fewer homes being built and therefore fewer landscapes being constructed, nursery sales declined across the state. The recent uptick in home construction as well as a renewed interest in landscape beautification, water wise and pollinator friendly landscaping offered an opportunity for this project. Plant California followed in the footsteps of the Arizona Association of Nurseries' successful *Plant Something!* campaign which realized an annual average increase in retail sales of 11% between 2010 and 2012. This campaign has continued to have a significant impact on the long-term success of the Arizona nursery industry. The timing of this project enabled the California *Plant Something!* campaign to capitalize on established messaging and collateral, outreach strategies, and strategic partnerships. This project became even more relevant as California's historic drought persisted into its fifth year. Triggering mandatory watering restrictions and water conservation efforts which created uncertainty among consumers due to water scarcity, resulting in an overall reduced market for nursery crops.

This project neither built upon a previously funded Specialty Crop Block Grant Program (SCBGP) project, nor was it submitted to or funded by another federal or state grant program.

Project Approach

In March 2015, the website PlantCalifornia.com launched, including a Learning Center with gardening tips and multimedia garden projects, and gardening workshops throughout California. It also featured a retail nursery locator and page on "Why to Plant." The website officially launched at the California Agriculture Day on March 18, 2015 when Plant California had a booth on the steps of the California State Capitol. The launch coincided with the start of the Plant California radio campaign. During March through May 2015, 30 and 60 second radio spots for Plant California ran on Sacramento, Los Angeles and Bay Area radio stations.

The radio and web marketing campaign inspired Californians to learn more about gardening and drove consumers to PlantCalifornia.com. Plant California's audience grew due to the radio spots, social media campaigns, leveraging partner networks, and promotion at public as well as industry facing events.

With social media representation on Facebook, Twitter, Instagram, Pinterest, and YouTube, Plant California saw measurable, consistent growth in engagement across all platforms. Facebook produced the most significant results measured by audience engagement and website referrals. As of October 2016, the Plant California Facebook page had 8,598 followers and growing. The campaign saw significant organic growth as well, which further reinforced that the messaging resonated.

The project team ran a booth within the CA GROWN Pavilion during two consumer facing events held in partnership with Sunset Magazine in 2015. On June 6 and 7, Plant California had a booth at Sunset Celebration Weekend, a 20,000+ consumer event in Menlo Park (located in one of the San Francisco bay area target market). The booth featured garden projects and tips. The team engaged with approximately 2,500 guests. Email addresses were collected in order to help build Plant California's audience on Facebook. Guests were also surveyed on garden topics of interest. The project team also attended Savor the Central Coast on September 26 and 27, 2015 which brought out over 10,000 attendees over two days in San Luis Obispo County. Plant California's booth featured the *Fall into Planting* campaign. Engagements centered on educating guests on September and October as the ideal time to plant in most regions of California. At the California Association of Nurseries and Garden Centers' (CANGC) Northern Region Kickoff in September 2015, nursery industry stakeholders were updated on Plant California's progress and encouraged to share Plant California's content, upload workshops, and engage on social media. On March 16, 2016, at the California Agriculture Day celebration on the steps of the State Capital, a Plant California booth featured gardening projects. Attendees learned of Plant California as a resource for gardening information, many were especially interested in learning "How to be a Water Wise Gardener." Plant California also had a table at two University of California, Davis Arboretum Plant Sales in October and March featuring the "Small Space Butterfly Garden" project to tie in with the Arboretum's plethora of pollinator friendly plants. A spike in followers and engagement was experienced after each of these events.

Through event outreach, social campaigns and partner outreach, visits to PlantCalifornia.com grew. Website analytics demonstrated that the home page, planting guide, and nursery finder were the most visited pages. Consumers also spent time watching garden project videos and reading garden tips on the websites Learning Center. These numbers did not take into account the views of gardening project videos that played natively on Facebook. While Facebook remained the top referral source to PlantCalifornia.com, partners including SaveOurWater.com, Bewaterwise.com (i.e. The Metropolitan Water District of Southern California), Plant Something and retail nurseries continued to be significant referral sources.

All SCBGP funds were used to solely enhance the competitiveness of California nursery products.

Leveraging CANGC member and partner networks to broaden the reach of Plant California has expedited and strengthened audience growth. Banners promoting Plant California were displayed at each CANGC member retail location. The banners helped to promote and inform the public of Plant California as a resource online and at events. Other notable partners included PlantRight and CA Grown, of which CANGC was a member, shared numerous content with their expansive audience, boosting the reach of Plant California by extension. Save Our Water also partnered with Plant California to educate Californians on how to be more water wise gardeners. This was for example, achieved by espousing the benefits of planting in the fall. The press release, "Save Our Water and Plant California Partner to Promote California-Friendly Landscaping this Fall," found here published in September 2016 detailed the efforts of this partnership. New content was also created through partnerships to provide access to relevant information. For example, the California Center for Urban

Forestry offered information on, "How to Help Trees Survive Drought" this content was rebranded and added to Plant California as a garden tip. When shared in July 2016 (at the height of summer intended public awareness of water conservation) this tip reached 8,126 (4,588 organic reach, 3,588 paid reach) users on social media.

Goals and Outcomes Achieved

Many California retail nurseries supported Plant California and used it as an industry resource, including posting workshops on the Learning Center, and the sharing of gardening projects and tips digitally as well as in print with flyers of the most popular projects and tips. CANGC members also provided plant sales data in the target markets (Los Angeles, Sacramento and San Francisco).

The outcome from this project was quantified by measuring its impact on baseline plant sales in California retail nurseries. Performance was measured by examining sales data and comparing it to a benchmark of prior years. The target of an 11% increase in plant sales was based on plant sales in Arizona retail nurseries in 2011-2012 after the launch of the *Plant Something!* campaign. The goal for outreach through the radio campaign was a minimum of 15 to 20 radio spots per week and a minimum of 200 gross rating points per week over the course of the schedule.

While quantifiable outcome measures were set, increasing long-term nursery crop sales by creating a sustainable consumer base for California nursery crops was an overarching goal of this project.

Taking into account that California entered its fifth year of historic drought and the announcement of the first ever state wide water reduction mandate immediately following Plant California's launch, an 11% increase in plant sales annually was no longer realistic. In 2011-2012, the first dry years on the West coast were not yet considered a drought and had little or no impact on water regulations and therefore consumers' purchasing behaviors in Arizona.

Based on sales data from Bay Area nurseries, total plant sales in the area increased by .5%. Based on data from Sacramento retail nurseries, plant sales declined by 2% and in Los Angeles plant sales decrease by 1.35%. The data indicated an average change in plant sales was negative 2.85% across all three markets.

The Governor's Executive Order directing the first ever statewide mandatory water reductions for residences as well as businesses was announced on April 1, 2015, two weeks after the launch of Plant California. After considering this unprecedented conservation mandate, the decrease in plant sales reflected a consumer response to restrict plant purchases due to the uncertainty of water availability. In some areas of the state, one day a week watering restrictions were implemented. Outdoor water conservation messaging, such as the California Department of Transportation highway signs that read "Severe drought limit outdoor water," also impacted consumer behavior.

One target market reflected a modest increase in plant sales and while Plant California was unable to achieve its full potential impact, without the educational and inspirational messaging from Plant California, it is likely that plant sales in these markets would have increased less or decreased further during this period of drought and water uncertainty.

The reach and frequency of the radio campaign was achieved and reflected in spikes during the time of the campaign. Below is a summary of the demographics of those reached by the radio spots and the frequency at which they were reached:

Gross Ratings Point Summary for radio campaign:

Multi-Market Summary

Market	Total Spots	Total Cost	CPP ($)	GRP	Reach	Rch %	Freq	GIMP	Pop
Los Angeles	650	$168,380	$641	262.6	3,672,979	64.8	4.1	15,008,200	5,668,100
Sacramento	334	$29,035	$151	192.6	469,461	52.1	3.7	1,737,600	901,200
San Francisco	558	$92,940	$438	212.2	1,653,354	50.9	4.1	6,715,400	3,250,400
Schedule Total	1542	$290,355	$1,212	239.5	5,795,794	59.0	4.0	23,461,200	9,819,700

Multi-Demo Summary

Demo	Total Cost	Rch %	Freq	GRP	GIMP
Adults 25-54	$290,355	59.0	4.0	239.5	23,461,200
Men 25-54	$290,355	58.1	4.0	235.8	11,485,200
Women 25-54	$290,355	59.9	4.1	241.8	11,970,200
Adults 18+	$290,355	52.2	3.9	207.1	36,604,400

CANGC received plant sales data from the three target markets during the year preceding the launch of Plant California (February 2014 – February 2015) and the year following the launch (March 2015 – March 2016). The benchmark year (February 2014 - February 2015) no longer offered a controlled dataset to compare with plant sales in the year following Plant California's launch because water restrictions began in early April 2015 and continue to influence consumer perceptions and purchasing habits.

Hundreds of thousands of Californians were reached by Plant California's mission to inspire and educate them to plant something. Fun and informative gardening projects and tips were viewed and read by experienced and novice gardeners alike, according to social media analytics which offered insight into user hobbies and interests. Helpful resources on PlantCalifornia.com such as upcoming nursery workshops in the Learning Center and a retail nursery locator helped to connect consumers with the garden experts and resources at retail nurseries. The content surrounding pollinator friendly plants resonated well with consumers. As did content focusing on the direct benefits plants offered wildlife (outdoor habitat and forage), and the direct benefits to gardeners such as the potential for shade trees to offer reduced energy consumption. Seasonal emphasis was placed on fall and spring for promotions to coincide with planting seasons to ensure the greatest impact.

The value of this campaign during California's historic drought was reflected in the strength of the organic reach received when sharing water wise gardening projects and tips. For example, when Plant California shared a gardening tip and video on water wise grasses and groundcovers in September 2016, it reached almost 20,000 people organically in part thanks to the strategic statewide partners listed and their affiliate agencies including the West Kern Water District and Folsom Water Conservation. Plant California also boosted posts to reach a greater number of consumers on social media. This provided a broader reach and higher return on investment.

How to save water and allow plants to survive and thrive was a void filled in part by engagement with Plant California. Messaging throughout the project was shifted to focus more on water wise gardening practices and projects. Best horticultural gardening practices were framed in the context of increasing soil moisture retention, for example watering less often and more deeply allows many plants to thrive within watering

restrictions. Water wise plant varieties were highlighted with a great response from consumers. A greater emphasis was put on the diversity, hardiness and beauty of water wise plants to educate Californians on how to garden during a drought. Photos and videos were repurposed to stretch their shelf life, for instance the plants featured in, "How to be a Water-wise Gardener" were re-edited into a video on water-wise plants. "How to be a Water Wise Gardener" continued to be a crowd favorite in-person events and online. Plant California's fall planting campaign was an extension of water wise messaging, focusing on the fact that planting in fall will allow winter rains to water thirsty young plants and better establish their roots before the summer heat returns. This core message and that most trees, shrubs, perennials and certain edibles do best when planted during fall was shared directly with consumers and through Plant California partners.

Beneficiaries

Retail nurseries and garden centers benefited from this project directly by having consumers driven to their stores by the radio campaign, nursery locator, and social media promotion of educational workshops and events and gardening in general. Retailers also shared Plant California's content, including many independent retailers without the resources for a marketing team. California nursery growers also benefited indirectly by increasing consumer demand for their products.

The number of public agencies that shared Plant California's fun and informative gardening content was a testament to the public benefits of this project and the value and timeliness its messaging offered. Dozens of different water agencies, districts and other public utilities and municipalities such as the Los Angeles Department of Water and Power, shared and requested to share content with their constituents directly and through social media. The water wise messaging proved to be the most relevant and in demand content with these groups, as demonstrated by the greater reach and success of social media campaigns with water wise messaging.

All California nurseries benefited and stand to benefit directly or indirectly from Plant California. The generic promotion nature of this project and of the demand it created benefited retailers and growers of every type and size. Plant California will continue to inform consumers during the drought and helped mitigate the negative impact on nursery crop sales.

This project directly affected 481 retail nursery and garden center locations throughout California. Additionally, over 100 growers of nursery products benefitted from increased consumer demand for their products at retail. Through the generic promotion of gardening, California growers benefited indirectly from Plant California's efforts to inspire and educate Californians to plant something.

Lessons Learned

As mentioned earlier, leveraging other partners' networks (CA GROWN, Save Our Water and PlantRight) helped to legitimize and increase exposure for Plant California. This allowed Plant California's budget to be stretched when targeting consumers, resulting in more Californians learning about gardening best practices equipping them with the information and confidence to make plant purchases. Working with partners to help customize content and messaging for their platforms and audience increased the number of partners and frequency at which they were willing and eager to share gardening content. Save Our Water approached Plant California with regard to partnering on the 2016 fall planting campaign after a successful 2015 campaign and a great response to shared content on social media. As the consumer facing campaign of Association of

California Water Agencies (ACWA) and the California Department of Water Resources, Save Our Water's partnership resulted in dozens of public water and utility agencies sharing Plant California's content.

There were a few negative responses with regard to the inherent water use of plants, especially in the first few months after the mandatory watering restrictions were in place. Negative comments such as this were mitigated by responding with information and instructions in the form of gardening tips and projects to show people how to garden in a drought and the importance of plants.

While the radio campaign reached California consumers in the target markets and at the frequency projected, a web radio component would likely have yielded even greater and more directly measurable results in driving consumers to PlantCalifornia.com. This would have allowed consumers to navigate to the site while listening to the radio spot on a computer, tablet or smart phone.

As a result of the persistent drought, Plant California's messaging needed to be even more dynamic and basic than expected. In response to negative consumer comments around the fact that all plants require some amount of water to survive, core messaging centered on answering the question "Why Plant." This messaging helped to explain the benefits of plants including: wildlife habitat, improved air quality, increased home value, cleaner air and reduced energy consumption. While the initial messaging was based on Arizona's *Plant Something!* campaign, the drought required that first consumers understand why planting something can be beneficial for personal health, community well-being and wildlife and that it is possible whilst still conserving water. This in turn informed nurseries developing messaging, to not simply assume that all customers believe that plants are good.

The five year drought in California was an ever present challenge throughout this project and greatly impacted sales. The 11% percent increase seen in Arizona nursery sales following the *Plant Something*! campaign was not achieved as nursery sales declined as the drought progressed, dropping off steeply after the mandatory water restrictions went into effect in April 2015. While the drought had begun when this project proposal was drafted in 2013, the extent of the duration and impact was not yet known and could not have been predicted. This serves as a reminder that climate can impact specialty crop markets in unique and unpredictable ways and when climate impacts are realized they should be incorporated immediately into the project action plan.

Additional Information

Web and social media links:
www.PlantCalifornia.com
https://www.facebook.com/PlantCalifornia
https://twitter.com/PlantCalifornia
https://www.pinterest.com/PlantCalifornia/
https://instagram.com/plantcalifornia/
https://www.youtube.com/channel/UC94nHx6ItcqQ0hEx5dTsT5g

USDA Project No.:	Project Title:	
11	Ensuring Grape Grower Viability by Driving Sales for Sonoma County Wines	
Grant Recipient: Sonoma County Local District 3 Winegrape Commission	**Grant Agreement No.:** SCB14011	**Date Submitted:** December 2017
Recipient Contact: Sean Carroll	**Telephone:** (707) 522-5865	**Email:** sean@sonomawinegrape.org

Project Summary

The purpose of this project was to raise grape returns with marketing and promotional efforts aimed at growing premium (over $15 per bottle) sales, leading to higher winegrape prices. As a marketing commission representing 100 percent of Sonoma's winegrape producers, Sonoma County Winegrape Commission (SCWC) is strongly aware of the needs facing the industry. Three year average Sonoma winegrape farmgate price in 2012 was only $7 per ton (0.3 percent) higher than 2002's three-year average, while 2002 through 2012 costs rose a cumulative 33 percent (averages used as prices fluctuate for many reasons). As opposed to taking market share from other regions or increasing total wine consumption, this project seeks to influence the price consumers and the wine trade will pay for premium Sonoma County wine, resulting in higher returns for growers.

Though prices have recovered some since the recession, they still significantly lag cost increases. Adding to the project's importance and timeliness, growers now face a devastating drought. Sonoma County Water Agency officials state the region is the "driest it's been in 120 years," which is widely expected to lower yields. The objective is to increase grape prices by $50 per ton per year by crop year 2016. SCWC assesses growers a percentage of crop value for marketing/promotions; a drought-reduced yield not only impacts growers but directly impacts SCWC's funding for marketing purposes. Grant funds solely enhanced the competitiveness of California specialty crops (winegrapes from Sonoma County).

This project creates economic opportunities for specialty crop producers through market development activities. This project projected to increase winegrape prices by $50 per ton per year by 2016, raising returns for Sonoma's over 1,800 growers by $10.45 million per year. Sonoma growers face rising costs with cumulative inflation of 33 percent from 2002 through 2012; the three-year average grape price rose just 0.3 percent. Sonoma, a high cost growing region, produces 6.7 percent of California’s winegrapes and accounts for 26.8 percent of California’s winegrape revenue. This project capitalized on new California law requiring conjunctive "Sonoma" labeling on bottles produced in the county by jointly promoting Sonoma wines with grower videos, website improvements, print/digital ads, printed materials, radio ads, and newsletters.

The importance and timeliness of this project was crucial to the success of SCWC marketing and promotional efforts, as well as to help increase the value of the winegrape grower’s grapes during a time of market uncertainty due to the drought conditions and other factors facing winegrape growers in this region.

2013 and 2014 were two of the largest grape crops on record for Sonoma County, which resulted in more grapes in the marketplace. In 2015, winegrape growers experienced a major decline in crop size, with some vineyard owners reporting a 35%-50% decrease of crop size compared to previous years. This not only impacted their vineyard operations and businesses, but it also impacted the SCWC marketing budget. As a

Winegrape Commission, the budget each year is based on assessment fees that winegrape growers pay from the sale of their grapes. Each grower that sells more than 25 tons of winegrapes is required to pay 0.5% (one half percent) of the gross dollar value of their grape sales. Those funds make up most of the budget funding, so when Sonoma County experiences a major decrease in crop size, it seriously impacts the budget and marketing efforts. The timeliness of this grant funding helped to continue the promotional and marketing efforts even in a year of crop size decline and a decrease in marketing funds.

Additionally, California has experienced a major drought, which has heightened the visibility and scrutiny of agriculture and grape growing to the public and media. The timing and importance of this grant also helped support the SCWC's efforts to promote, communicate, and showcase all the great water conservation efforts and sustainable farming practices that were making a difference.

Overall, the importance and timeliness of the grant funding was a major factor for the success and ability to promote the multigenerational winegrape growers and help increase the value of their grape crop, even in times of a smaller crop size and drought conditions.

This project built upon the 2012 Specialty Crop Block Grant Program (SCBGP) Project 13: *Branding Sonoma County Wines* which launched a branding campaign between SCWC, Sonoma County Vintners, and Sonoma County Tourism to build Sonoma wine awareness and create/enforce consumer value perceptions for Sonoma County wines. The primary purpose and goal of the 2012 SCBGP Project 13 was to recover a large portion of lost grower returns from the weakened economy and from wineries dropping Sonoma American Viticulture Area labels to purchase cheaper non-Sonoma wine grapes. The primary purpose and goal of this project was to continue that momentum and build on that success by further increasing prices paid to Sonoma County grape growers by $50 per ton per year.

None of the promotions were duplicated, just expanded and enhanced. For example, the 2012 SCBGP Project 13 included some print advertising and promotions in partnership with a food and wine magazine. Due to this strong partnership with one of America's most influential wine and food magazines, the project team negotiated to have an executive wine editor and a leading authority on wine, appear in the grower video series activity for this grant project. This brought further credibility to the video series and helped expand its reach and awareness to consumers.

In addition, this grant project allowed the expansion of Sonoma County consumer brand awareness campaign that was started during the 2012 project. This included expanding the reach of digital ad campaign on social media channels, such as Facebook, to promote grape growing in Sonoma County year around. Seven additional print ads were purchased in national, regional, and local newspapers to promote grape growers and vineyards in Sonoma County.

Collectively, these two projects helped expand consumer awareness for Sonoma County and its grape growers by millions of wine consumers across the entire United States.

Project Activities

The SCWC is proud of all the work accomplished and the successful results of the activities from this grant project. The following is a summary of activities and accomplishments:

Creative Agency: In collaboration with the project's creative agency partner, SCWC developed, designed, created content, and produced a series of print and digital advertisements, print collateral and maps, and other promotional print material, to promote Sonoma County's grape growers and their leadership in sustainability and responsible farming. These new creative advertisements helped revise SCWC "We Are Sonoma County" brand campaign and better align the look/feel, communications, content, and other aspects of the promotions towards SCWC's commitment to sustainability. This included promoting their farming practices, multigenerational history of grape growing in Sonoma County, and other aspects of grape growing and vineyards. More than 450 hours were spent on these creative and design activities to ensure it met brand standards and to promote grape growing in Sonoma County.

As a result of these activities to develop and create new material for print and digital ads, SCWC was able to create more than a dozen new print ad templates that were used for advertisements and promotions across a multitude of publications, including national, regional, and local distributed publications. This included more than 11 different wine magazine, and others. These print and digital ads were also able to be used in presentations to Sonoma County grape grower community, wine industry representatives, media, influential sommeliers and wine buyers, community members, and the public.

Video Production: In partnership with the creative agency and the film producer, SCWC produced a series of eight videos that showcase Sonoma County grape growers, their vineyards, history of farming for multi-generational families, promotes sustainable farming practices, explains the winemaker and winegrower relationship dynamic, and provides background about Sonoma County's diverse winegrowing regions. This activity included working on the storyline and format of each video, scouting vineyard locations, recruiting grape growers to appear in the videos, 2 ½ full days of primary filming at locations across Sonoma County's winegrowing region, and post production that included editing each video down to 4-6 minutes in length, working with SCWC staff on approval and release of each video in the series.

This activity is a huge success from a promotional and branding perspective. When planning began for the storyline, and focus for each video, SCWC approached an executive wine editor at a well-known wine magazine to ask if he'd be willing to appear in the video so SCWC could create an "In conversation" feel to these videos. Because of the strong relationship with this magazine, they agreed to let him participate and appear in the videos. This was a huge success since this wine editor has never appeared in a regional video prior to SCWC's videos, and it provided even further credibility since he's one of the leading authorities on wine in the world and well respected by consumers, winemakers, and others. This partnership also provided another channel to promote the videos through the magazine's own marketing and social media efforts.

Each video features grape growers discussing their sustainable farming practices, history of grape growing in Sonoma County, educational information on what it takes to grow premium wine grapes, and why Sonoma County is an ideal winegrowing region. These videos help share the story of grape growing in Sonoma County and provides a lot of education about the passion, hard work, and legacy of farming in this region. The videos feature a range of vineyards, from small family farms to larger vineyards to vineyards dating back to the 1880's.

To date, these videos have been viewed more than 100,000 times and the overall promotional campaign has reached more than eight million consumers through digital advertising campaigns with Food & Wine, Facebook and other social media promotions, and media outreach. In addition, the webpage where these

videos are housed was one of the top three most visited/frequented pages on the SCWC website from June 2016-October 2016. These videos can be viewed at http://www.sonomawinegrape.org/backroads-backstories

Website Improvement: Working with project design partner, SCWC conceptualized, created, designed, and launched a new website at www.sonomavineyardadventures.com in support of the organization's recently re-launched Vineyard Adventures program that features self-guided vineyard walks for wine consumers and tourists visiting Sonoma County. Vineyard walks are a widely popular agri-tourism trend that showcases the diversity, unique terroir, and farming practices of the region's grape growers. SCWC has expanded the program and wanted to create a website that promoted the experience, shared information about grape growing, showed visuals such as vineyard photos, maps of Sonoma County, and other educational information to promote and persuade visitors to take a Vineyard Adventures walk. Activities included redesigning the Vineyard Adventures website to include maps of where these vineyards are located, vineyard photography, educational material on Sonoma County and its sustainable vineyard practices, and other important information to help promote grape growers and entice visitors to participate and take a vineyard walk next time they're in Sonoma County. The site was launched in August of 2016 and SCWC will continue monitoring the results and website metrics.

Another result of the great partnership between SCWC and the design partner was the activity was completed under budget, which allowed use of those funds for other activities within the grant project.

Print/Digital Ads: Using the new print and digital ad concepts, SCWC purchased space for print and digital ads that appeared in more than 25 national, regional, and local publications, as well as wine trade outlets. This comprehensive advertising campaign was designed to promote Sonoma County Winegrowers and Sonoma County wines to consumers in key wine markets across the U.S. to expand awareness for Sonoma County wines, increase wine purchases at local wine retailers and restaurants, and increase consumer attendance at local Sonoma County events, such as the SCWC's annual Grape Camp harvest experience.

There were more than 21 print advertisements and marketing brand awareness campaigns. Publications garnered more than 100 million impressions over the campaign. In addition, these efforts helped SCWC sell out of the annual Grape Camp consumer experience months in advance during the project, in fact, creating demand and a waiting list for 2015 and 2016 program events.

In addition, SCWC purchased more than a dozen digital ads on Facebook and launched an online social media tracker app to promote grape growing, sustainable farming, SCWC news and events, as well as share content from grape growers and winemaker during the important harvest season. This social media tracker allowed SCWC to aggregate social media posts from hundreds of grape grower and winemaker sources and display them in a uniform manner that helped promote the region, tell the story of harvest in real time and provide media with updates on all the activities during harvest. All of these digital activities helped SCWC reach more than eight million consumers.

In total, these print and digital ads helped convey the value and importance of vineyards and grape growers and told their story and impact on the quality of wines in Sonoma County. They also allowed SCWC to educate consumers about Sonoma County's sustainable vineyard practices and explain why wine is an agricultural product that starts in the vineyards. These promotional efforts also increased awareness and branding for Sonoma County winegrowers, allowed SCWC to position Sonoma County grape growers as

leaders in agriculture, sustainability, and as a quality source of premium winegrapes. The campaign also helped increase grape pricing year-over-year and demand is on the rise.

These efforts were also instrumental in helping build momentum and morale for grape growing in Sonoma County and helped to promote the positive aspects of sustainable farming practices in the local community, including water conservation efforts, dedication and support for vineyard employees, and other aspects.

Print Materials: SCWC created, designed, and printed a variety of collateral pieces to serve as promotional material for consumers, key wine trade representatives, and others at wine events, community events, and other venues. Over the duration of the project, postcards were created, fact sheets, brochures, pocket guides, regional maps, and more. All of these printed material helped to educate and inform the public, including consumers, members of the local community, as well as the regions grape growers, about key facts, information and other details about grape growing, sustainable farming, and other vineyard details. Thousands of these collateral print materials have been distributed at events throughout the U.S. has helped SCWC promote vineyards and wines in Sonoma County.

Radio Ads: SCWC, in partnership with a radio production company who produces and hosts a new sponsored radio program called "Off the Vine" with the Sonoma County Winegrowers. This program airs twice a month on Tuesdays from 4:20 PM to 5:00 PM during the peak drive time and commute hour for North Bay radio listeners. The show is also the top radio program in the North Bay region with approximately 110,000 listeners and provides a great forum for educating the community about issues related to grape growing and to help increase awareness for Sonoma County grapes. The show features members of the Sonoma County Winegrowers staff and local grape growers discussing vineyard practices, sustainability, and what it takes to grow and produce premium wine grapes. Since launching the show in 2014, SCWC has aired close to 50 episodes. In addition, SCWC shares each episode with the grape grower members in email newsletters, posted on SCWC website at http://www.sonomawinegrape.org/radio, and promoted on Social Media channels to expand its reach and showcase the results to the region's grape growers and project partners.

This radio sponsorship and advertising buy has been a major success for the project, as well as for SCWC marketing and community relations efforts. SCWC originally approached the radio station about purchasing traditional drive-time ads to promote vineyards and grape growing and the conversation and negotiations moved to creating a dedicated sponsored show all about grape growing in Sonoma County. It has been a major success and another communications channel to tell the story of the region's grape growers and add value to their vineyards. These efforts also gained SCWC access to the radio station's news division, resulting in additional opportunities to be interviewed during their morning news talk program about grape growing, newsworthy topics, and more.

Newsletters: SCWC created, designed, wrote, and printed several newsletters, as well as email newsletters, that were distributed to more than 4,500 grape growers, local community members, partners, and media. These newsletters featured profiles on grape growers, grape growing and vineyard trends and analysis, sustainable vineyard practices, SCWC news and updates on marketing and promotional efforts, and coverage of key events.

This was an effective way to keep the public apprised of SCWC news and provide the latest information, research, and other details useful to the region's grape grower community and other audience members.

This project did not benefit other specialty crops. Throughout the project, SCWC ensured that funds were used only to solely enhance the competitiveness of specialty crops (winegrapes) by making grape growing and grape growers the focus of all promotional efforts. This was completed using photos and videos of vineyards and grape growers, explaining their sustainable farming practices and showcasing the hard work and attention to detail it requires to grow and produce quality winegrapes, while also promoting key facts and other information about Sonoma County grape growers.

Goals and Outcomes Achieved

As stated in the above Project Approach section, SCWC completed a variety of activities to achieve the performance goals and measurable outcomes. The mission of the SCWC is to increase the value of Sonoma County winegrapes and to nurture and protect this agricultural resource for future generations. One of the goals of this project was to raise grape returns with marketing aimed at growing premium (over $15 a bottle) sales, leading to higher winegrape prices and higher returns for growers.

All activities stated earlier in this report were created, designed, and executed to increase demand for premium Sonoma County wines. This was done throughout each activity by highlighting the sustainable vineyard practices, the attention to detail, the history and legacy of grape growing in the region, the partnership between winemakers and winegrowers, the key facts and messages about grape growing and winemaking in Sonoma County, showcasing images, visuals, and other graphics depicting grape growing and vineyards, as well as interviewing winegrowers and other leading experts on SCWC's radio show, and much more. These promotions helped convey all the work that happens in the vineyards and winery to produce a high quality, premium Sonoma County wine. SCWC conducted consumer research in the fall of 2015 that showed consumers ranked Sonoma County second out of nine winegrowing regions around the world for level of high quality wines. In this same survey, consumers also ranked Sonoma County as the top value wine region, which means consumers believe they get a high-quality wine for its price. That data conveys that consumers will be more drawn to SCWC premium priced wines at $15 or more because they perceive SCWC wines as higher quality and excellent value.

Other survey results showed several positive outcomes for Sonoma County grape growers, including that 20% of survey respondents were familiar with Sonoma County grape growers' sustainable farming practices and they recognized Sonoma County brandmark that is used in advertisements and other promotional material. In addition, the survey concluded that consumers are now more apt to purchase wines in the $15 and above category. Most consumer respondents say they buy wine $20 or more either monthly (62%) or several times a year (81%), which proves that the goals are being met for consumer purchase behaviors in that $15 or more category. Both data points are consistent with messaging that Sonoma County grows and produces high-quality wines, a result of the vineyard practices and attention to detail by grape growers. In addition, Sonoma County was the most recognized wine region in California for its sustainability practices, which is also result of SCWC's marketing and promotional activities showcasing grape growing practices and farming techniques.

The other goal of this project was to help increase grape prices by $50 per ton, per year by crop year 2016. Most of the activities already mentioned in this report have played a major role in helping drive the increase in grape prices in 2014 and 2015. (2016 winegrape crop data will not be available until June 2017).

In 2014, Sonoma County winegrapes average per ton price increased 3.7 percent or $82.97 year over year, from $2,235.95/per ton in 2013 to $2,318.92/per ton in 2014. That resulted in an additional $21 million in winegrape crop value for Sonoma County during that harvest year.
In 2015, Sonoma County winegrapes average per ton price increased 5.3 percent or $124.06 year over year, from $2,318.92/per ton in 2014 to $2,442.98/per ton in 2015. That resulted in an additional $22 million in winegrape crop value for Sonoma County during that harvest year. This is very significant for Sonoma County's grape growers and farmers because the 2015 harvest season saw roughly 40% decrease in winegrape crop yields and tonnage. This increase in per ton pricing helps offset some of those losses from a lower tonnage harvest season.

Sonoma County winegrapes average per ton price increased 9.2 percent or $207.03 from 2013 to 2015. That is well above the $50 per ton, per year increase goal. In addition, those per ton price increases resulted in an additional $43 million in winegrape crop value for Sonoma County during the duration of this project.

In summary, all these activities have all contributed to building the demand for Sonoma County grapes and increasing grape pricing and values over the past two years. These efforts have positively impacted and enhanced the competiveness of Sonoma County grapes in the marketplace. They have also helped increase exposure and awareness for grape growing in Sonoma County, the grape growers, and wines.

There were no long-term outcome measures for this project. All of them were based on increasing sales of Sonoma County wines in the $15 and over category and a $50 increase in per year, per ton pricing of Sonoma County winegrapes by 2016.

The baseline data gathered to show the progress and results of achieving the goals of this project include:

Consumer Brand Awareness for Sonoma County grape growers: Activities completed created a significant amount of consumer and media attention to Sonoma County. Print ads, radio promotions, video series, website improvement, print material, and newsletters have all contributed to expanding brand awareness to more than 150 million consumers across the U.S. In addition, this momentum has also generated more than 500 media articles about Sonoma County grape growers since 2013 reaching a readership of more than 250 million. That is an impressive increase of brand awareness and recognition for Sonoma County grape growers and brings unmeasurable value to their vineyards.

Winegrape pricing and value to Sonoma County's agriculture industry: All activities in this project have helped support and influence a per ton price increase of 9.2 percent or $207.03 from 2013 to 2015 for Sonoma County's winegrapes. That is well above the $50 per ton, per year increase target goals. In addition, those per ton price increases resulted in an additional $43 million in winegrape crop value for Sonoma County.

Consumer Research data collection: Consumer research was conducted in collaboration with a third party, to monitor success and whether SCWC's marketing efforts were changing consumer perceptions and behaviors for Sonoma County wines and vineyards conducted in the fall of 2015. The research showed that consumers ranked Sonoma County second in level of high quality wines, out of nine wine growing regions around the world. In this same survey, consumers also ranked Sonoma County as the top value wine region, which means consumers believe they get a high-quality wine for its price. Another way of describing this is that Sonoma County wines exceed expectations on a quality vs. price ratio. Other survey results showed several

positive outcomes for Sonoma County grape growers, including that 20% of survey respondents were familiar with Sonoma County grape growers sustainable farming practices and they recognized Sonoma County brandmark that is used in advertisements and other promotional material. Finally, most consumer respondents said they buy wine $20 or more either monthly (62%) or several times a year (81%), achieving the goals for consumer purchase behaviors for the $15 or more wine price category.

Beneficiaries

The primary specialty crop group that benefited from this project were Sonoma County's 1,800 winegrape growers, who are mostly family owned and operated. In fact, 85% of Sonoma County's vineyards are family owned, with 40% of the vineyards being 20 acres or less in size, and 80% of the vineyards being 100 acres or less. These grape growing farmers, who own and operate small businesses, depend on the work of the SCWC to help market, sell, and raise values for their specialty crop. Many of these families are multigenerational, therefore, this project was important to help SCWC promote, build brand awareness, and increase the value of their grapes so that their business can endure long term.

California's wine industry in general also benefitted from this projects as a result of focus on promoting sustainable vineyard farming practices and displaying growers' commitment to preserving agriculture and grape growing in Sonoma County. This messaging and outreach helps reinforce the California Wine Industry's own marketing efforts to promote sustainable viticulture and winemaking across the state.

Other stakeholder that benefitted from the completion of this project included 450+ wineries in Sonoma County that purchase grapes from Sonoma County grape growers, bottle the wine, and sell them to consumers. A majority of the wineries in Sonoma County are also family owned and they are small business.

Tourism businesses, such as hotels, restaurants, and tour companies, also benefitted from this project as the brand awareness created for Sonoma County increased visitors and tourism to the region.

There are thousands of beneficiaries that were positively impacted by the projects accomplishments. With 1,800 winegrowers, 450+ wineries, and over a thousand tourism businesses, it's clear that the projected impacted the entire Sonoma County community, which has always been one of the leading agricultural communities in California, and the nation.

From an economic perspective, this project has helped grape growers continue to be the leading driver of the agriculture industry in Sonoma County. Since this project started in 2014, wine grapes have brought more than $1.03 billion dollars in total value to the economy, according the Sonoma County Agricultural Commissioner's Crop Report. That represents roughly 65%-75% of the total value of Sonoma County's agriculture industry.

In addition, it is stated that Sonoma County's wine community (including grape growers) provides over $13 billion in economic impact. It generates more than 50,000 full time jobs, which accounts for 1 in 3 jobs in Sonoma County. This project helps support the community and those workers by increasing awareness for Sonoma County wines and providing a marketplace and strong demand for Sonoma County winegrapes.

Lessons Learned

SCWC is very proud of the work and successes from this grant project, and its positive impact on the grape growers and agricultural community of Sonoma County. There were several lessons learned throughout the process of this project that are worth noting.

Throughout the process and promotions, a shift was noticed in how all target audiences perceived grape growing and their role in creating high quality, premium wines. This included consumers, influential wine buyers and sommeliers, winemakers, media, and other members of the community who are all now paying more attention to grape growing and have found a much stronger interest in sustainable vineyard practices, the role of farming in the winemaking process, and the thousands of decisions made over the course of the grape growing season that impact quality. More and more consumers, media, and sommeliers are interested in talking to Sonoma County grape growers for a better understanding of their role and perspective on wine. This has led to more communications and more print advertising campaigns directly focused on the region's grape growers and reminding consumers that wine is an agricultural product.

Another strong lesson learned is the value of partnerships in this project. SCWC was fortunate to have many great partners willing to collaborate and provide resources, information, and other support to move activities forward and improve them. This included offering their insight through brainstorming sessions to discuss marketing strategies related to marketing and promotional campaigns, making introductions to new grape growers with interesting stories to tell that supported goals and messaging points, as well as helping to communicate the successes of this grant project to their own audiences. In addition, their support helped us save on costs of production and artwork, such as photography, etc. by sharing their own graphic and digital assets, or proving information that could be repurposed or re-used in SCWC collateral pieces.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 12	**Project Title:** California Specialty Crop Export Promotion	
Grant Recipient: State Center Community College District, Center for International Trade Development	**Grant Agreement No.:** SCB14012	**Date Submitted:** December 2017
Recipient Contact: Alicia Rios	**Telephone:** (559) 324-6401	**Email:** alicia.rios@scccd.edu

Project Summary

International market development programs have had a significant and positive impact on California agricultural exports of specialty crops. The United States Department of Agriculture (USDA) has worked aggressively to open new markets through export promotion programs and breaking down trade barriers. With 95 percent of the world's consumers of food and agricultural products residing outside its borders, it is vital that the United States builds on its established momentum of increasing exports or risk seeing its global market share decline due to the aggressive export promotion programs of foreign competitors.

The opportunities created by the National Export Initiative (NEI) had a significant economic impact on California's foreign market development and job growth. With the NEI project concluding in 2014, self-sustaining projects based on a similar structure are critical to promote the sale and use of California specialty crops. California needs to maintain access to key export markets for its specialty crop industry, otherwise California will be at a competitive disadvantage. Access to trade promotion not only opens markets but broadens opportunities for specialty crop producers, giving them the tools to make them leaders in global trade.

This project supported the California specialty crop industry by creating opportunities to export to global markets through trade missions and product promotions. The Center for International Trade Development (CITD) coordinated two reverse trade missions with 20 foreign importers of California specialty crops from a variety of global markets (six or more), as well as one trade mission which developed a virtual specialty crops product showcase directing foreign buyers to California specialty crop suppliers. During these missions, the CITD facilitated one-on-one meetings between foreign buyers and California suppliers of specialty crops, facility site visits, product demonstrations, and specialty crop awareness via product promotions. Projected export sales generated is $3.5 million; a return on investment of $11.50 for every allocated dollar.

This project enhanced the marketability and competitiveness of California specialty crops by developing economic opportunities for California specialty crop producers to open new global markets and sell products to viable foreign buyers. Foreign buyers typically represent a larger end-user network when compared to domestic buyers. By utilizing the CITD's statewide specialty crop cooperator network for outreach, an extensive number of qualified specialty crop producers in California had an opportunity to participate in a program that provided them with a range of export sales opportunities.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Project team formed a five (5) member Advisory Council (AC). This group met informally via conference call on a quarterly basis throughout the project to provide guidance and feedback on program missions and logistics. The AC provided critical insight to the ever changing market trends.

Request for Proposal (RFP) was developed to hire foreign contractors for reverse trade mission. Prior to securing foreign contractors, project team leveraged resources by working directly with USDA Agricultural Trade Officers to assist in buyer recruitment for reverse trade mission.

In order to maximize outreach, marketability and competiveness to specialty crop companies, the CITD facilitated and leveraged additional inbound trade missions which resulted in exceeding the project's sales goal and outreach to the specialty crop industry. The successful recruitment and qualification of 56 foreign buyers and 164 California specialty crop exporters for the project was broken down as follows:
Korea Inbound Buying Mission/Product Awareness and Outreach (October 5-7, 2015) in Los Angeles and San Francisco, California. Mission included five (5) Korean importers and 20 exporters of California specialty crops.

India Inbound Buying Mission/Product Awareness (October 22-24, 2015) in Los Angeles and San Francisco, California. Mission included four (4) Indian importers and 13 exporters of California specialty crops.

Europe Dried Fruit & Nuts Inbound Buying Mission/Product Awareness (December 9-11, 2015) in Central and Northern California region. Mission included six (6) European importers and 31 exporters of California specialty crops.

Mexico/Taiwan Inbound Buying Mission/Product Awareness and Outreach (May 25-28, 2016) in San Francisco and Los Angeles, California. Mission included four (4) Mexican importers, five (5) Taiwanese importers, and 18 exporters of California specialty crops.

Central America (six buyers)/Mexico (seven buyers)/Southeast Asia (six buyers) Fresh Produce Buying Mission/Product Awareness in Fresno and Tulare Counties, California on July 27-29, 2016, and recruited 30 California specialty crop exporters.

China (four buyers) Nut Buying Trade Mission/Product Awareness in Sacramento, Modesto and Fresno, California on September 26-27, 2016, and recruited 12 California specialty crop exporters.

Europe (five buyers)/South Korea (four buyers) Dried Fruit and Nut Buying Mission/Product Awareness in Fresno, Modesto and Sacramento, California on December 7-9, 2016, and recruited 40 California specialty crop exporters.

Each trade mission conducted required the following to be completed by project team:
Coordinate mission logistics, schedule buyer/seller meetings, hotels, transportation, air travel, qualify exporters, and confirm agenda.

Facilitation of one-on-one buyer/exporter meetings, facility site visit, and product demonstration; include mission briefing/debriefing with foreign buyers; evaluations.

Conducted post-mission evaluation surveys and counseling of importers and California specialty crop exporters.

Conduct 90 day, 180 day, and end of project follow-up surveys to track export sales, successes and areas for improvement.

Developed and promoted "California Specialty Crops Showcase," a website that contain lists of specialty crop handlers and industry information which served as a virtual showcase of California specialty crops connecting foreign buyers to 10 specialty crop industry. In facilitating this virtual showcase, the project team:
Selected top 10 specialty crop commodities to showcase on http://www.fresnocitd.org/export-programs/california-specialty-crops-showcase website;

Promote virtual showcase to five plus foreign markets, e.g. past buyer participants, agricultural trade offices, foreign contractors;

Setup analytics to track country of origin and number of visits to virtual showcase.

This project only benefitted the California specialty crop industry. To ensure that only the specialty crop industry was served, project team members cross-verified all products against the Specialty Crop Block Grant approved product list, and qualified all companies that registered for activities – thereby ensuring each product represented was a California specialty crop.

Project partners assisted in promoting trade mission through website links and social media as well as by direct outreach to specialty crop industry members/network to share opportunity to meet foreign buyers through the project's trade missions and promotion activities.

Goals and Outcomes Achieved

Based on the reversed trade mission completed, $74,309,639 in initial export sales data has been reported from survey/evaluation forms completed by California specialty crop participants as follows:
Korea Inbound Buying Mission/ Product Awareness and Outreach (October 5-7, 2015): $15,590,000 in export sales reported.

India Inbound Buying Mission/Product Awareness (October 22-24, 2015): $150,000 in export sales reported.

Europe Inbound Buying Mission/Product Awareness (December 9-11, 2015): $35,643,524 in export sales reported.

Mexico/Taiwan Inbound Buying Mission/Product Awareness and Outreach (May 25-28, 2016): $125,000 in export sales reported.

Central America Buying Mission/Product Awareness and Outreach (July 27-29, 2016): $3,787,000 in initial export sales reported.

Mexico Buying Mission/Product Awareness (July 27-29, 2016): $7,350,000 in initial export sales reported.

Southeast Asia Buying Mission/Product Awareness (July 27-29, 2016): $2,102,115 in initial export sales reported.

China Nut Buying Mission/Product Awareness (September 26-27, 2016): $450,000 in initial export sales reported.

Europe/South Korea Dried Fruit and Nut Buying Mission/Product Awareness (December 7-9, 2016): $9,112,000 in initial export sales reported.

Buyer evaluations and surveys (after each trade mission) indicated an increase of more than a 25% in knowledge in the following areas related to the California specialty crop industry:
2-5 year Production trends: What products are on the rise and what will no longer be in production;

Varieties: New varieties in production and when available for export;

Palate Testing: Buyer receiving information on palate testing of products to assist in determining which products would sell best in their respective markets.

Marketing of the California specialty crop product showcase (virtual showcase on http://www.fresnocitd.org/export-programs/california-specialty-crops-showcase) to foreign markets increased product awareness, industry resources, and access to over 500 California specialty crop handlers.

Outcome measures were completed during the project period. This project will continue to have long-term success for the specialty crop industry in terms on additional sales that will develop over the next few years as the buyer/seller relationship continues to develop and can be directly attributed to participation in this project's activities.

MEAURABLE OUTCOMES	EXPECTED	ACTUAL
Generate Export Sales	$3,500,000	$74,184,639
California specialty crop companies served through project activities	560	664
Increase knowledge and awareness of California specialty crops	25% increase	25-50% increase
Specialty crop promotion	California Specialty Crop Showcase – 10 commodities	California Specialty Crop Showcase – 10 commodities

One of the most successful outcomes of this project came from project team development and coordination of trade missions that had buyers from two-or-more foreign markets attending.

- Multi-markets added value to project activities that attracted more California specialty crop companies to participate in that they could come to one location and meet with multiple qualified buyers.
- This format also attracted high value buyers in that they would be able to meet with significant number of potential qualified California specialty crop suppliers.
- Sales from this format far exceeded what was projected.

Beneficiaries

The beneficiaries of this project included producers, marketers, and distributors of California fresh produce, dried fruits, nuts, and other qualified specialty crop products. Indirect beneficiaries included over 15 California specialty crop cooperators and the California Grown promotion (by providing additional consumer awareness of California grown specialty crops) that serves the entire specialty crop industry.

This project directly impacted over 164 beneficiaries that participated in the reverse trade mission activities. This project also impacted an additional 500 specialty crop companies through virtual California specialty crop industry showcase that has links to each industries grower/handler lists (10 specialty crop commodities x 50 suppliers on average). This project solely benefitted California grown specialty crops.

Lessons Learned

Reverse trade missions are effective to attract new specialty crop companies to expand into foreign markets as well as monitor and measure the economic growth from existing specialty crop exporters.

One of the most successful aspects of this project was when the project team developed and coordinated reverse trade missions that paired buyer groups from two-or-more foreign markets in a single mission:

- Multi-markets added value to project activities that attracted more California specialty crop companies to participate (i.e. one location to meet with multiple qualified buyers).
- Sales using this format far exceeded what was projected.

An issue that negatively impacted this project was the postponement of the scheduled outbound trade mission:

- Outbound mission was originally scheduled to take place first but was postponed several times to accommodate other activities that project team was able to leverage and add value to California specialty crop exporters.
- Outbound mission was rescheduled to take place just prior to end of project term. Political unrest in one of the target countries ended up collapsing the entire mission with both buyers and exporters pulling out.
- Project team recommends that all scheduled trade missions, especially outbound missions that require up to six months lead time, take place well ahead of project end date so that adjustments can be implemented to ensure the event can be rescheduled or substituted with another similar activity should challenges arise.

When implementing reverse trade missions with buyers from multi-markets, the project team did not anticipate that this would attract such a high number of California specialty crop companies to register and participate. Sales from each of the multi-market reverse trade mission far exceeded the overall project goal of $3.5 million in new sales developed.

This project originally had a specialty crop foreign promotion component whereby foreign media would participate in the outbound trade mission activities to develop articles in foreign newspapers to promote the industry. This promotion was tied directly to the outbound trade mission that did not take place.

Recommendation to others is to develop work plans whereby multiple measurable outcomes are not tied to a single activity. In hindsight, the media promotion should have been both independent as well as a component of the outbound mission.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 13	**Project Title:** Market Enhancement for Small-scale Organic Farmers	
Grant Recipient: Agriculture and Land-Based Training Association	**Grant Agreement No.:** SCB14013	**Date Submitted:** December 2017
Recipient Contact: Chris Brown	**Telephone:** (831) 594-7816	**Email:** chris@albafarmers.org

Project Summary

The Agriculture and Land-Based Training Association (ALBA) operates as a school for aspiring farmers. Over the course of five years, ALBA provides educational and business development services which enable participants to make the transition (often from a background as a migrant farm worker) to independent organic farm owner and operator.

The 'food hub' – ALBA Organics – aggregates and markets produce on behalf of over 50 small, specialty crop farmers in any given year, enabling them to reach markets they would not otherwise be able reach individually. Access to this marketing channel also allows them to focus on learning challenging production, business and compliance issues in their early years of farming. Furthermore, interacting with ALBA Organics exposes beginning farmers to the quality, timeliness and packing demands of the market, which better prepares them to operate in California's competitive agribusiness industry.

The purpose of the Market Enhancement for Small Organic Farmers (MESOF) project was to strengthen ALBA's marketing operation to enable the specialty crop farmers to access markets and reach viability. ALBA's specialty crop (organic produce) sales had grown by ten times in five years leading up to the beginning of the project, but internal systems had not kept pace with this growth. The plan was to formalize marketing operations and finance the market research, systems and personnel to further enable this growth.

This project was important for several reasons:

- The farmer population is aging, calling for the preparation of the next generation of farmers.
- Markets for organic specialty crops continue to grow at a double-digit pace, tripling in the last decade.
- Consumer demand for produce grown locally by small-scale farms is also on the rise.
- Markets cater to large scale growers and shippers, making it difficult for small-scale growers to cost-effectively access markets and compete.

Consumers and the agricultural sector want more small-scale farms. New, small-scale farms often have difficulty in accessing markets. Without this market access, all but the most resilient few will not succeed. Based on these observations, ALBA proposed the MESOF project to improve market access for small-scale farmers to give them a fighting chance in competing with large growers with much deeper pockets.

This project built upon the 2013 Specialty Crop Block Grant Program Project 25: *Farmer Education and Enterprise Development (FEED)* which focused on ALBA's first two core services: farmer education and farm business incubation. MESOF is a market enhancement project which focuses on improving ALBA's third core service: market access for small specialty crop producers. In doing so, MESOF built on FEED by expanding

market access, and marketing knowledge to increase the business viability of the next generation of farm operators.

Project Approach

MESOF kicked-off with a fast start in implementing the work plan. Initial activities focused on consolidated operations, improving IT functionality and evaluating client and farmer satisfaction doing business with ALBA Organics. The latter part of the year was spent in developing and implementing tools to better coordinate with small farmers to source produce and fulfill client orders. The first year of the project consisted of the following activities:

- ALBA moved out of the Watsonville facility, re-locating to the main, smaller cooler in Salinas, cutting $200k+ in fixed costs (rent, utilities, and staff).
- Purchase and installation of new transmission dishes and re-wiring of the cooler for better IT network functionality.
- Reviewed and selected an inventory management software package.
- Workshops held on: (i) Developing direct markets; (ii) Quality control and pack for strawberries; (iii) Marketing roundtable; (iv) Food safety. (repeated in 2016 and 2017)
- Training on the new software package was provided by the vendor. Additional IT services were utilized to select and set-up a new server for the new software package.
- A marketing consultant was hired to survey clients, producing the following results:
  - Staff learned that though clients love ALBA's story, buying from ALBA is challenging due to erratic order fulfillment from the beginning farmers.
  - Based on input, staff were to hone in on key clients that are willing to invest the time and resources in to marketing ALBA Organics specialty crops (and mission) to consumers.
  - An analysis of sales by client, product demand and average prices led to halving the number of crops on the master crop plan, which simplified operations.
- A consultant evaluated ALBA Organics' operations and staffing. As a result:
  - Job descriptions were revised for the GM, Director of Sales and Warehouse Assistants.
  - Two new employees (Warehouse Assistants) were hired in early and late March.
  - Staffing schedule and cooler hours were revised to improve efficiency, reduce overtime.
  - Better pricing on boxes were negotiated and the box distribution system was improved.
  - Inexpensive, but essential improvements were made to cooling and storage capacity.
- The GM met individually with farmers to solicit feedback on working with ALBA Organics, which led to development of an improved system of crop planning and coordination.
- The Executive Director travelled to Rhode Island and Massachusetts to visit five food hubs with the objective to learn about other business models and approaches.
- ALBA created tools facilitating development of a master crop plan for the farm and individual crop plans for farmers, helping to plan and establish a steady stream of product, making it easier to monitor, receive, store and distribute perishable specialty crops on behalf of beginning farmers to the portfolio of clients.
- A promotional flyer created for Sales Manager to market services to new clients.
- Cooler and systems upgrades and safety improvements were made.

With new Food Safety Modernization Act regulations finalized, ALBA prioritized farmer assistance to farmers to develop their own food safety plans and prepare for third party audit. This was essential for the

food hub to continue business as clients were hinting that they may discontinue orders in the absence of certification.

In addition, ALBA developed a Quality Management System (QMS) for the entire marketing operation. ALBA's QMS takes commitment a step further, facilitating and monitoring adoption of Good Agricultural Practices (GAP) by cooler staff and farmers.

The second year of the project focused on analysis of competition and operational flow, leading to development of new tools and processes to streamline operations. Additional hiring was done in field operations and back office.

- ALBA engaged consultants to:
  - Conduct a comparative analysis of marketing fee structures of other produce marketers.
  - Assess cooler operations making recommendations on staffing structure, performance metrics, food safety and team building.
  - Assess tools and practices for sourcing from farmers and develop a simplified system.
  - Train the newly placed Ag Operations Supervisor in this method.
- Hire/groom Ag Operations Supervisor – A former Driscoll's forecaster was hired to do crop planning, quality control and forecasting. He was trained by the field operations consultant.
- Revision of crop planning, quality control and forecasting protocols.
- Train staff on use of inventory software.
- Hire/groom Sales Representative – A new Sales Representative was hired to assume more sales responsibilities, allowing the General Manager to oversee the whole operation.
- A new Office Manager and bookkeeper was hired.
- Re-writing of job descriptions was done to better reflect current responsibilities and new protocols.
- Negotiate with and engage a new partner, Aggrigator, Inc. to test launch its new marketing platform.
- Additional activities included:
  - Field trip
    - To Pinnacles Organics, an established grower and marketer of organic specialty crops
  - Supervised direct marketing of Asian Vegetables to a distributor catering to Korean clients.
  - A workshop on running a Community Supported Agriculture business.

Originally a two year project, ALBA got a nine month extension in light of the developing partnership with Aggrigator, Inc. The partnership was formalized in March of 2016, when the tech start-up chose ALBA as its flagship food hub in which to test launch its newly designed on-line marketing and logistics platform. By the end of the year, the partnership has become more involved with Aggrigator taking over operations of ALBA Organics' operations as of the first day of 2017.

The food hub remains under ALBA ownership and staff are working in tandem with Aggrigator as a liaison to participating farmers. The partnership not only brings new capital and expertise to the marketing of specialty crops, it will meet the MESOF goal of strengthen small-farm businesses through new market opportunities and increased focus on capacity development. Furthermore, after testing the platform, Aggrigator has plans to market it to other food hubs in California, which will create new opportunities for small-scale specialty crop growers statewide.

ALBA continues to advise farmers on crop planning, cultivation, quality control, harvest, pack and order fulfillment to enable strong coordination with Aggrigator. The Farm Manager has simplified crop planning tools for easier use by farmers and the sales team. With ALBA removed from most daily marketing responsibilities, staff can now be impartial about how farmers' products are marketed.

Aggrigator is approaching off-site specialty crop growers with the intent to ramp up the volume of specialty crops sold through the food hub. This will be important for the farmers ALBA assists because the larger volume of produce will open market channels for their produce as well.

Over the last 18 months, the Community Alliance with Family Farmers (CAFF), which runs the California Farm to School Network, has advised ALBA Organics on serving school clients. In turn, ALBA connected Aggrigator with nearby schools, which buy through a regional purchasing cooperative. Staff from ALBA and Aggrigator attended CAFF's Farm-to-School Conference at the end of March to develop new contacts. Aggrigator recently qualified under the USDA fresh fruit and vegetable pilot program, which is necessary to source food to schools. The firm is also approaching processing companies to create markets for product that isn't top grade. This is important for ALBA's beginning farmers, who grow a lot of produce which is unfit for retail sale.

Meanwhile, Aggrigator's programming team – located in Bangalore, India – continues to refine the platform to make it more user friendly. Two new user interfaces were developed, one for farmers and another for transacting future contracts. The challenge will be to convince both farmers and clients to transact online in an industry that operates by phone through well-established relationships. So far, potential users remain cautious, but Aggrigator hopes to appeal to a new generation of tech-savvy millennials, driving the success of small-scale specialty crop growers.

The project solely benefitted specialty crop farmers.

Project partners include:

- Aggrigator, Inc. is now running ALBA Organics in coordination with ALBA's team, using on-line technologies to open up new markets for farmers.
- Community Alliance with Family Farms assisted ALBA and Aggrigator in the challenges and opportunities of doing business with public schools.
- David Mancera Consulting developed produce sourcing tools and engaged potential produce buyers in the Salinas and Gonzales communities and communicating prospects to the Aggrigator team.
- Carlson Food Safety Consulting provided food safety training and assistance to farmers and Aggrigator to ensure their eligibility to sell to mainstream wholesale and retail clients.

Goals and Outcomes Achieved

Activities were listed in detail above, but they did not result in the desired outcome of higher sales of farmers' produce at the food hub. Instead of experiencing a continued rise, the food hub experienced a steady decline in sales ending up at half of sales levels at the beginning of the project. This is not to say that actions taken during the project period were not necessary or positive. However, unanticipated changes caused disruption that project initiatives could not offset during the project period. Staff hope this turns around in the long-term as positive changes take hold.

The project got off to a fast start in terms of delivering on outputs, but it soon became clear that sales targets were off trajectory. To retain and build on a client portfolio in the midst of repeated changes in management and at the sales desk proved impossible.

In light of this, ALBA re-oriented for long-term results, emphasizing improvement of internal systems as staff vied to place a lasting management team. Cooler upgrades were made, sourcing tools refined, new field staff hired, market analysis done and a new partner put in place. Staff expect these MESOF initiatives to bear fruit for farmers in the coming years.

Developing alternative markets for farmers was another key objective. This happened through ongoing training and matchmaking for farm businesses. It also occurred indirectly. Disruptions at ALBA Organics caused farmers to more aggressively seek alternative marketing channels. There aren't many willing to buy direct from small farmers, but Coke Farms in San Juan Bautista and A&A in Watsonville fit the bill for many of the farmers. This is a very positive development – albeit unplanned – which will result in greater farmer independence, the ultimate goal.

In the end, staff aim to drive specialty crop farmers' success by offering marketing assistance through ALBA Organics in addition to other viable channels to best meet their business needs.

Starting at $5.5 million, the proposal projected 15-20% annual increases, ending up at $8 million annual sales in the final year. Instead ALBA experienced significant declines in sales, ending up at $2.4 million.

- Goal 1: Sales through ALBA Organics were targeted at $15 million, rising from $6 million in the year prior to the project, to $7 million then $8 million.
  - Actual: Sales dipped to $4.4 million, $3.4 million, and $2.4 million in the third year.
- Goal 2: The number of specialty crop farmers selling over $5,000 in produce rises from 35 specialty crop farmers to 52 specialty crop farmers.
  - Actual: Approximately 30 specialty crop farmers sold over $5,000 in produce. This number was slightly lower than baseline due to lower sales at the food hub.
- Goal 3: At least 30 specialty crop farmers raise sales by 33%.
  - Actual: Similarly, ALBA and farmers did not meet this target. The actual number is roughly 15 farmers increasing sales 33%, many of whom had alternative markets and/or transitioned off ALBA land to farm a larger plot.

Despite the sales decline, prospects for the food hub and ALBA as a whole are encouraging.

- Transferring operations to a partner with resources and expertise stands to enhance the market opportunities available to small-scale farmers.
- Renewed focus resources on farm business incubation and their long-term viability.
- The cooler itself has enhanced IT resources, electrical system, storage and cooling capacity.
- The operational footprint of running the cooler is straightforward due to centralizing operations at one cooler.
- 12 farmers have transitioned off ALBA land to continue farming; and another four are expected to do so at the end of 2017. Supporting viable specialty crop farm businesses is, after all, the point of running a food hub, whether or not it is profitable.

As a non-profit, ALBA is in a better position to serve specialty crop farmers due to less complexity and financial risk brought about during the project period. Staff are still vying for effective ways to market the farmers' produce in partnership with Aggrigator. Admittedly, the new model has yet to be proven out, but staff feel that the partnership is a step in the right direction to tackle a challenging business model.

Ultimately, staff feel the investment was very worthwhile for the businesses it served. Despite the decline in sales, ALBA maintained a very strong retention rate of farm businesses and continue to have strong demand from participants. ALBA will continue to work with Aggrigator to reach profitability. Regardless, the marketing service the food hub provides is key to small farm business viability which produces new farms, jobs and investment in the competitiveness of California's specialty crop industry.

Beneficiaries

The main beneficiaries were over 40 specialty crop farmers launched and/or incubated on ALBA land. Most of ALBA's farmers come from a background of field work and are determined to make a better life for their families through pursuing farm ownership. Their business provide employment to themselves, family members and outside workers.

ALBA provided marketing services to over 30 specialty crop farms, which are still in business. Roughly 80 full and part time jobs are supported by these businesses. Over the course of the project, $10 million in sales were made by the food hub. Additional economic impact was made through the purchase of inputs and services from local ag industry businesses.

Lessons Learned

- The food hub model is costly. Doing business with dozens of beginning farmers means increased time receiving, inspecting and aggregating product, assembling mixed pallets, and more back office work, while educating farmers about forecasting, harvest and pack all along the way. Moreover, revenue per farmer is low because of the small volume of product being grown. This makes it difficult to compete and be profitable in a highly developed industry.
- Technology will likely make the difference. Connecting small farmers to buyers of all sizes can only be made efficient through a technology platform to automize ordering and provide delivery solutions. The Aggrigator platform is still unproven, but it is a step in the right direction toward solving marketing challenges for small farms.
- People are key. Running a food hub is complicated. Management should ideally enter the job with a farming background, sales experience and strong operational skills. To be effective, they then require at least two years learning the idiosyncrasies of the food hub model (and ALBA specifically). Staff learned this under MESOF, which took place in the immediate aftermath of a General Manager who had spent eight years building the business. His talents, farmer relationships and client contacts were sorely missed, despite the positive changes made during the project.

Unexpected results include:

- With disruptions in food hub operations, farmers were forced to seek out their own markets. Many were successful and now have a more diverse marketing strategy.
- Aggrigator, Inc. brought a new marketing platform and assumed operations of the food hub. They market under the ALBA Organics brand and coordinate with ALBA staff in sourcing product.

- ALBA now bears less financial risk and can focus its energy on new farm viability.

For future projects:

- Find and retain good people. The cost of turnover is greater than paying them a bit more.
- If serving beginning, small farmers, accept that the model will never reach the efficiencies of the industry at large, but remain committed to minimizing order fulfillment problems to bring new growers up to market standard.
- With all the other challenges of the model, do not skimp on inventory management software. Good information to analyze business performance and pinpoint problems is essential.
- Invest in good cooler and cooling equipment to minimize shrinkage.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
14	Old Routes, New Paths	
Grant Recipient: Hopland Band of Pomo Indians	**Grant Agreement No.:** SCB14014	**Date Submitted:** December 2016
Recipient Contact: Terri McCartney	**Telephone:** (707) 472-2100 ext. 1304	**Email:** tmccartney@hoplandtribe.com

Project Summary

Tribes in Sonoma, Lake, and Mendocino County have faced poverty, isolation, and poor nutrition since European contact. Tribes traditionally maintained a sustainable food system utilizing traditional environmental knowledge and land management techniques to create the bountiful landscape that was noted by the European settlers. Inter-Tribal trade and distribution supported this system, and allowed the Tribes to not only share their bounty but enhance the nutritional value of their diets. The initial purpose of "Old Paths, New Trails" was to support inter-Tribal marketing and distribution of their current specialty crops. There are 22 Pomo Tribes in Sonoma, Lake, and Mendocino County, with land bases that are suitable for a variety of specialty crops and value added products. These crops include heirloom apples, blackberries, wine grapes, walnuts, and a wide range of vegetables. Hopland Band of Pomo Indians have been working on the development of an inter-Tribal agriculture system for the past six years, by coordinating inter-Tribal workshops on a variety of sustainable agriculture topics, ranging from soil sciences, dry farming, seed saving, planting, harvesting, safe food handling, specialty food processing, organic certification, running a farm stand, packaging, label, and more. The next step in the project was to make it economically sustainable, by supporting inter-Tribal trade, marketing, and distribution of their specialty crops. This would support Tribes, as well as independent Native Americans.

Renewed interest and awareness of locally grown specialty crops coupled with the trainings and workshops of the past six years made marketing and distribution a natural sequel in the inter-Tribal sustainable agriculture program. Hopland Tribe has hosted a farm stand featuring specialty crops from local farmers and have received numerous inquiries from other Tribes on how to go about implemented a similar project. Inter-Tribal trade, marketing, and distribution supports participating Tribes in their specialized crops.

This project has not been built on a previously funded Specialty Crop Block Grant Program project.

Project Approach

Hopland Tribe coordinated all the following workshops:
"Introduction to Old Routes, New Paths": This workshop was coordinated twice, with attendance at the first workshop of 19, representing 8 Tribes, and the second 92, from 16 Tribes. In order to reach the greatest number of potential tribal specialty crops producers, project staff developed the strategy of coordinating workshops with inter-Tribal special events and outreach opportunities. This included venues such as the Lake County Consolidated Health Blessing of the Gardens Event, and monthly Mendocino, Lake, and Sonoma County Tribal Environmental Programs gatherings.

The "Old Routes, Traditional Trade and Distribution of Native American Specialty Crops" included 22 attendees from six Tribes. Surveys were distributed to access the location of specialty foods producers, and the best methods for supporting trade, marketing, and distribution of specialty foods products.

The "New Paths, Creating an inter-Tribal Distribution Hub" included 22 attendees: This was a roundtable idea-sharing forum, with several tribes contributing their thoughts about how to best go forward with an inter-Tribal Food Hub. Utilizing the existing farm stand was the most popular method.

The "Good Handling Practices" included 16 attendees from 3 Tribes. This class included Safe Serve Certification for selling specialty foods at the farm stand.

The "Good Agriculture Plan" included 18 attendees from 4 Tribes. A "Good Agriculture Plan" template was provided, and shared with attendees to customize to their projects.

Project staff combined "Creating a Native Brand and Label" with "Becoming a Native Vendor of Specialty Crops" because the curriculum was very similar and was utilized for both workshops.

The "Creating Value-Added Products from Your Specialty Crop" included 20-30 participants from 6 Tribes. This was the most popular workshop, and there were requests for additional workshops on this topic, which project staff were able to accommodate for a total of 4 workshops. Attendees were eager to bring their specialty food products and increase their value for selling at the farm stand and other venues.

The "Internet Opportunities for Native Specialty Crops" was an online discussion forum for how to provide ongoing support and an online presence for Native American specialty foods after the grant ends. There are several online farmers markets that offer the framework for a farmers market at a very affordable cost that could be utilized for this. Project staff are developing a plan for moving forward with this beyond this project term.

The 'USDA Program Support for Native Specialty Crops" included 90 attendees form 18 Tribes. This was one of the workshops timed to coordinate with larger events so that project staff can reach the greatest number of participants, especially decision makers for the Tribes.

The "Inter-Tribal Specialty Food Show" consisted of 2 shows coordinated. The show was extremely popular, so an additional show was coordinated to showcase the specialty crops and value added products from this program, and additional Native American food producers. Each show had well over 100 attendees with representation from Tribes throughout Northern California, 12 presenters of their products, and many additional booths. The highlight of both shows was Native American youth presenters who clearly articulated how sustainable agriculture improved the lives of their communities and families.

"Next Steps and Project Evaluation" include the development of an online intertribal farmers market. Evaluation of the program showed overall very positive response, with the requests for more workshops on value added products.

Project staff also coordinated the scheduled farm stands on the reservation land, at special events, and at a more visible site in downtown Hopland. Staff also attended the National Heirloom Seed Festival in Santa Rosa, California with an outreach booth, which displayed of Native American specialty crops and made many valuable contacts for further sales.

This program proved to be a valuable step in the formation of an economically sustainable food system for Tribes in the tri-county region of Sonoma, Lake, and Mendocino County. Tribes and individual Tribal specialty crop producers have learned many valuable skills to maintain and expand their marketing and distribution of Native American specialty foods, and work toward reducing and eventually eliminating dependency on grants and other outside sources of funding.

The coordination of further value-added products would be valuable, and developing a program designed to support moving towards dry-farming. Almost all of the reservations in this area have extreme water shortages, and have little to no water in excess for expanding farming, limiting the ability to increase food security.

The overall scope of this project benefitted only specialty crops.

Goals and Outcomes Achieved

Goal one was to increase participation in workshops. This was accomplished by increased outreach and coordinating the workshops with other inter-Tribal events, such as Big Times, Health Fairs, the inter-Tribal Specialty Food Show, and dances. This improved Tribal participation significantly, as well as interest from individual Tribal members. The program met and in many cases exceeded the goals of improving attendance by 20% individuals and 50% Tribes.

Goal two was to increase the average number of specialty crops available on the farm stand. The program was able to increase the number of specialty crops available at the farm stand, but due to the drought conditions, the level was not as much as anticipated. Instead of an average of 25 specialty crops at the farm stand, project staff were able to average out at around 20. This is still an improvement over the prior years' numbers before this project funding.

While the outcome measures were positive, the long term main indicator of success has been the ability of Tribes and Tribal individuals to create economically sustainable specialty crop businesses. Project staff told the participants that although they will not get rich, this will provide extra income and healthy food for the community. That is what the program has accomplished; the specialty crop producers were able to maintain their programs at their current level of production, with the goal of increasing production and sales while maintain economic viability and sales.

Project staff coordinated 16 workshops and two Pomo Specialty Foods Shows, instead of 12 workshops and one Pomo "Specialty Crops and Value Added Food Show." Workshops increased Tribal participation overall from four Tribes to 12, much more than the initial 50% goal. Individual participation at five workshops was over 80, which was really an improvement, and the rest were around 20-30, exceeding the goals of increasing individual participation by 20%, and increased participation 25% -50%.

Progress towards set targets:
Food Hub: The specialty crop producers used the Hopland Farm Stand as their Food Hub, and base for marketing and distribution. There is a working group that is continuing to design an online farmers market that can be utilized as a more regional food hub, with more Tribes participating from Northern California.

Specialty Crops Value Added Foods Products: Project staff have met the target of assisting Tribes and individuals develop marketing and distribution opportunities for their crops, through the farm stand, and in the

future on the online Pomo Farmers Market. When the program was started, four Tribes were interested in further marketing and distribution of their specialty crop value added food products, all have continued to produce, market, and distribute their specialty crops.

The major successful outcome of the project is the core inter-Tribal specialty crops producers continuing to meet and discuss next steps towards developing an online farmers market which will serve as the food hub, (marketing and distribution) of Pomo specialty food. The group is actively working with their communities and councils to promote sustainable agriculture and specialty crops and value added foods.

Beneficiaries

Beneficiaries include members of the 22 Native American Tribes in Sonoma, Lake, and Mendocino County. Also, Tribal members from Humboldt County Tribes such as the Yurok, Hoopa, and Karuk attended and participated in workshops. Tribal youth and families on the Reservations enjoyed improved access to locally grown fresh specialty crop foods.

There was a core group of 6 Tribes and around 30 workshop participants that were most engaged in the project and likely to carry on with the program. Overall there were over 160 different Tribal members that participated in various workshops over the course of the program. This program has already provided the needed support to make the Hopland Band of Pomo Indians sustainable and organic agriculture and specialty crop foods project economically sustainable, by supporting the Tribe in marketing and distribution opportunities. This provides seasonal work for Tribal members on the Hopland reservation, and encourages Tribal members to expand into a variety of specialty crops. Members of the Scott Valley Tribe are now working on marketing and distributing their walnuts, Kashia Tribal members are creating value added products with their apples.

Lessons Learned

What went really well were the workshops, outreach, and Native American specialty crops and value added foods shows. This opened the door for many individual Tribal members to network with their products and create their own distribution network, through Big Times, inter-Tribal Health Fairs, and other Tribal Events. The challenge for staff was working with the effects of the drought, reducing the ability of Tribal members to produce specialty crops and products in volume enough for consistent distribution.

An unexpected result was the support from Tribes and Tribal members outside of this area, from as far away as Humboldt County and Sacramento. Project staff also had substantial support from the inter-Tribal Agriculture Council of America, offering technical, outreach and other support for the program. Also, it was unexpected that many producers were interested in the formation of an online farmers market for year-round specialty crop distribution.

The goal of increasing number of specialty crops was not fully reached due to the drought conditions during the grant period. Many of the Tribe's farmers were not able to plant due to extreme water restrictions for the past two years. As climate change is a reality faced by us all it is imperative that future planning for food security addresses dry farming and drought resistant varieties for food production, particularly in areas that are already vulnerable to water shortages.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
15	Specialty Crop Farmer Training and Toolkit for a Sustainable Future	
Grant Recipient: The Regents of the University of California, Santa Cruz	**Grant Agreement No.:** SCB14015	**Date Submitted:** December 2017
Recipient Contact: Jan Perez	**Telephone:** (831) 459-3235	**Email:** jperez@ucsc.edu

Project Summary

A flood of new growers were entering into farming in California, many of them interested in starting or scaling up mixed specialty crop operations for direct sales and wholesaling. These small-scale growers were in need of training in and information on crop culture, varietal selection, organic production practices, and economic data critical to successful specialty crop farming and marketing. In addition, shifting climate patterns necessitated a flexible approach to crop planning, with the ability to grow a range of crops based on available water resources and other climate factors.

There was very limited information available on the benefits and growing criteria for some of the newer or heirloom vegetable crops. Additionally, little information existed on the cost of production data for mixed vegetables crops. This information would be critical for new and beginning farmers to make informed decisions on which crops to plant, and how much, in order to make a net profit. Focusing on this information was timely as consumers and distributors were increasingly interested in locally grown organic "niche" crops. Also, as heirloom and alternative varieties of vegetables had the potential for both direct sales and wholesale scaling that beginning farmers needed to help access new markets.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Demonstration Crop Blocks: Specialty crops (peppers, potatoes, dry farm tomatoes, flowers, beans and winter squash), and cropping systems (Community Supported Agriculture (CSA) mixed crops), were planted, maintained and harvested for demonstrations. This also included the maintenance and harvesting of blueberries and apple fields.

Data Collection: A large variety of peppers, potatoes and flowers were planted in the market garden to research the best varietal breeds to use. The growers tracked a number of qualitative aspects of these crops, such as how well they grew, yield per plant, harvest timing, taste, and how well they sold. The findings from these demonstration crops were used to select a few of the most promising looking varieties to be grown on the 30-acre farm (the field).

Crops planted in the field at a larger scale were tracked on a wider variety of measures to determine basic crop growing and yield data, hours spent on production, and ultimate costs of production (economic analysis). All time spent in the field on bed preparation, planting, weeding, irrigating, and harvesting was tracked. The ultimate goal of the data collection was to help farmers understand the input costs in terms of labor, materials, and water in order to make informed decisions to increase economic viability.

Grower Guides and Signboards: The data collected, along with staff experiences with these crops, was used in the production of Grower Guides. The following nine guides were produced and printed:

1. Tillage, Bed Formation, and Planting to Moisture: A Guide for Beginning Specialty Crop Growers
2. Organic Dry-Farmed Tomato Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers
3. Organic Cut Flower Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers
4. Organic Pest and Disease Management of Selected Crops on California's Central Coast: A Guide for Beginning Specialty Crop Growers
5. Organic Potato Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers
6. Organic Pepper Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers
7. Organic Winter Squash Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers
8. Fresh Market and Dry Bean Production: A Guide for Beginning Specialty Crop Growers
9. Organic Mixed Production Blocks for Direct Markets on California's Central Coast: A Guide for Beginning Specialty Crop Growers

An additional guide on apples was also drafted and began the early stages of editing for future production. This guide was originally replaced with a guide summarizing pest and disease issues across all the crops. Additionally, the guide focusing on planting to moisture for large-seeded specialty crops was separated into two different guides – one focused on planting to moisture for all crops, and the other focused on beans.

Each of the specific specialty crop Grower Guides provided a summary of production practices, a graphic of the production sequence (showing activities before, during and after initial planting), growth phases by day, descriptions of varieties, pest and disease information, as well as an appendix with a production schedule and economic data.

The dry farmed tomatoes, peppers, winter squash, and the tillage sequences/planting to moisture Grower Guides were translated into Spanish. The project team also developed one page visual guides for the equipment referenced in these guides.

A series of large interpretive posters (signboards) illustrating organic growing practices were developed for the following crops: dry-farmed tomato, potato, winter squash, pepper, CSA cropping systems and cut flowers. These were placed in the field for the 2016 and 2017 cropping seasons to serve visiting specialty crop growers, students, and others (see attachment 1).

Photographs of cropping sequences were taken to be used in the Grower Guides and educational posters, and for the online PowerPoint slideshows that were made available to supplement the Grower Guides. A series of illustrations were also developed to use for production sequence graphics and other practices.

Apprenticeship Training: Information about the growing of these specialty crops, as well as data from the production and economic analysis, was shared with the University of California, Santa Cruz (UCSC) Center for Agroecology and Sustainable Food Systems (CASFS) six-month apprenticeship during classroom

instruction sessions as well as during in-the-field training. For the two and a half seasons that this project was in operation, the information learned was shared in the following classes (some of which were held more than once):

1. Cut flower production
2. Making flower bouquets for market
3. Blueberries
4. CSA basics & Crop planning
5. Peppers
6. Curcurbitaceae (curcurbits – winter squash)
7. Deciduous fruit trees
8. Introduction to Summer Pruning
9. Summer pruning and fruit trees
10. Summer tree care
11. Seasonal orchard update
12. Introduction to temperate zone deciduous fruit
13. Irrigation principles and practices (planting to moisture)

Weekly instruction also took place in the field and market garden with the six-month apprentices, where more information on specific growing techniques and issues were shared and practiced. Advanced apprentices were also taught this information in field-based lectures and practice sessions.

Field Day Workshops: Information learned from the demonstration crops was also shared in eight workshops or field days. Six of these sessions, offered in the CASFS demonstration fields, included:

- Apple tree pruning – January 24, 2016 – 12 attendees
- Introduction to apple pruning – February 10, 2016 – 10 attendees
- Irrigation (planting to moisture – big seeded crops) – March 9, 2016 – 9 attendees
- Cut flower production – June 13, 2016 – 45 attendees
- CSA production field day – August 15, 2016 – 24 attendees
- Peppers and potatoes production – September 15, 2016 – 18 attendees

Two of these sessions were offered at other farms in the region.

- Apple orchard care and summer pruning – conducted at Pie Ranch in Pescadero, California – August 25 & September 1, 2016. – 23 attendees
- Planning and planting the small orchard block – conducted at Fifth Crow Farm in Pescadero, California – 20 attendees

Mentoring: Information learned from the demonstration crops, as well as staffs' personal experiences with specialty crops, was also shared through mentoring and technical assistance to beginning farmers. Staff helped these beginning farmers with crop rotations, crop planning, soil consultation, orchard consultation, setting up irrigation, and cut flower advice. Mentoring was also provided on apple tree pruning and flowers.

A total of 61 farmers received mentoring. Several were helped on more than one occasion. There were 22 beginning farmers mentored through email, phone calls, and on-site visits. There were another 20 whom received mentoring services at a special session at the EcoFarm Conference where all of the attendees

received individual assistance on specialty crop farming. For three of the farmers served, CASFS staff also provided mentoring on apple tree pruning and flowers to the farmers' interns – for a total of 19 people.

All grant fund were tracked and monitored to ensure that all expenditures were used to solely benefit the competitiveness of specialty crops.

Goals and Outcomes Achieved

The goal of the project was to increase the crop knowledge and production efficiencies of small-scale beginning specialty crop growers, with an emphasis on organic and sustainable production practices. The performance measures were as described below for each proposed activity:

1. 250 of each guide will be downloaded and 250 will be distributed in year three
2. 85% of apprentices will have an increase in knowledge
3. 75% of workshop attendees will plan to implement something they learn
4. Train 100 beginning farmers in eight CASFS farmer workshops or field days
5. Those mentored will have an 85% increase in knowledge and a 65% report in changed practices.

To help increase farmers' knowledge and encourage behavior changes, program staff first planted demonstration plots and studied growing methods and economic analysis factors to get information on new varieties and growing strategies to better help new farmers be successful. The information learned along the way was shared with aspiring and beginning farmers in the CASFS Apprenticeship Program, as well as aspiring, beginning and other farmers through eight workshops/field days and mentoring services. The Grower Guides were distributed to apprentices. They were also distributed via hard copy at events and conferences, as well as through CASFS's main office. Approximately 250 hard copies were distributed. The Grower Guides were also made available online and included in the UC eScholarship repository. Notice of the completion and availability of the Grower Guides was sent out via the CASFS website, the Grow a Farmer site (CASFS's apprentice alumni site), the Farmer Educator Network (FEN), Appropriate Technology Transfer for Rural Areas (ATTRA), etc.

The project performance measures were either met or exceeded:

1. Produce and distribute eight Grower Guides in print and online - 250 of each guide will be downloaded and 250 will be distributed in year 3.
    a. A total of nine Grower Guides were completed. Approximately 250 hard copies were distributed. The site containing the Grower Guides received 174 hits.
2. Train 120 six-Month Apprentices – 85% of these apprentices will have an increase in knowledge.
    a. There were 120 apprentices trained in 22 classes. Apprentices were asked to complete a survey for each class. Across the 22 classes, 90% reported an increase in knowledge (487 out of 544 responses), exceeding the target.
3. Train 100 beginning farmers in eight CASFS farmer workshops or field days - 75% of whom of will plan to implement something they learned.
    a. There were 162 farmers in attendance at all the field days, exceeding the goal for the number of people served in this manner. Participants were asked to complete a survey after each workshop. For all workshops, 90% (103 out of 114 responses) of the respondents said they had learned either "a great deal" or "a moderate amount." Similarly, for all workshops, 88% (100 out of 114 responses) said they had planned to implement something they learned.

4. Mentor 30 beginning farmers in the Central Coast region - Those mentored will have an 85% increase in knowledge and a 65% report in changed practices.
    a. There were 61 farmers whom received mentoring services – exceeding the goal set for those served in this manner. The primary farmers served during each year (not including those served at EcoFarm or interns of the mentees) were asked to complete a survey in March of 2016 ad 2017. The survey asked about the mentoring services they received in the previous year. There were nine respondents in 2016 and 16 in 2017. Overall, 76% (19 out of 25 responses) changed a production practice. Similarly, 88% (22 out of 25 responses) reported that their knowledge changed a great deal.

The primary goal of the project was to increase the crop knowledge and production efficiencies of small-scale beginning specialty crop growers, with an emphasis on organic and sustainable production practices. The ultimate desired impact was that this effort would help insure the viability of California specialty crop farmers and expand the use of sustainable practices.

The effort served approximately 343 beginning farmers (potentially duplicated) through training, workshops and mentorship. Of those whom completed post workshop or class surveys, 90% learned something from them. Of those whom completed workshops, 88% planned to implement something they learned. Of those whom completed the mentoring survey, 76% changed a production practice. These numbers quantified the success of the project to reach and impact farmers.

While economic impact for individual farmers could not be tracked, there was anecdotal evidence that the information provided by this project had been extremely helpful. Staff found that many beginning farmers were very excited about the information shared through both trainings (classes and workshops), mentorship activities and the Grower Guides. In particular, the data collected on the costs of production – appeared to be a huge service.

Overall, the project team felt that the data collected provided a tremendous service, and was a major success of the project, for several reasons. First, beginning farmers were provided with detailed information about cropping systems, and were also provided a real understanding of the work and time needed to put into crops – including the time spent tilling the ground, buying seeds, transplanting, watering, weeding and harvesting. This will help beginning farmers more realistically plan for the time necessary to produce a specialty crop. Second, it highlighted the importance of certain strategies, such as weed management. When a farmer sees that hand weeding takes 80 hours an acre, it can be an incentive to implement recommended weed reduction strategies (e.g., planting to moisture) up front to mitigate spending that much time on weeding later. Third, due to the extensive amount of time needed to collect, enter and analyze these data that other farmers could not be expected to do it. Fourth, while no farm will work exactly like the UCSC farm, and timing and other factors will be different, this information provided a starting point for beginning farmers to think about strategies, and clearly and consciously plan to adapt them. Finally, this information sped up the learning curve, in that the beginning farmers would make a few less mistakes when starting out.

The Grower Guides, in particular, were seen by staff as a significant contribution to the distribution of important agronomic and economic information. These guides will provide a reference that farmers can return to when needed. For example, new farmers that have gone through the apprenticeship program, or workshops,

can revisit the guides to remember the specifics covered in classes. The guides' graphics demonstrated particularly useful pieces of information that could continually be reference and use.

Beneficiaries

Over 300 beginning and aspiring farmers benefitted directly from this project. Although the exact number of beginning farmers whom may be served was difficult to assess, the Grower Guides produced could potentially serve all California specialty crop growers to some degree, representing close to 4,000 farms. Based on national use of other training and production materials developed by CASFS, specialty crop growers beyond California may benefit from parts of the Grower Guides as well.

Training and written information will primarily benefit small-scale, organic specialty crop growers with regionally specific information on high-value crop production as well as information on water and labor-saving techniques. The economic impacts of these efforts were difficult to predict. However, production efficiencies gained from this information could increase dollars earned from two percent to ten percent. For example, dry farm tomatoes sold at farmers' markets brought higher prices and attracted more buyers than other varieties. By focusing on high-value, organically grown specialty crops, this project was able to help the next generation of beginning farmers get established and gain economic traction based on higher margins.

Lessons Learned

The project team learned several particularly useful things from their research and education activities. For example, the economic analysis helped confirm informal farmer assumptions about what a mixed specialty crop field could earn. It used to be assumed that these farms in California should bring in around $18,000 to $20,000 an acre (gross). However, a lead farmer noticed that people had started expecting more, $25,000 to $30,000 an acre. Due to the numbers collected in this project, it was thought that those higher numbers were justified. Additionally, feedback through mentoring and workshops showed that flowers were the star crop. This crop provided a niche to new farmers to help increase their revenue stream as they started out. The flower workshop offered as part of this project drew the largest audience, and numerous follow-up questions from growers.

This project further confirmed the need for a team to support growers. The project team found that growers needed the assistance provided by this project – to organize meetings, help set up field days, have someone leading the administrative and reporting effort, as well as prompting, coordinating and editing the writing. The structure created worked well, and the team suggested re-using this strategy again in the future.

Regarding strategies to change for the future, the project team would hold more workshops in farmer fields instead of at the CASFS farm. While the team had hoped to get farmers to come to the CASFS farm to see the demonstration fields, some farmers found it difficult to get there. Since a bulk of the agricultural land was at least 30 minutes away, it might be best in the future to conduct the field days on other people's farms – particularly in the Pajaro Valley. It was also suggested that the production of the Grower Guides begin earlier. This would allow more time for more editing and reviewing, and build in more time for economic analysis work.

The project also provided some unexpected benefits. Tracking the data on crop growing helped the team to better do their own crop planning in the field. Additionally, having written down the agronomic strategies

used in the Grower Guides helped to improve the teaching of these topics. Clearly laying everything out in writing helped the team to better articulate the lessons learned.

Another unexpected outcome was the very positive reception to the field posters. These posters summarized different growing strategies and activities for the project research fields. They were (and continue to be) stationed in the fields next to the demonstration crops. These received good feedback from many people, from apprentices to tour participants. This was a good lesson in reaching a lot of visitors in an easy/low-cost way.

Project staff did not originally fully plan for the need for agronomic and economic data to be collected through most of the project, and thus the Grower Guides were not completely finished until the end of the project. Additionally, right after the first year of the project, the project team lost a key member who was to do a bulk of the writing. It took a long time to get the people needed to finish the writing. This situation also pushed back the publication completion time. Thus, there was less time than originally planned for the full distribution of the Grower Guides.

Additional Information

1. Tillage, Bed Formation, and Planting to Moisture: A Guide for Beginning Specialty Crop Growers (See attachment 2)
2. Organic Dry-Farmed Tomato Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers (See attachment 3)
3. Organic Cut Flower Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers (See attachment 4)
4. Organic Pest and Disease Management of Selected Crops on California's Central Coast: A Guide for Beginning Specialty Crop Growers (See attachment 5)
5. Organic Potato Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers (See attachment 6)
6. Organic Pepper Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers (See attachment 7)
7. Organic Winter Squash Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers (See attachment 8)
8. Fresh Market and Dry Bean Production: A Guide for Beginning Specialty Crop Growers (See attachment 9)
9. Organic Mixed Production Blocks for Direct Markets on California's Central Coast: A Guide for Beginning Specialty Crop Growers (See attachment 10)

USDA Project No.:	Project Title:	
16	Specialty Crop Education and Entrepreneurial Development for Transition Age Youth (SeedTRAY) Project	
Grant Recipient: The Noyo Food Forest	**Grant Agreement No.:** SCB14016	**Date Submitted:** December 2017
Recipient Contact: Cornelia Reynolds	**Telephone:** (707) 494-2149	**Email:** admin@noyofoodforest.org

Project Summary

The purpose of the project was to provide opportunities for youth to develop awareness of, and job skills appropriate for, employment in the specialty crop sector and related businesses. There are no vocational skills training opportunities for local students, and low awareness of academic training opportunities. To address the problem, the Noyo Food Forest (NFF) was to develop and provide an experiential training program to inspire local youth to pursue careers in the specialty crop industry, while increasing local consumption of specialty crops, providing nutrition education in the community, and developing a curriculum for publication.

The local market for specialty crops is currently a growth sector. Production of specialty crops has lagged behind demand, while awareness of the range of employment opportunities and training for employment in this sector has been very low. The program had demanding objectives which were to train youth and familiarize them with career opportunities, increase local specialty crop consumption, improve nutrition knowledge among local students, and develop and publish a curriculum to inspire similar school-based farm training programs around the country.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

NFF hired the Program Manager once the grant project started. The Director and Manager developed the project production plan with input from the primary project partner, the Fort Bragg Unified School District (FBUSD). The plan was completed in April 2015; it was adjusted over time due to weather and other conditions, but proved a solid basis for ongoing planning. The Manager and Director developed and put in place data collection and monitoring systems. During regular monthly meetings with FBUSD, the developing curriculum was reviewed and aligned with the project production plan. The Director and Manager hired the project Apprentice, who started in April 2015. The Apprentice selected stayed with the project, contributed to its success, mastered many skills, and made a commitment to a career in agriculture. He developed projects, such as a compost sifting machine, which contributed to the ongoing curriculum development.

Intern recruitment included radio, online promotion and classroom visits. The outreach had a positive impact on partners and community, particularly classroom presentations. Intern intensive summer sessions began in 2015. Twelve enthusiastic interns completed the program and gave it high marks. Staff were surprised by how hard it was to recruit interns and by a high dropout rate. These issues continued through the course of the program. Staff conclude that the issues were a result of the rigor of the program. The rigor also was responsible for the strong success, among those who completed the program, at attracting youth in specialty crops, nutrition, and agriculture as a career interest. Staff were also surprised and unprepared for the strong

interest on the part of high functioning special needs students. This had a negative effect on recruiting in 2015, but staff were able to shift the program's image by publicizing a wide range of intern success stories.

Intern training sessions continued over the life of the grant, with more success in the summer programs than the after-school sessions during the winter. Winter's impact was unforeseen in two ways: Student interns did not want to travel home in the dark at the end of after-school sessions; and severe winter had an impact on the garden in 2016, and in 2017 caused so much damage to the garden from flooding and wind that the garden was shut down for several months. During that time, intermediate level interns and local volunteers helped repair roofing, fencing, electric and drainage. Some lessons from this were added to the curriculum, which staff members regularly met to review and develop. Local experts delivered workshops for interns on topics that included propagation, food handling safety, the food system, Farmers Market business, fruit tree pruning, and more. Field trips to local farms and specialty crop distributors gave interns an overview of raising and distributing specialty crops. Interns regularly attended the local weekly farmers market and sold specialty crops there, often sharing their knowledge of how to cook the specialty crops with customers. Staff continued developing the curriculum with insight from all these activities.

The specialty crops grown were used by FBUSD in the Harvest of the Month tasting program, which involves 1,500 local students who have the opportunity monthly to try a fresh and often unfamiliar fruit or vegetable. A 2017 summer session began in June 2017 and continued the curriculum and data collection practices, training two intermediate interns and six new interns. The curriculum was completed in spring 2017 and published on the NFF website in June 2017. It was printed over the summer and is the subject of a promotion campaign to raise awareness of it among appropriate educators.

All activities conducted and funds expended contribute to the competitiveness of specialty crops as the NFF only grows specialty crops.

The most valuable partner was the Fort Bragg Unified School District. They fulfilled their matching funds commitments, providing the project with free use of the land and water. Their support went beyond their original commitment to include electricity, and internet and computer support. The Nutrition Services Director was involved in the day to day review and decision-making throughout the term of the grant. Staff met monthly, planned changes in the garden, and reviewed developments with the interns and staff members. The relationship continues on a very positive basis. Staff were also in regular contact with many educational institutions and organizations as they developed and publicized the curriculum.

Goals and Outcomes Achieved

The key performance goal was to train 65 interns over the life of the grant. There were 60 students who began the program, and only 42 who completed the program. Eight interns also participated in the intermediate level program, five of them under auspices other than the grant (that is, their stipend was supported by a donor/sponsor, Work Ability or other source). The expected measurable outcome was that youth would pursue education or employment in the specialty crop industry. Questionnaires were administered on admission to the program. Youth were asked to rate their interest in agriculture as a career. They are asked about their eating and nutrition habits. They are also asked to self-rate their knowledge of (1) gardening and farming practice, (2) farming business, and (3) the food system overall. Exit surveys and personal interviews are conducted at the completion of the program. More in-depth and detailed information about their experience was gathered from those who completed the intermediate level of the program. Long-term

participation in the industry was to be measured at the end and after the project with an increase of 10%. To establish trends and accomplishments to date staff have tracked increased interest in agriculture as a career, improvement in diet, and increased knowledge of farm practice and business.

Long-term participation in the industry was measured at the end and after the project with a 10% over baseline. Most of the interns start as high school freshman and have not yet completed high school. Staff planned to track interns after high school through Facebook, but social media has moved on and interns do not participate in Facebook anymore. Staff will track interns with email and help through their high school alumni association, and through contact with their parents. Two Interns from the summer 2015 sessions are currently active in agriculture, one in college, one locally employed. A third who just completed high school has firm plans to start a farm. These three are 7% of the 42 interns.

Forty-two interns completed the program, out of a target of 65. Eight of them participated in intermediate training. Sixty students started the program and participated in the initial data survey; of these, 60% indicated a low interest in agriculture as a career (2.0 or lower on a scale of 5). The dropouts invariably came from this group. The remaining 40% averaged 3.25 on a scale of 5.

Of 42 who completed the program 45% expressed interest in additional agricultural training. Sixty-five percent increased their knowledge of farming practice and business, 50% reported that they increased their consumption of specialty crops, and 5% are pursuing related high school courses. Three interns, 7% of those who completed the program, have continued to be involved in agriculture, through additional education or employment.

Community awareness and consumption of specialty crops was increased because over 1,500 local students participated in school tastings, 800 attended a tasting event in September 2016, and 2,000 attended a community tasting event in spring 2017. The curriculum for the program was successfully developed and published online to encourage other school districts to develop similar programs.

Beneficiaries

With the support of the grant, NFF successfully expanded its operation to make the intern program available to the local high school aged community of >1,000 in two local school districts. Staff classroom visits increased awareness of specialty crops far beyond the 60+ who actively participated in the program. The program benefited FBUSD as it complemented academic offerings at Fort Bragg High School, providing hands-on training and practical experience. The FBUSD and its students benefited from the Harvest of the Month tasting program for which the Learning Garden (project garden) donated specialty crops. The Learning Garden was also available for visits from classes to observe the garden and the interns. The local specialty crop industry benefited from increased awareness among youth and increased consumption resulting from youth education, farmer's market sales and large public tastings done during the course of the program. Tastings staff participated in September 2015 and September 2016 drew 800 people each, promoted the intern program and presented delicious salads of specialty crops grown by the interns. A large community event staff produced in spring 2017 brought 2,000 community members together, over half of whom tasted salad and smoothies produced with specialty crops grown by interns.

It is expected that continued promotion of the successes and the methods through promotion of the curriculum will extend the benefits to school programs nationwide.

Through nutrition education, specialty crop tastings, and program activities, the project benefited ~1,800 school children in a school district with a high percentage of free lunch students (68-70% varying year to year). The program was available to ~1,000 local students ages 14-19. Among those, 60 participated and 42 youth completed the program. In a community with few entry level jobs, the program provided first jobs to many disadvantaged students. The program also had an impact on the vitality of the local farmer's market, attended weekly by up to 500 people, where customers seek out the specialty crops grown by the interns.

Lessons Learned

The staff found that the scheduling needs and complexities of high school demanded more attention in planning the program. The after-school sessions as originally envisioned were not viable. A more flexible approach had to be developed which allowed interns to complete their time as they could. However, this made the teaching opportunities in the after-school sessions much more informal as groups of interns were less often together for demonstrations and projects. Although this approach enabled some youth to complete the program who would not have otherwise, its informality may have contributed to the high dropout rate.

The negative events created by the winter weather were extremely disruptive, particularly in the most recent winter, but they also contributed to staff's awareness of the importance of water management—as in less than three years staff had to deal with both drought, which lowered production, and flooding, which lowered production, was destructive to the garden, and discouraged interns from participating. Water management is identified as a primary area for further curriculum development, using what staff learned from these experiences. Drainage improvement is a facility improvement priority.

Another unforeseen area of curriculum development was created by the Project Apprentice who taught interns to build from scratch regularly used supplies such as start trays, creating more durable items and reducing repeat purchases.

The project had a dramatic and unexpected impact on a number of families who reported that their diet was significantly impacted by the intern's involvement. In three cases, two youth from a family followed each other in the program, the second inspired by the first. In one family, the second child participating was autistic. His transformation, and first social interaction in a public place, which was at the Farmers Market, is perceived by his family as life-changing. Many of the plants the interns were growing were unfamiliar to them. Specialty crops did not need to be exotic to be unfamiliar to these youth, zucchini is a good example.

The project also unexpectedly served as an incubator program for entrepreneurial gardeners. Although staff experienced it as a challenge keeping a Project Manager, beginning with the original Project Manager in the grant proposal, three gardeners left to pursue opportunities they perceived—through the program—in the local market. Two started farms; the third started a specialty crop distribution company.

The original goals of the project were too optimistic, if not unreasonable given the size of the community. The launch of the project was late, causing a setback in ways that staff failed to foresee. The NFF and the project partner, FBUSD, did not want to launch the program during the last trimester of the school year, so the first intern session did not begin until June 2015. The unforeseen weather damage experienced in the 2016-2017 winter was a final blow that closed the garden for a period due to flooding and damage, preventing staff from achieving the intern goal. NFF credits the rigor of the program with both the high dropout rate and the high success at interesting the youth who stay in the program in agriculture. Staff credit the narrow thinking as

responsible for the failure to foresee the number of special needs youth for whom this program proved appropriate.

Additional Information

The curriculum developed by this program is entitled “Grow People, Grow Soil, Grow Food.” It is available for download at http://noyofoodforest.org/youth-internship-garden-curriculum/

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
17	Colusa County Grown-Specialty Crop	
Grant Recipient: Colusa County Resource Conservation District	**Grant Agreement No.:** SCB14017	**Date Submitted:** December 2017
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Project Summary

Agriculture is of vital importance to California yet the general public was mostly unaware of the environmental and health benefits provided by agriculture. As California faced one of the worst drought crisis in recorded history, immediate actions were needed to promote the importance of agriculture and the environmental stewardship provided by farmers. The Colusa County Grown-Specialty Crop (CCG-SC) project was utilized to increase the marketability and competiveness of specialty crops (SC) through greater product demand fostered by strengthening the farm to consumer connection. CCG-SC focused efforts on increasing producer ability and opportunities to market SC, increasing agritourism, and increasing awareness of the nutritional benefits and environmental stewardship provided by SC producers. CCG-SC provided public and producer outreach utilizing Colusa County Grown (CCG) and capitalize on existing high profile venues for statewide impact. The timing of the CCG-SC project was perfect to build on current local support and momentum generated through the conception of CCG and take full advantage of the public's interest in where their food comes from.

At the time the proposal was written Colusa County ranked #1 in the state for unemployment, 70.2% of the adult population is overweight/obese and 15.2% are living below the national poverty line. It was felt that a greater demand for SC would improve employment opportunities, increase profit to support higher wages, and serve as an indicator of healthier food choices. The timing of this project was perfect to build on the local support and momentum generated through the fledgling CCG campaign and to capitalize on the current interest in the farm to fork movement.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Social Media-Facebook: The CCG-SC Facebook page was kept current and relevant throughout the entire project period with grant staff making 425 posts during the span of the project. A total of 55,204 reaches, and 6,267 actions were generated throughout the project. The CCG website was kept current with basic information about the program. During the final reporting period of the grant, the website was re-created in WordPress to replace the outdated software used to originally create the website and currently used for maintenance.

CCG Center: In the early months of the project the Colusa County Resource Conservation District (CCRCD) worked diligently with the Colusa County Board of Supervisors to help generate support for establishing an agricultural center on the Interstate 5 corridor. An exhibit was erected at the 2015 Colusa Farm Show promoting the concept for the center. The center would sell local SC, teach the public about agriculture practices and serve as the hub for agritourism. A presentation was also given at the annual Joint County and

City dinner meeting and during CCG stakeholder meetings. A story about the center was included in the 2015/2016 CCG Food Guide. Local government applied for a couple grants to pay for the center but were not successful. The Supervisor that was the driving force for the center was not re-elected. Due to the fact the CCRCD was only serving in a support capacity for this endeavor the task of developing a conceptual plan for the center could not be realized. To replace this activity the CCRCD worked with new local businesses to connect them with sources to purchase local SC, promoted the businesses on the CCG Facebook page and advertised them in the Farm & Food Guides. The promotion of these businesses will continue long after this grant has ended. A data base of 290 Colusa County SC producers was generated.

SC editions of the CCG Food Guide: During this project the CCRCD created two CCG Farm & Food Guides-SC editions. A total of 7,535 Food Guides were printed featuring stories about local SC producers, seasonal SC charts, SC commodity group information, local farm directory, nutritional information and much more. The Food Guides included 24 full color glossy pages of information pertaining to highlighted SCs. A portion of the guide's material was translated into Spanish. To date a total of 5,380 Food Guides have been distributed throughout the county and beyond. Approximately 20% of the guides were translated in Spanish to reach the large portion of Colusa Counties Non-English speaking community.

SC Exhibits: The CCRCD erected an exhibit on the nutritional value of SCs at the 2015 Colusa County Fair. It is estimated that 29,750 fair visitors viewed the popular exhibit which received first place. The 2016 Colusa Farm Show exhibit on the nutritional value of SC was viewed by an estimated 34,000 spectators during the three day run. The exhibit included soliciting 100 random visitors to complete a pre and post exhibit survey to demonstrate the effectiveness of the exhibit.

Specialty Crop Marketing Workshop: A SC Agriculture Marketing Workshop was held in conjunction with the 2016 Colusa Farm Show. The workshop featured local producers active in agritourism as speakers along with the California Agritourism Coordinator and a couple of speakers from a social media firm specializing in promoting agriculture.

CCG Model Farm Tour: The CCRCD hosted a model Farm Tour designed to build support and generate ideas for a future Farm Tour open to the public. The target audience was local elected officials, specialty crop producers and the local media. The tour featured visits to five SC operations and a presentation on liability associated with opening your farm to the public. Although the target of 50 attendees was not reached the input obtained from the 15 participants will be extremely valuable in designing future farm tours. The goals for the model tour was for the attending media to commit to writing at least three stories about agritourism (one story was written and published immediately following the tour and upon contacting the writer in June 2017 it was stated two additional articles will be published in the near future), elected official to commit to supporting agritourism and of the SC producers attending 85% pledged to include agritourism in their marketing approach (target 50%). A proclamation was written and presented to the Colusa County Board of Supervisors to adopt pledging their support for specialty crop agritourism. The Colusa County Board of Supervisors signed a proclamation pledging their support for specialty crop agritourism in Colusa County. CCRCD staff attended an all day workshop in April 2015 to learn more about agritourism and hosting such an event.

Unique Specialty Crop Nutritional Awareness Presentation: A presentation on the nutritional value of SC, environmental benefits of raptor boxes in almond orchards and value of soil used to grow SC was wrapped into one presentation at the 2017 Colusa Farm Day. A total of 205 students and 27 adults (target 200-500)

attended. A total of nine sessions were given throughout the day. A SC coloring book was created by CCRCD staff with Spanish translation. A total of 2,000 copies of the coloring book were printed and a total of 1,400 were distributed at the Farm Day, local 2nd grade classes throughout the county, Chico Summer Camp, Family Action Centers in Arbuckle and Williams, preschool programs, local fruit stands and local restaurants.

Connections between producers and opportunities to increase sales: Efforts were taken to connect a new business in Colusa with producers to fill the shelves with SC. The CCRCD received contact from a number of other businesses asking where to find certain SC. The Food Guide and Facebook continued to promote local venues selling specialty crops and connect consumers.

CCRCD staff worked diligently to keep the focus of this project on SCs throughout the project. The nature of CCG naturally lends itself to the promotion of SCs as they are the crops that farmers tend to play a larger role in the marketing process and have more direct contact with consumers. Because the CCG campaign had the potential to benefit non-specialty crops, staff tracked their time and the CCRCD billed a portion of the hours promoting the program to other sources. The creation and launching (6/28/17) of the updated CCG website will benefit commodities other than SCs. A portion of the hours was billed to another source, and CCRCD staff tracked time spent on the project. The new website fees were furnished by CCG and not by grant funding. Additional funding was also generated through local government contributions and solicited from others sources to offset any potential benefits to non-specialty crops.

The Natural Resources Conservation Service was a major contributor to the project through the donation of office space, use of office equipment, Ag stewardship materials and the use of a vehicle for much of the travel needs of the project. Another significant contributor was the Center for Healthy Community who made sure all SC nutritional material in publications and exhibits was correctly presented. They provided much of the Spanish translations for the publications and partnered with the CCRCD for a SC nutritional presentation at the 2017 Colusa Farm Day. The Colusa County Board of Supervisors provided financial assistance to help promote the CCG Center in year one of the project. Significant contributions were made by SC producers who served as presenters at the workshop, hosted a model farm tour site, helped erect the County Fair Exhibit, and serve on the CCG Board of Directors. The 44th District Agriculture Association donated exhibit and workshop space at the annual Colusa County Farm Show in 2015 and 2016. The California Agritourism Coordinator for the UC Small farms program for assistance with the workshop and providing agritourism training to staff. Also making a significant contribution to the project was the CCRCD Board of Directors who volunteered many hours to staff exhibits, help with events, and attend meetings where important actions were taken to support the sustainability of CCG after the grant was completed.

Goals and Outcomes Achieved

The following activities were completed in order to enhance marketability and competiveness of SCs through greater demand supported by a stronger farm to consumer connection: a relevant and active social media campaign was created that included a CCG SC Facebook page where 425 posts were made by staff during the project and the CCG website was improved and updated resulting. A 290 SC producer database was compiled which included nearly 100% of the local SC producers in Colusa County and was utilized for event/educational outreach. The nutritional value of SC was promoted by creating and erecting exhibits at the Colusa County Fair and Colusa County Farm Show. Two SC editions of the CCG Food Guide (7,535 copies) were created and published. The guides included local farmer stories and a local food directory. Producer's tools to increase their ability to market their SC were enhanced through the Innovative Ag Marketing

Workshop and model Farm Tour. The tour was designed to collect information for future tours to be open to the public, give SC producer a glimpse in to hosting an on the farm event and to engaging the media and local elected officials to support agritourism. The CCRCD requested the Colusa County Board of Supervisors to sign a proclamation pledging support to increased agritourism in Colusa County. A unique SC nutritional awareness and environmental stewardship presentation was given at the Colusa Farm Day for children and featured a specialty crop coloring book created and illustrated by project staff.

The long term outcome measure for this project is the sustainability of the CCG campaign. Much progress was made during the project to secure the continuation of the program. The CCRCD Board appointed a Steering Committee to oversee CCG. The president of the committee is a very active SC producer in the community. The committee meets monthly and will continue to oversee the program and take more of a leadership role after the grant ends and CCRCD staff is no longer available to assist at the current level. The Membership drive is in full swing with a total of 23 members to date and increasing weekly. Members have joined at various levels including member, producer and supporter. Membership fees, advertisements in publications, fees to attend events and financial support from the Colusa County general fund will sustain the program. The CCG website and Facebook pages will continue to be maintained.

The project's goals were to increase producer ability and opportunities to market SCs, increase agritourism and improve nutritional and environmental awareness of SCs. The following actual accomplishments were completed in support of these project goals: A model farm tour was held to increase producer's knowledge of agritourism and garner media and local government support for agritourism. The Innovative AG Marketing workshop was also held to support the goal of increasing agritourism knowledge. Social media and the CCG website was used to increase SC nutritional knowledge and provide increased marketability of SCs. Facebook generated 55,204 reaches resulting in 6,267 actions. The CCG website had a total of 4,054 visits during the grant period. The project target was to print 5,000 Farm and Food Guides, the accomplishment of printing 7,535 was realized. The two Food Guide Editions successfully supported all project goals. During the project at least 13 articles promoting SC and project events were written and published in six different media sources with a total circulation of approximately 90,956. Exhibits were erected at the Colusa County Fair and Colusa Farm Show promoting the nutritional value of SC and the environmental stewardship provided by specialty crop agriculture. At least 85% of the spectators attending the events walked past the exhibits. Presentations were made at the Colusa Farm Day to increase SC nutritional knowledge in children. A SC coloring book supporting the same goal was created, 2,000 copies were printed and distributed throughout the county and beyond. A SC producer data base was compiled containing close to 100% of the contact information for SC growers in Colusa County. Assisting local government to develop an Action Plan for the CCG Center was the only project objective not reached during the grant period. However, notification to the community concerning the desire to build such a facility was realized through exhibits, presentations, publications and newspaper articles.

Because this is an educational project most baseline data was determined by pre-event polling and questionnaires. The target was to increase knowledge base by at least 50% as a result of each educational activity. The 2016 Colusa Farm Show Exhibit included 100 random visitors completing a pre and post exhibit viewing survey. The pre viewing survey results revealed only 26% could name a SC and in the post survey 97% of participants stated they had a better understanding of SCs (an increase of 71%), 99% stated they would add more SCs to their diets and 97% stated they would eat more SCs in general. The Innovative Ag Marketing Workshop included pre and post event surveys. The surveys revealed the following; of the SC

producers attending the workshop 71% (80% Target) reported increased knowledge about Ag marketing and 57% expressed a higher desire to implement new Ag marketing practices. The Model Farm Tour also included pre and post event surveys with the following results: The SC producers completing the survey revealed 100% showed an increase in knowledge about agritourism after the event and 90% pledged to include agritourism in their marketing approach (target 50%): Of the media completing the survey 100% pledged to write at least three stories about agritourism. Of the elected officials attending the survey showed 100% had a high level of pre and post event knowledge about the value of agritourism and pledged support to increase agritourism efforts in Colusa County. The CCG website baseline data was 800 visits with an end-target of 1,600 visits, at the end of the project there were 4,054 visits which was over 200% of the original goal. The target of the CCG Facebook page was to download 286 posts during the project period, 425 post were actually made, the target for reaches was 16,500 with the total at project end of 55,204, the target for Actions was 1,650 and at project end the total was 6,267. CCG Center, target making public aware 2015 Farm Show Exhibit exposing 45,000 visitors, presentation to 40 business leaders, two newspaper articles with total circulation of 35,056 circulation. When 205 students were polled at the beginning of the Farm Day SC session 13% of the students reported that they eat SCs. Post session poll showed 96% (90% target) of those attending stated they would eat more SCs every day, an increase of 83%.

7,535 copies of the CCG SC editions of the Farm & Food Guide were printed
5,380 Food Guides distributed (remainder targeted for distribution in 2018)
6,257 actions were generated by the CCG Facebook page posts and reaches
4,056 Visitors to the CCG Website
23 paid CCG memberships received and growing weekly
2,000 SC coloring books printed and 1,500 distributed (remainder targeted for 17/18 school year)
2 SC Exhibits erected exposing 33,150 visitors to SC information

Beneficiaries

Local SC producers benefited from this project, they were promoted in the social media, in the food guides and by the knowledge they gained through attending the project's events. SC growers that sell their produce at Farmer's Market's also benefited. SC entities, organizations, and boards that were promoted in the two editions of the Food Guides also benefited. Spanish speaking community benefits from the publications that included Spanish translations.

Approximately 95 local SC producers benefited from the project's accomplishments. Benefits will be enjoyed for many years to come as consumers continue to increase their consumption of SC's as a result of the knowledge gained through this project's educational outreach endeavor. The 7,535 Food Guides printed are a keepsake publication that will remain in homes throughout the county and beyond to reference often to find out when, where and why to purchase local SC's. The number of beneficiaries affected by the project's educational outreach endeavors included visitors and participants in SC educational events/exhibits totaled 102,321. The total visits to the social media campaigns where knowledge was gained about SC during the project was 59,234. Total circulation for all SC articles published in newspapers, special event handouts and Ag related newsletters were approximately 100,000.

Lessons Learned

Hiring and maintaining qualified staff was a challenge throughout the project. The project was originally written to capitalize on the talents of the current CCRCD Watershed Coordinator. This individual left the

employment of the CCRCD at the time the grant award was announced. The CCRCD Executive Director was able to step up and serve as the Project Manager throughout the grant. During the grant period hiring efforts occurred three separate times. The hiring process and bringing new employees up to speed on the project was very time consuming. A lesson learned is not to be too conservative with time estimates for staff to complete grant tasks. The CCG Center plan did not materialize which was out of the control of the CCRCD. The district did not and could not anticipate these conditions when the proposal was created.

It was unexpected that the CCRCD would become the go-to place for businesses to contact to find where to purchase SCs. The strong connections made with SC producers will last well into the future. This project had an even greater impact than what was originally anticipated on elevating CCG's ability to become self-supporting.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 18	**Project Title:** Engaging Agriculture within the Local Community	
Grant Recipient: California Department of Food and Agriculture	**Grant Agreement No.:** SCB14018	**Date Submitted:** December 2016
Recipient Contact: Nicole Sturzenberger	**Telephone:** (916) 900-5123	**Email:** nicole.sturzenberger@cdfa.ca.gov

Project Summary

One in six Californians is considered food insecure, and despite the fact that California is the leading producer of specialty crops, many Californians are unable to obtain sufficient access to specialty crops. This project addressed issues associated with food insecurity (specifically lack of access to specialty crops), agricultural awareness in rural and inner city communities, as well as resources to better connect consumers to specialty crop producers. By enhancing specialty crop farmer engagement and participation in consumer food interest issues, the project is improving the propensity of consumers to engage in local food purchases. The overall objective of this project is to increase direct-to-consumer farm sales through farmer engagement on issues impacting local communities and community engagement with specialty crop farmers. This project addressed three issue areas: food access, agricultural education, and outreach in local communities.

This project was important and timely because consumers are increasingly interested in food production practices and access to nutritious foods yet access to specialty crops continues to be a challenge for many consumers in California. However, direct-to-consumer food sales represent less than five and a half percent of all farm sales. By enhancing specialty crop farmer engagement and participation in consumer food interest issues, and consumer engagement with specialty crop farmers, the project aimed to increase the purchases of specialty crops within local communities and increase donations to food banks statewide.

Although this project does not directly build upon a previously funded Specialty Crop Block Grant Program (SCBGP) project, it does complement and enhance the 2010 SCBGP Project 75: *Farm to Fork Website Development – Phase I* website: www.cafarmtofork.com The website educates consumers on the seasonality of specialty crops throughout California and highlights some local efforts to promote specialty crop consumption. This grant enhanced the current website by adding additional resources and best practices and using the blog as a platform to communicate the successes of the projects, the materials produced as part of this project, and general information about specialty crops to consumers.

Project Approach

This project addressed food access, agricultural education, and outreach in local communities.

Food Access

Food Access Resources: A list of Food Access Resources was compiled and added to the cafarmtofork.com website under the “Resources” tab (http://cafarmtofork.com/FoodAccessResources.htm). The resources provide information, links to organizations, and other tools to help increase access to specialty crops. The list is divided into three major sections (by target audience): Individuals, Organizations, and Farmers.

1. The Individuals category has four major subtopics: Certified Farmers Markets/Consumer Supported Agriculture, Food Banks/Pantries, CalFresh/Supplemental Nutrition Assistance Program, and Healthy

Eating on a Budget. These subtopics contain information on determining eligibility and how to apply for CalFresh, searchable maps, and how to shop and cook healthy foods on a limited budget.

2. The Organizations category has subtopics on Funding and Resources/Reports.
    a. Funding lists several relevant sites that have consolidated various grants focused on the topic of food access.
    b. Resources/Reports provides useful tools, reports and webinars for organizations working in the area of food access.
3. The final category is for Farmers. Listed are resources for farmers who are just starting out farming, how to work to create a food hub, as well as how to donate excess harvest to those in need.

The California Department of Food and Agriculture, Office of Farm to Fork (Office) will continue growing and promoting these resources in the future.

Food Access Working Group: The Food Access Working Group (Group) was designed to bring together representatives from the Central Valley community to address food insecurity problems and barriers. The Group met multiple times and created an action plan report that contains recommendations to increase access to specialty crops for underserved communities in the Central Valley. The first meeting of the Food Access Working Group took place on October 20, 2015. The meeting was well attended and had representatives from many diverse groups, including specialty crop farmers and packers, county agricultural commissioners, food banks, community organizations, University of California Cooperative Extension, and governmental agencies (local, state, and federal). During this initial meeting, the group outlined priority areas around food access and split into four subgroups: Coordination and Food Waste; Food Access – Long Term; Food Access – Short Term; Education, Job Training, and Nutrition Education. These subgroups then met (via phone) to discuss the food access barriers within their topic areas and brainstorm preliminary solutions to present to the full group. At the next full group meeting (January 20, 2016) the subgroup presented the barriers and possible recommendations to the full group for feedback. Office staff then worked with the contracted facilitator to write up the draft recommendations and coordinated with the subgroups again via phone to refine the recommendations. Those recommendations are included in a final report that can be found in the attachment. The Office, in partnership with the California Department of Public Health, will continue working with the Group to begin implementing some of the recommendations.

Agricultural Education and Outreach in Local Communities

Specialty Crop Farm Tours: Three farm tours were completed during the project in Northern (Sacramento Area), Central (Fresno Area), and Southern California (San Diego Area). The tours were held in those locations with the goal of representing as much of the state as possible. Each tour aimed to increase access to California grown specialty crops by helping connect target audiences with specialty crop farmers.

The Office offered the first tour in January 2016 in the Fresno area, primarily for Food Access Working Group attendees. The tour aimed to expose the group to some of the food access specialty crop programs that were discussed in the meeting. Attendees visited a packing shed that purchases seconds from other sheds, and donates the edible fruit to food banks. During the visit, employees were sorting Cara Cara oranges into multiple streams depending on quality. The edible fruit was loaded up on a truck to be delivered to a food bank, while lower quality fruit was sent for processing or to be animal feed. The group also visited a school district's central kitchen to better understand how schools can directly support specialty crop growers and can simultaneously help expose children to different types of specialty crops and teach them the benefit of eating

specialty crops. Attendees were shown a snack pack including fresh kiwis, carrots, and packaged raisins to be served later that day. The district's food service director also discussed work the district had done purchasing strawberries directly from a local farmer.

The second tour was held in conjunction with the California Small Farm Conference in March 2016 in the Sacramento area. The tour showed small specialty crop farmers different avenues for selling their crops. Attendees first visited a large retail chain and met with their produce buyer, then a large school district that purchases directly from farmers for their school meal programs, and last a food bank that accepts produce donations on a regular basis.

The final tour was held in April 2016 in San Diego County, with the goal of exposing youth interested in culinary arts to the benefits of working directly with specialty crop farmers. Two classes of culinary arts students from a school distict's Career Technical Education program visited a working farm and educational center in Southern California. The high school students had the opportunity to learn about the specialty crops they grow, harvest some vegetables in the field, and cook a communal meal using the specialty crops they harvested. Many of the students had never visited a farm and did not have the opportunity to grow their own fruits and vegetables. "I use to have a tomato plant but my new apartment doesn't have a balcony," remarked one student. The tour was a great opportunity to connect young people to the fruits and vegetables that grow around them and that they often prepare in the culinary arts classes. Three blog posts describing the tours in more detail are included in the attachment.

Mobile Farm: Many California students and adults have limited knowledge of where their fruits and vegetables come from – they just know they end up at the store or on their school lunch tray. The Office of developed the Mobile Farm concept as an educational mechanism for taking the farm to schools, fair grounds, and community events in order to decrease geographical barriers to agriculture and increase general knowledge of farming specialty crops. During this project, the Office worked with Eat Think Design (ETD) students at UC Berkeley to develop possible directions for Mobile Farm specialty crop curriculum and outreach materials. Office staff performed the final review of all materials which are included in the attachment. In the 2015 SCBGP Project 12: *Promoting California Specialty Crops through Education and Enrichment*, Office staff will further develop this project by creating the vehicle design, incorporating the curriculum, business plan, and outreach materials.

Specialty Crop Ambassadors: The Office funded four student specialty crop outreach projects from a Farm Academy. The funding assisted projects supporting consumption, education, and access to California specialty crops in one of the following areas: (1) Developing or furthering farm to school efforts through use of specialty crops; (2) Decreasing food insecurity and increasing access to nutritious food options through the use of specialty crops; (3) Promoting farming specialty crops as a career to the community; or (4) Increasing public awareness of the health and environmental benefits of specialty crop production. The consultant helped solicit and review applications from Farm Academy applicants. Four individuals were selected as ambassadors based on the strength of their proposals. One ambassador worked with area youth at a farm in West Sacramento teaching them how to grow specialty crops in an urban environment. They also brought basil seedlings, small pots, and soil to the West Sacramento Farmers Market to show children the basics of growing. Another ambassador worked on a project to expose people with mental illness to the work of farming specialty crops. Their Farm to Mouth program allowed people struggling with mental illness a place to feel soil and experience the joy and healing power of growing fruits and vegetables. Ambassadors

chronicled their experiences through three blog posts each that were posted as part of the web-based stories of specialty crop engagement. The Specialty Crop Ambassador Program was a huge success, as it showed often neglected populations the beauty and benefits of growing fruits and vegetables, whether as a career or for their own personal consumption. The Office is continuing a variation of this project in the 2015 SCBGP Project 12. This will bring the project to Southern California to work with veterans learning specialty crop farming skills.

Web-based Stories of Specialty Crop Engagement: The Office posted 26 blogs on specialty crop engagement, ranging from the stories told by the specialty crop ambassadors to the details of each specialty crop farm tour. The Office also posted stories centered on specialty crops to further engage consumers. The blog posts helped expose the general public to the individual experiences within each of the grant projects. Photos and sample posts are included in the attachment.

Annual Report: In order to communicate the project development and success stories within the grant, the Office created an Annual Report for the 2015/16 fiscal year. The report provides a general overview of the Office as well as the details from the Specialty Crop Ambassadors, Farm Tours, and Food Access Working Group. The annual report has been an effective way of communicating the Office's successes and the successes of the projects funded by this grant.

The project did not benefit commodities other than specialty crops. Project staff worked to ensure that only specialty crops were represented in all data, resources, blog posts, curriculum, tours, and working group content. The Office's Annual Report did cover non-specialty crop items, which were covered by matching funds of 40 percent. The Office proposed using a 60/40 split (specialty crop/non-specialty crop) in the initial grant proposal. This "known target threshold" is based on the farm gate value of specialty crops vs. non-specialty crops in California (60% of the state's farm gate sales come from specialty crops as indicated in the CDFA's California Agriculture Statistics Review, 2013, with non-specialty crops making up the remaining 40%).

Project Partners included:
Food Access Working Group: Facilitators helped facilitate both in person meetings of the Food Access Working Group. The Facilitators also compiled the final report of recommendations based on the meetings. The members of the Group also contributed a tremendous amount of time and knowledge during the project – the Group was a true working group and all members actively participated and contributed to the final report.

Farm Tours: During the Northern California Farm Tour, the Office worked with a food bank a to lead a tour of their facilities and discuss their produce donation programs. The produce buyer of a grocery store led a tour of the produce department and spoke to the tour attendees about the process of selling to the grocery store and the company's engagement with specialty crop famers. The Food Service Director of a school district led a tour of the district's central kitchen and spoke about the small specialty crop farms they purchase from. For the Central California Farm Tour, the Office coordinated with a packing shed to show Food Access Working Group attendees a program working to improve specialty crop food access. The group also visited school district and met with their food service director. The Office coordinated in advance with all site hosts to discuss specialty crop priorities and to profile group attendees, in order to tailor the tour content. Coordination with staff aided in organizing two successful tours of 60 students who visited a farm and education center. The farm led all tours and exposed these students to the details and wonder of farming specialty crops either at home or as a business.

Mobile Farm: Eat Think Design Students from UC Berkeley were integral in developing the mobile farm curriculum and business plan. Using their backgrounds in engineering, public health, healthcare, and business they were able to lay the foundation for this project's future development.

Specialty Crop Ambassadors: The agricultural learning consultant acted as the host organization for the Ambassadors. The organization advertised the opportunities to students and helped select the finalists. They also worked directly with students to ensure deadlines were met and specialty crops were solely represented in their projects throughout their duration.

Goals and Outcomes Achieved

The overall objective of this project was to increase direct-to-consumer farm sales through farmer engagement on issues impacting local communities and community engagement with specialty crop farmers. This project addressed three issue areas: food access, agricultural education and outreach in local communities. The measures established to assess if goals were achieved were: (1) Increase the number of specialty crop farmers participating in certified farmers' markets (measures promotional efforts to encourage direct farm sales within each issue area); (2) Percentage of school districts identified in the United States Department of Agriculture (USDA) Farm to School Census as participating in farm to school activities (measures the success of agricultural education issues area); and (3) Number of specialty crop growers contributing products to the Community Food Bank (measures the success of food access issues).

The Office worked to engage specialty crop farmers and introduce new sales opportunities for them through the Specialty Crop Farm Tours and the Specialty Crop Ambassadors. The Food Access Working Group was also used as a tool to show farmers the option of donating produce to a local food bank.

The Specialty Crop Farm Tours aimed to increase access to California grown specialty crops by helping connect target audiences with specialty crop farmers. The tours were completed during the project in Northern (Sacramento Area), Central (Fresno Area), and Southern California (San Diego Area). The tours were held in those locations with the goal of representing as much of the state as possible. The Central California tour had primarily Food Access Working Group members in attendance. During the tour they visited a packing shed that purchases seconds from other sheds, and donates the edible fruit to food banks. The group also visited a school district's central kitchen to better understand how schools can directly support specialty crop growers and can simultaneously help expose children to different types of specialty crops and teach them the benefit of eating specialty crops.

The Northern California tour was held in conjunction with the California Small Farm Conference. The tour showed small specialty crop farmers different avenues for selling their crops. Attendees first visited a large retail chain and met with their produce buyer, then a large school district that purchases directly from farmers for their school meal programs, and last a food bank that accepts produce donations on a regular basis.

The tour in Southern California focused on exposing youth interested in culinary arts to the benefits of working directly with specialty crop farmers. Students from a school district Career Technical Education program visited a working farm and educational center and had the opportunity to learn about the specialty crops they grow, harvest some of those crops, and cook a communal meal using the specialty crops they harvested.

With the Specialty Crop Ambassadors, the Office supported consumption, education, and access to California specialty crops in one of the following areas: (1) Developing or furthering farm to school efforts through use of specialty crops (2) Decreasing food insecurity and increasing access to nutritious food options through the use of specialty crops (3) Promoting farming specialty crops as a career to the community; or (4) Increasing public awareness of the health and environmental benefits of specialty crop production. Each of the ambassadors chronicled their experiences through three blog posts that were posted as part of the web-based stories of specialty crop engagement. The Specialty Crop Ambassadors were a huge success, as they showed often neglected populations the beauty and benefits of growing fruits and vegetables, whether as a career or for their own personal consumption.

The Office posted 26 blogs on specialty crop engagement, ranging from the stories told by the Specialty Crop Ambassadors to the details of each Specialty Crop Farm Tour. The Office also posted stories centered on specialty crops to further engage consumers. The blog posts helped expose the general public to the individual experiences within each of the grant projects. Photos and sample posts are included in the attachment.

The Mobile Farm project will increase farm to school activities in the future. During this project, the Office worked with Eat Think Design students at UC Berkeley to develop possible directions for Mobile Farm specialty crop curriculum and outreach materials.

All measures in this project were set to four years, which is beyond the duration of the project itself. Many of the projects in this grant were only recently completed so it is too soon to measure their full effect. For example, the Specialty Crop Farm Tours were only completed in 2016, so their effects are still unfolding – for example, specialty crop farmers that learned about new markets for their products during the Northern California Farm tour have only just begun to utilize that information they gained this past spring. The same is true of many of the resources developed as part of this project. Therefore, the true measures of the project's effects are long term – beyond the four years mentioned – as many of the connections made and lesson learned in this grant will take time to come to full fruition.

This project aimed to increase agricultural awareness and engagement with local communities, with the end goal of increasing direct sales of specialty crops to consumers. The activities completed did increase agricultural engagement with local communities. The Specialty Crop Ambassadors all conducted outreach events in their communities to directly engage consumers and promote direct farm to consumer sales. The Food Access Working Group brought together a wide range of agriculture and community stakeholders and developed recommendations to strengthen those connections and better increase access to specialty crops in the Central Valley. The Mobile Farm plan was developed to maximize youth engagement with agriculture. And the Specialty Crop Farm Tours brought together specialty crop farmers with different community members. It is expected that as these connections have time to mature, there will be even more direct sales of specialty crops to consumers.

Performance Measure and Target: Increase by 25% the number of specialty crop farmers participating in certified farmer's market programs within 4 years.
Benchmark: 2012 - 2,356 total certified producers for farmer's market– 1,413* specialty crop certificates issued
Outcome: 2015 - 2,579 total certified producers for farmer's market– 1,547* specialty crop certificates issued

This shows a 9.5 % increase over the past three years. As data is only available for three years, the Office cannot say what these numbers will be in year 4. While the percent increase doesn't meet the initial goal of 25% increase, it points to a larger absolute number of specialty crop farmers selling at farmers markets.

* Since certificates are not categorized by specialty crop/non-specialty crop, the Office proposed using roughly a 60/40 split (specialty crop/non-specialty crop) in the initial grant proposal. This "known target threshold" is based on the farm gate value of specialty crops vs. non-specialty crops in California (60% of the state's farm gate sales come from specialty crops as indicated in the CDFA's California Agriculture Statistics Review, 2013, with non-specialty crops making up the remaining 40%). The 60/40 split likely underestimates the number of specialty crop growers selling at certified farmers' markets.

Performance Measure and Target: Increase by 10% the number of school districts participating in farm to school activities within four years.
Benchmark: 2012 – 51%* of school districts participated in farm to school activities according to the USDA Farm to School Census
Outcome: * Due to an error, the initial benchmark was actually 50.1% of school districts who participated in farm to school activities in the school year 2011/2012 based on the 2013 USDA Farm to School Census. In the 2015 report 49.5% were participating in farm to school activities in the school year 2013/2014. Therefore a decrease in the percent was seen. The reason for the decrease was several fold. The 2013 USDA Farm to School Census looked solely at public school districts. The 2015 USDA Farm to School Survey looked at public school districts, private schools, and charter schools and a few states included residential childcare institutions and other non-school-based sites participating in the National School Lunch Program. Therefore the new set of numbers being reported are not directly comparable to the first. What can be concluded is that the number of school districts reporting being involved in farm to school activities increased between the 2013 report, where only 316 school districts were involved in farm to school activities, compared with 2015 where 336 school districts reported participating in farm to school activities.

Performance Measure and Target: Increase the number of specialty crop farmers providing product to the Community Food Bank to 50 farms in 4 years
Benchmark: 2013 - 39 farmers were providing specialty crops to Community Food Bank
Outcome: 51 farmers donated specialty crops to the Community Food Bank – crops that may not have made it to market otherwise, reaching approximately 3.36 million individuals (280,000 individuals per month). The Community Food Bank in Fresno was used because of the work the Office did with the Food Access Working Group. At a statewide level, the California Association of Food Banks reports partnering with over 120 farmers, resulting in the distribution of over 150 million pounds of produce.

This project successfully engaged specialty crop farmers and consumers to better connect both groups with the goal of increasing direct specialty crop sales.

- Three Farm Tours were held across California that forged new connections between the community and specialty crop farmers
    - Southern California: 60 high school students had the opportunity to visit a working specialty crop farm in their region and created lifelong connections to fruits and vegetables.
    - Northern California: current and future farmers were exposed to different avenues for selling their crops through the Specialty Crop Tour held in Northern California. Of the attendees

surveyed, 50% said they learned about one new market for their specialty crops and 33% said they learned of three new markets for their specialty crops.
    - Central California: Food Access Working Group members were exposed to different models of increasing specialty crop access through foodbanks and school meals.
- Four Specialty Crop Ambassadors were selected to create projects that informed the next generation on the benefits of growing and consuming specialty crops, as well as the career opportunities therein.
- Fifty-one farmers were able to sell food at cost to a food bank that may not have reached the market, feeding approximately 3.36 million individuals (280,000 individuals per month).

Beneficiaries

Farm Tours: During the Specialty Crop Farm Tours across the state of California, culinary arts students, specialty crop farmers, non-profit leaders, food service directors, and supporting agencies were exposed to the entire system that grows, distributes, sells, and cooks with specialty crops improving information sharing, awareness, and creating direct relationships and connections.
Farmers who donate or would donate to food banks in California were provided information for them to help facilitate such interactions in the future.
Food Access Working Group: Over the course of the food access working group meetings, relationships were created and information was shared amongst stakeholders. The group also addressed issues and developed realistic action steps to combat existing problems. As a result of these meetings and recommendations, a plan to assist individuals who are food insecure in the Fresno area has been initiated.
Mobile Farm: The Mobile Farm plan and curriculum developed during this grant will benefit students across California.
Specialty Crop Ambassadors: the four Specialty Crop Ambassadors reached a range of audiences – including inner city kids and people struggling with mental illness – and introduced them to the importance of cultivating and eating specialty crops.

- 60 high school students had the opportunity to visit a working specialty crop farm in their region and create lifelong connections to fruits and vegetables
- 5 specialty crop farmers were exposed to different avenues for selling their crops through the Specialty Crop Farm Tour held in Northern California
- 7 members of the Food Access Working Group had the opportunity to participate in the Central California farm tour, exposing attendees to the resources in the community as well as ways to incorporate specialty crops into school districts as well as the food bank.
- 4 individuals were funded as Farm to Fork Specialty Crop Ambassadors to create projects that informed the next generation of the benefits of growing and consuming specialty crops, as well as the career opportunities therein.
- 36 members of the Food Access Working group were exposed to working models to improve food access in their area and introduced to the individuals who responsible for their success
- 34 organizations directly benefited from the information pooled through the food access working group discussion and central valley farm tour.
- 51 farmers were able to sell food at cost to the Community Food Bank that may not have reached the market, feeding approximately 3.36 million individuals (280,000 individuals per month).

Lessons Learned

The biggest lesson that the Office learned throughout the course of this project is that education and outreach are at the core of all improvement. By taking people to visit farms and witness the benefits of farming specialty crops within their community, recipients are able to directly benefit from the experience. The experience also raises awareness of the specialty crop growers in their region and ways they can interact with them in the future. This was especially true of youth who will grow up to be the next generation of specialty crop consumers and chefs. Many of the students from the Southern California Farm Tour were so impacted by the tour that they continued to visit the farm and volunteer there after the tour. The impact will go long beyond the duration of the project.

Additionally, the Office learned of the importance of bringing together stakeholders from many different areas – food banks, farmers, government– to have the greatest impact on increasing access to specialty crops. Because the issues impeding food access are complex and span many different areas (transportation to education), it was important to bring representatives with diverse backgrounds to the table. The Office worked with Food Access Working Group members to bring additional members to the table after the first meeting to make sure the group encompassed as many different perspectives as possible.

No unexpected outcomes affected the implementation of this project. The Office did take longer to finish the project due to contracting difficulties and staffing shortages but these setbacks did not impact any project results.

Throughout the grant, farmers were introduced to sales opportunities and the idea that donating produce through their local food banks is a viable option. Students were shown the benefits of growing fruits and vegetables or pursuing a career in specialty crop farming. Though the Office did not fully reach its goals, staff felt that the measures did not accurately communicate the effectiveness of the project. Many of the outcome measures will likely continue to increase as those affected by this grant continue their work and continue implementing the lessons learned from the grant activities (for example, farmers learning about new avenues to sell their crops start pursuing those new markets, etc.). Future projects should set a longer time frame to evaluate effectiveness.

Additional Information

The Office of Farm to Fork has included the following items in the Attachment as they contribute to telling the full grant story:

- Sample *Tales from the Field* blog posts, including ambassador profiles and farm tour posts
  - Ambassadors
    - http://blogs.cdfa.ca.gov/TalesFromTheField/?p=464
    - http://blogs.cdfa.ca.gov/TalesFromTheField/?p=444
    - http://blogs.cdfa.ca.gov/TalesFromTheField/?p=436
    - http://blogs.cdfa.ca.gov/TalesFromTheField/?p=432
  - Farm Tours
    - Southern California: http://blogs.cdfa.ca.gov/TalesFromTheField/?p=641
    - Central California: http://blogs.cdfa.ca.gov/TalesFromTheField/?p=663
    - Northern California: http://blogs.cdfa.ca.gov/TalesFromTheField/?p=636
- Mobile Farm curriculum and business plan: See attached.

- Food Access Working Group Final Report and Recommendations: See attached.
- Student Feedback from Southern California Farm Tour: See attached.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
19	Ventura County Farm to School	
Grant Recipient: Ventura Unified School District	**Grant Agreement No.:** SCB14019	**Date Submitted:** December 2017
Recipient Contact: Kara Muniz	**Telephone:** (805) 641-5000	**Email:** kara.muniz@venturausd.org

Project Summary

A fragmented distribution system and decades of disinvestment in school staffing, training, and facilities limited schools' ability to access and utilize local specialty crop products in school meals. The purpose of this project was to expand access to California specialty crops in Ventura County schools by: 1) facilitating production planning, marketing, and distribution of specialty crops in schools; 2) providing school staff training and development to increase utilization of specialty crop products in school menus; and 3) developing and disseminating educational tools to increase students' and families' awareness and consumption of California specialty crops.

This project built on the momentum and progress achieved by a farm to school working group of school food service directors, farmers and community organizations funded by the United States Department of Food and Agriculture (USDA) Farm to School grant program in 2012 to work on local fruit and vegetable procurement for school meals. This project funding enabled the team to expand its efforts and incorporate critical initiatives on education, outreach, and professional development to ensure the successful incorporation of local specialty crops into school meals and student eating choices. Like most of the country, children in Ventura County, including a high percentage of low-income children eligible for free and reduced school meals, are experiencing an explosion in rates of chronic diet related diseases such as Type II diabetes. Development of lifelong good eating habits including a substantial increase in consumption of fresh fruits and vegetables is a matter of vital importance to these children's future.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Local Sourcing of Specialty Crops:

1A. One of the priorities of the grant was to define and communicate best practices for produce supplier contracts to promote local sourcing of specialty crop items sold to the Ventura County Farm to School Collaborative (VCF2SC). The operations specialist was tasked with developing this guide and spent about one-third of his time for the first five months of the grant synthesizing research into a user friendly guide. This research included USDA and California Department of Education (CDE) procurement regulations and speaking with other school districts across the nation who are leading the way to implement more local sourcing into their produce bids. A significant result from this activity was including a stipulation in the produce contract that the vendor must submit their original purchase invoices. This helps ensure specialty crop growers are receiving a fair price for their products, and that the district is not being overcharged. Another key result was creating a requirement in the produce contract for distributors to submit monthly velocity reports, which will be discussed in the next section. Finally, the language in the bid promotes the sourcing of local specialty crops by requiring the chosen distributor to work with local farms identified by the

district. This best practices guide was implemented into the 2016 produce bid and has helped increase the amount of California specialty crops sold to the VCF2SC.

1B. At the onset of this grant project, much time was devoted to working with the VCF2SC produce distributor to establish a methodology to collect baseline and trend data on school produce sourcing. This data was essential in informing the collaborative if project staff were on target to meet the performance goals. It took a few months to work out the major kinks and set up the proper parameters, but as a result, the produce distributor now submits monthly velocity reports to the operations specialist. These reports contain the following information: item name, item size, pack size, type of produce (Fruit or Vegetable), unique item code (e.g. must differentiate local gala apples from Washington gala apples), country of origin, state of origin, quantity purchased, item price, average price, total dollar amount of produce purchased, amount purchased from within 150 miles, and amount purchased from Ventura county, list of the producers sourced from within Ventura County. This data has been useful in analyzing trends of purchase prices and quantities of specific specialty crops during the grant.

1C. A core component of the project was the VCF2SC Harvest of the Month program. Each month project staff featured a different specialty crop grown by a Ventura County farmer. The operations specialist began by developing forecasts for each Harvest of the Month item for the 2015-2016 school year. After that, he started identifying and reaching out to local specialty crop growers who would be willing to sell their products either directly to school districts or to the school districts' produce distributor. The majority of farmers preferred to work with the distributor based on ease of operations. The operations specialist developed a memorandum of understanding (MOU) between the farm and the produce distributor that clearly outlined the procedure and requirements of the Harvest of the Month purchase and delivery. During the 2016-2017 school year, the VCF2SC sourced $31,134.07 worth of specialty crops for classroom taste tests alone. The majority of this came from small scale farmers, where in a couple of cases the VCF2SC purchased their entire crop for that year. A favorable outcome of this activity is that one local large scale grower is supplying three school districts directly with organic oranges that are being served to students in less than 72 hours after they are harvested.

1D. Another objective of the grant was to educate students on the importance of eating local specialty crops. Therefore, the operations specialist developed a project in conjunction with Ventura Unified School District to start a ¼ acre mini farm at Balboa Middle School. The purpose was to produce specialty crops for the cafeteria and educate staff, students, and the surrounding community about California specialty crops. To date, the farm has produced 300 pounds of lettuce, 130 pounds of green beans, 20 pounds of carrots, and 250 pounds of peas. This produce has been served on the salad bar in six different schools or consumed directly by students on the farm. So far, over 700 students and community members have been involved in the farm, either through education or helping to harvest. A positive result of this project was giving students the hands-on opportunity to see how food is grown. Students who visited the farm were more likely to consume peas from the salad bar than those that had not visited the farm. This project is entitled Salad Bar Farms and being built as a model for other schools and districts to emulate. The goal is that by providing students the opportunity to see how food is grown, it will give them a greater appreciation for local agriculture and more likely to consume California Specialty crops.

Child Nutrition Department Development:
2A. The VCF2SC spans six school districts with each being at a different stage of Farm to School implementation. Therefore, the operations specialist developed a survey for each districts' food and nutrition services director to complete to gain a better understanding of the school food landscape of each district. This tool was synthesized from previous surveys put out by, the National Farm to School Network, Cornell University, Vermont FEED, Mathematica Policy research and other relevant entities along with questions developed by the VCF2SC to help increase the promotion of California specialty crops. This survey was then conducted by the nutrition specialist and child nutrition directors and assessed the kitchen facilities, staff capacity, cooking skills, and training, menu planning and produce purchasing processes at each of the six participating school districts. This information helped guide the Child Nutrition Services development plans.

2B. As a result of the assessment, it was determined that staff development was the most pressing action item needed to improve Child Nutrition Departments' capacity to utilize fresh, local and seasonal produce in their school meal programs. The most critical topics included: storing and receiving fresh produce, food safety, working with less than perfect produce, and knife safety skills. The assessment also revealed that many of the older kitchens are lacking the modern equipment necessary to conduct scratch cooking. A short list of this equipment includes food processers, blenders, and convection ovens. Unfortunately, VCF2SC does not have the funds available to help kitchens purchase these items, but with this projects' funding, project staff were able to implement staff development trainings at each district.

2C.The operations specialist developed a guide entitled, "Pura Ventura: A Guide to Cooking with Local Produce." This guide includes an introduction about Farm to School in Ventura County along with seasonal recipes and list of specialty crops that are in season for Southern California. This guide book was given to cafeteria staff members of participating districts. Along with the guide book, the operations specialist delivered a training that included an introduction to Farm to School, basic food safety, and knife skills components. Eight trainings were conducted at Harrington Elementary School, DeAnza Middle School, Ojai Unified School District, Rio Plaza Elementary, Driffill Elementary, Rio School District, Ventura Unified School District, and at the VCF2SC Growing Edible Education Symposium over the course of the grant. In total, 120 kitchen staff were trained. During year one of the grant, 30 cafeteria staff members participated in the training. This number tripled in year two, with 90 staff members participating in the training. A favorable result of this activity was discovering that some kitchens already have a culture of scratch cooking.

2D.The assessment tool that was developed analyzed school districts' kitchen facilities, staff capacity, cooking skills, training, menu planning, and produce purchasing processes. This tool was disseminated region wide during the second Annual Growing Edible Education Symposium on October 14-15, 2016. A recommendation that came out of this activity would be to have additional funds available to help kitchens update their kitchen infrastructure. While the assessment is a great planning tool, it would be beneficial to have resources available to help districts purchase basic scratch cooking equipment.

Nutrition Education and Community Outreach:
3A. The VCF2SC Education and Outreach Committee oversaw activities over the course of the project with support from the VCF2SC Steering Committee, operations specialist and nutrition specialist's team. The nutrition specialists and operations specialist created 18 farmer videos that were shown in the classroom. Each video was averaging at least 250 views. Approximately 450 key community partners were reached monthly through VCF2SC social media postings and quarterly through VCF2SC newsletters. Led by the nutrition

specialists team, over the course of the project more than 25 schools participated in the Harvest of the Month program including specialty crop tastings, agricultural education featuring VCF2SC produced grower and farm videos, and cooking lessons. The program reached approximately 34,000 students each month in the six participating school districts (Conejo Valley Unified School District, Hueneme Elementary School District, Ojai Unified School District, Oxnard Elementary School District, Rio School District, and Ventura Unified School District). The Education and Outreach Committee conducted one farm to school mixer to communicate with farmers and community members about the project, and developed and delivered a regional Growing Edible Education symposium which included two farm and school garden tours.

3B. The nutrition specialists team conducted a three-hour Farmer in the Classroom training, after which each participating farmer was paired with one school district and taught four Farmer in the Classroom days, each at a different school within the district. Over the course of the project six farmers presented 30 Farmer in the Classroom programs in 24 schools in six school districts, reaching over 8,000 students.

3C. At the beginning of each school year the nutrition specialist's team met with each of the six participating school districts to assess farm to school needs, gaps and priorities and to develop action plans for the coming year. Over the course of the school year the nutrition specialists team worked with school principals, teachers, and farm to school champions to implement action plans, including Harvest of the Month, Farmer in the Classroom and other programs tailored to individual districts' needs and resources, such as after-school cooking classes and in-class nutrition education curriculum.

Professional development for teachers was a common need identified across school districts, focused on 1) creating and sustaining school gardens, 2) curriculum integration with garden-based education, 3) connecting nutrition education with farm to school procurement, and 4) food service staff development. To address this need the committee partnered with a tri-county effort to plan, host, and present a regional Growing Edible Education Symposium October 14-15, 2016, in Oxnard Elementary School District. Over 130 Farm to School practitioners including nutrition educators, teachers, food service staff, farmers, community activists, and administrators from Ventura, Santa Barbara, and San Luis Obispo Counties participated in the two-day symposium. Participants reported increased knowledge and a commitment to participate in farm to school activities as a result of the symposium. The nutrition specialist's team reported new teachers joining Harvest of the Month activities as a result of symposium participation.

This project did not benefit commodities other than California specialty crops.

It took many partners to help meet the targets that the VCF2SC set for itself. The Ventura County Farm to School Collaborative is grateful for all the farms that supported this project, but most notably the Abundant Table, McGrath Family Farms and San Miguel Produce. Leadership members of these farms helped provide guidance and expertise in helping the VCF2SC source more local produce. Additionally, the produce distributor for the six participating districts, The Berryman Inc., was an integral part of the entire project. At the beginning of the grant, the Berryman, was not required contractually to provide the data on local sourcing that was demanded, however they did this. Now, as result of this grant, no matter who the produce distributor is for the collaborative, this information is required by the produce bid to be delivered to school food service Directors. Further, the collaborative continually seeks to source more Ventura County grown specialty crops from small to mid-sized farmers for the Harvest of the Month program and school salad bars. Distribution becomes the linchpin in this operation and the Berryman has been very flexible and fair with the new growers

the collaborative has identified to source specialty crops from. Without their support, it would have been much more difficult to achieve the performance measures.

Furthermore, tri-county partnerships have been critical in developing and implementing cross county farm to school trainings and effective resource sharing. Farm to School practitioners, such as educators, teachers, food service staff, farmers, community activists, and administrators from Ventura, Santa Barbara, and San Luis Obispo Counties participated in the two day, second Annual Growing Edible Education Symposium in October 14-15, 2016. As a result of tri-county partnerships, the VCF2SC will support San Luis Obispo in hosting the 2017-2018, third Annual Growing Edible Education Symposium.

Goals and Outcomes Achieved

The project's performance goal was to increase the amount of fresh, seasonal, locally grown specialty crop products consumed by students in Ventura County schools. Measurable outcomes included increased dollar volume of Ventura County and Southern California specialty crop growers selling their products to Ventura County schools, and increased number of participating schools and students reached.

The first activity completed in order to increase in dollar volume of local and regional specialty crops sold to Ventura County schools was to work with the produce distributor for the collaborative, to create a user-friendly system to track produce purchase data on a monthly basis. The project staff defined the parameters of this system to track specialty crop purchases within 150 miles of Ventura, California. The project staff narrowed the focus to solely Ventura County when it came to measuring the number of specialty crop growers selling to VCF2SC. The reason for this was that project staff could have direct contact with the specialty crop growers, and a greater capacity of building stronger partnerships. Once this system was in place, the operations specialist had baseline data to measure the outcomes over the course of the grant. Concurrently, the operations specialist worked with the Ventura County Ag Commissioners office to get access to the county's grower database. This information was essential in helping him develop sourcing plans for the 2015-2017 Harvest of the Month. This database contains contact information for all the growers in Ventura County, all with the acreage of each specialty crop they are growing. Much of the work that was then done by the operations specialist was calling and visiting farmers to assess whether they were willing and able to supply specialty crops to the six districts participating in VCF2SC. For the responsive farmers, an MOU between the farm and the produce distributor that clearly outlined the procedure and requirements of the Harvest of the Month purchase and delivery was signed. For the remainder of the grant, the operations specialist liaised with these farms and the distributor to help manage the logistics of pick-up and delivery of produce items to school sites across the county. This produce was then utilized in the cafeteria or the classroom either by a teacher or a nutrition educator. Throughout the duration of the grant, the operations specialist continued to work with the school food service directors, produce distributor, and other local growers in the county to increase the amount of specialty crops in the cafeterias across Ventura County.

The nutrition specialists team and the operations specialist addressed the second measurable outcome, increased number of schools and students reached by VCF2SC activities, through Harvest of the Month programs; development of a pilot school farm; Farmer in the Classroom programs; farmer videos; social media and e-newsletters; teacher and food service staff trainings; a VSF2SC mixer; and a regional Growing Edible Education symposium including two farm and school garden tours.

The goals for the project period were 1) Seventy five percent of fresh specialty crop products purchased by at least six to eight participating school districts sourced from growers in Southern California by the end of year 3; and 2) Fifty percent of purchases from within 150 miles and meeting minimum standards of Los Angeles Food Policy Council (LAFPD)'s Good Food Procurement Guidelines.

The data from the primary source, the produce distributor to the six participating school districts, was not able to provide meaningful data for the first goal (75% of fresh specialty crops sourced from Southern California), though they did provide an estimate that well over 75% of fresh specialty crops sold to the school districts is sourced from within the state of California.

For the second measure, 50% of fresh specialty crop purchases from within 150 miles: The distributor undertook an effort to identify and code purchases in order to track this data, which demonstrated that in each of the project years local purchases met and exceeded the 50% target. After extended investigation and discussion with the leaders of the Center for Good Food Purchasing (formerly a project of the Los Angeles Food Policy Council), it determined that project staff did not have the funds and the distributor did not have the data to enable to rigorously verify that the participating school districts' purchases met the Center's Good Food Purchasing minimum standards.

The performance measure for this grant was to increase the number and dollar volume of Ventura County and regional specialty crop growers selling their products to the VCF2SC and increase the number of participating schools and students reached. The project staff set a target that 50% of fresh specialty crop products purchased by VCF2SC would be sourced from within 150 miles. The baseline data set is from August 2014-May 2015. The project staff defined this as School Year 2014-2015 and measured the progress toward achieving the targets against this baseline for the proceeding school years, School Year 2015-2016 and School Year 2016-2017.

It is important to note that specialty crops are highly variable due to seasonality, weather, and market conditions. In particular, the unusually wet 2016-2017 winter year resulted in a significant drop in local specialty crop availability and purchases. On account of this, it is more reliable to measure the success of the project based on the percentage of the total dollar volume of specialty crops that came from within 150 miles of Ventura County. The baseline data for school year 2014-2015, showed that 56.68% of specialty crops came from within 150 miles. The following school year, 2015-2016, this increased to 63.55%, a 6.87% increase from the previous year. The final school year of the grant, 2016-2017, 59.51% of specialty crop purchases came from within 150 miles. This is a 2.83% increase from the baseline year.

The project resulted in participating schools purchasing nearly 60% of fresh specialty crops from local growers, totaling over $3.9 million in specialty crop purchases over the course of this project.

In addition to tracking purchases from within 150 miles, project staff also tracked purchases from growers within Ventura County. It was noted that there was a significant increase in the number of farmers selling to Ventura County growers and in total amount of produce purchased from Ventura County growers over the course of the project. Specialty crop purchases from Ventura County growers totaled more than $1.8 million over the course of the project.

Overall, through the combination of specialty crop purchasing for school meals and Harvest of the Month, Farmer in the Classroom, school farm and other nutrition education programs, the project reached a total of 107 schools and over 74,000 students in the six participating school districts, which collectively represent nearly half of the total school enrollment in Ventura County.

School Year	# of Ventura County Farmers Selling to schools
2014-2015	9
2015-2016	16
2016-2017	21

Beneficiaries

The two groups that benefited the most from the completion of this project's accomplishments were the specialty crop farmers and students of Ventura County. The specialty crop growers benefited because this project opened up a new market channel for them to sell their crops to schools. School cafeteria staff benefited as well by the farm to school trainings. For some of them, it was the first time they had any knife skill training or an introduction to the benefits of using local/in-season produce.

Ventura County specialty crop growers: Twenty one. Economic impact: School produce purchases totaling $1,836,058. A total of 67 specialty crop growers within 150 miles of Ventura County were involved in supplying the collaborative during the project. Economic impact: school produce purchases totaling $3,902,875.Ventura County K-12 students: 74,169 students based on 2015-2016 enrollments in six participating school districts.

Lessons Learned

One of the greatest lessons learned was around the challenges and benefits of county-wide collaboration. The benefits included introducing many more students to specialty crops and sharing and leveraging expertise, resources, strategies and learning from one end of the county to the other. Additionally, the collaboration made farmers more interested and willing to sell to schools because project staff was able to purchase a larger, more consistent volume of produce. The major challenge of county wide collaboration was that every school district was at a different place in its level of experience, resources, and engagement in Farm to School procurement, scratch cooking, and nutrition education, which meant that strategies, action plans, trainings and even assessment tools had to be customized for each individual school district and in some cases for individual school within a district. Ultimately the project staff concluded that although this was enormously resource intensive, the benefits of county-wide collaboration far outweighed the challenges. Going forward, the collaborative will seek to continue its role of cross-county coordination and sharing of learnings and expertise, while working with school districts to institutionalize farm to school programs and resources to meet their particular circumstances.

An unexpected result of implementing this project is that two of the project team positions turned into ongoing positions within two of the participating school districts, helping to carry the project's work and benefits forward. Another unexpected outcome was the formation of a local food hub pilot project which is seeking to create a mechanism for supplying not only local fresh produce to schools but also to provide lightly processed local specialty crop products such as carrot sticks and fresh-cut leafy greens for school salad bars.

Additional Information

Project materials and media can be found at the following links:
www.facebook.com/vcfarmtoschool.org
www.youtube.com/channel/UCWSo0WBwLsPvAmAz1q1qPOg
https://www.geesymposium.org

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
20	Community-Based Food Project in Underserved Sacramento Neighborhoods	
Grant Recipient: International Rescue Committee, Inc.	**Grant Agreement No.:** SCB14020	**Date Submitted:** December 2017
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Project Summary

Recently proclaimed "America's farm-to-fork capital," the Sacramento area is one of the most productive agricultural regions in the world, with nearly 8,000 acres of small farms generating $3.4 billion in sales. Although city policy mandates a transition to 20 percent, currently only 2 percent of consumed food is produced locally. Additionally, farmers aged 65 or older outnumber those under 35 by a ratio of nine to one, indicating an urgent need to support emerging businesses. Sacramento is home to diverse, multilingual communities - over 50 percent of residents are first, second, or third generation immigrants. A recent National Institutes of Health (NIH) study revealed that immigrants' health often declines after arrival in the United States, and a lack of access to culturally appropriate fruits and vegetables is often to blame. In other words, the retention of traditional diets high in fresh local produce is a critical health determinant for the majority of households in California. Furthermore, the food sector is a practical point of economic entry for new Americans, many of whom arrive with a strong background in fresh food production, distribution, or sales. Over the past few generations, newcomer populations have transformed the landscape of American cuisine, including clients of the International Rescue Committee (IRC), which resettles more than 7,000 refugees in the United States each year. Through improved land access, nutrition education, and business development programs, IRC's New Roots model has already had a dramatic impact on health and food access in urban low-income communities nationwide. By establishing a New Roots program in Sacramento, IRC aimed to create an education, training, land, and marketing infrastructure that will: 1.) Make it possible for diverse refugee households to continue to consume a healthy, culturally appropriate diet focused on fruits and vegetables; and 2.) Support the growth of economic networks based on the traditional agricultural/culinary practices and purchasing habits of global populations living as neighbors in urban communities.

This project is important and timely because over the past few years, Sacramento has become one of the city's most heavily impacted by the arrival of refugee and Special Immigrant Visa holders (SIVs) across the U.S. Last year, over 4,000 individuals were resettled in Sacramento, more than doubling previous years' figures. Studies have shown that populations of newly arrived refugees and immigrants face malnutrition due to a lack of nutrition education and misunderstanding of American foods, in addition to having lower-than-average incomes. With the growing number of refugee arrivals in Sacramento, programs designed to target and assist refugees were in great demand and very timely.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Market research, healthy food access, and specialty crop produce sales:
The IRC conducted market research among both individual low income refugee consumers and retailer markets to identify market gaps and barriers to access desired specialty crops, and inform production plans and methods to address existing market gaps and food access barriers among retailer markets and individual

consumers. The IRC interviewed 50 retailer markets to identify market gaps in specialty crops and better inform production goals. Specific in-demand crops by market type and retailer were identified, and detailed more below in the "Goals and Outcomes" section. The IRC partnered with leading research institutions, including the Middlebury Institute of International Studies at Monterey (MIIS), University of California at Davis (UC Davis), and the California Department of Public Health – Office of Refugee Health (CDPH) to conduct consumer market research and identify existing challenges and barriers that may affect access and consumption of healthy specialty crops among low income refugee households in Sacramento markets through surveys of 259 individuals and development of a community food map in Sacramento.

The IRC discovered there are distinct barriers and market gaps among consumers and market retailers. Both consumers and market retailers show demand for a variety of diverse specialty crops, including pumpkin greens, cowpea, and okra. An interesting discovery was that a significant market gap existed not just within the market availability of the specific crop or variety grown, but also the maturity stage of the crop when harvested or the part of the plant used for eating. For example, kuri pumpkins are available in many markets, but the leaves are not as many consumers from Bhutan prefer and India Market wants to sell. Cowpeas are prevalent in many markets as well, but as dried shell beans, not fresh green beans in pods, as many consumers from the Middle East prefer and Babylon City Market wants to sell. Similarly, the okra available in markets represented an acceptable variety, but are larger and more fibrous, whereas many consumers prefer the okra to be harvested earlier when it is smaller and tenderer. In general, refugee-desired specialty crops were largely underrepresented, as many existing markets were not familiar with and did not carry refugee-desired specialty crops and many conventional farmers did not grow such produce where many refugee consumers shopped, such as small ethnic markets. In this project, the IRC was able to identify the previously unknown refugee consumer and market preferences and link the two through production and selling of specialty crops. The IRC will continue to support production and sales of this previously unidentified and growing market niche to support refugee farmers and the improved healthy food access among low income refugee consumers.

The IRC provided market access, technical assistance and training, and land access to support the production and consumption of locally grown specialty crops by valued at $772,835. The value of produce grown by farmers and gardeners for household consumption was valued at $134,835. Market sales were valued at $638,000.

Education and training:
The IRC developed curriculum and administered trainings to support nutrition and food education among 1,349 newly arrived refugees and farmer education among 50 refugee farmers. Nutrition education workshops were administered weekly and included topics in nutritional health, U.S. food markets, diet-related illnesses, and culturally appropriate healthy diet composition. Farmer trainings were administered 1-2 times monthly and included topics on crop production, food safety, and business development.

Food production:
The IRC supported the production of specialty crops at 4 farms (1 IRC-operated, 3 independently operated) and 3 community gardens (2 IRC-operated, 1 independently operated). For all IRC-operated locations, IRC secured the land and developed the parcels for crop production, including preparing and amending the soil, building garden beds, and installing temporary irrigation. IRC assigned plots to individuals and provided technical assistance and training (detailed in "Education and Training" section above) to support production activities. The IRC supported 50 farmers and 60 gardeners who produced over 50 different specialty crops,

including chili peppers, eggplant, okra, and pumpkin greens that were grown most recently. The IRC will continue to operate the farm and garden sites and support farmers and gardeners growing crops on-site after the program period ends.

The overall scope of the project did not benefit commodities other than specialty crops.

This project received significant contributions from a variety of project partners over the course of the project: The California State Parks is the landowner of leased land and provided discounted land access and additional resource provision. Chefs' Harvest and Educational Foundation (CHEF) is a non-profit organization consisting of restaurateur business partners, which acted as retail market partners and supported marketing activities for farm. The City of West Sacramento provided permitting and regulatory support, and waived costly permitting fees required to support the initial farm launch. Soil Born Farms (SBF), University of California at Davis (UC Davis), USDA Natural Resource Conservation Service (NRCS), University of California Cooperative Extension (UCCE), and the National Center for Appropriate Technology (NCAT) provided support of farm training program, on-site farm demonstrations, and technical assistance. Middlebury Institute of International Studies at Monterey (MIIS), UC Davis, and the California Department of Public Health – Office of Refugee Health supported the consumer community food mapping and food access studies to better understand specialty crop food access barriers and inform potential interventions to improve access and consumption of specialty crops among low-income refugee and immigrant communities. UC Davis D-Lab supported on-farm technical analysis through design and development of farm technologies, including a produce wash station that was used for the on-farm demonstration of food safety practices and to support produce washing activities prior to selling to markets, and conducted a feasibility study on retrofitting a shipping container into a cold storage unit for produce storage. Private residents and business owners contributed in-kind support through donations to support farm storage, seeds, irrigation systems, compost materials, seeds, and volunteer time in excess of $30,000.

Goals and Outcomes Achieved

Market research, healthy food access, and specialty crop produce sales:
The IRC conducted market research among both individual low income refugee consumers and retailer markets to identify market gaps, existing barriers to access desired specialty crops, and inform production plans and methods to address existing market gaps and food access barriers among retailer markets and individual consumers.

Retailer market research:
IRC conducted surveys with over 50 different retailers to identify market gaps in specialty crops and better inform production goals. Purchasing partnerships were secured with 15 local retailer markers. An abbreviated list of top 5 crops identified by different market types is detailed below:

- Corner stores: strawberry, melon, carrot, onion, and tomato
- Restaurants: broccoli, chard, tomato, lettuce, and kale
- Ethnic retail markets: fava bean, parsley, cowpea, chive, and basil

Consumer market research + barriers to access:
IRC partnered with MIIS to conduct a study to identify the challenges and barriers refugees face in accessing and consuming fresh fruits and vegetables in existing Sacramento markets. Key findings included: many challenges and barriers refugees face upon arrival impact refugees' ability to access and consume fresh fruits

and vegetables they desire, including transportation, finances, childcare, language, confidence, and cultural familiarity. For example, many refugees are able to find certain culturally significant produce items in ethnic markets that are not available in mainstream grocery retailers, but it is often more expensive to shop at those small ethnic markets, which is a significant barrier for low income consumers enrolled in CalFresh benefits. Meanwhile, discount grocery stores have the best prices, but poorest availability of diverse specialty crop offerings.

The IRC partnered with and UC Davis and the California Department of Public Health – Office of Refugee Health identify to create a baseline study of the food security status and key stressors of refugee farmers and gardeners enrolled in the IRC program. Key findings included: food insecurity was identified among a majority (62%) of individuals surveyed, and key stressors included feeling a loss of cultural identity and difficulty accessing culturally significant fresh fruits and vegetables since coming to the U.S.

An abbreviated list of crops identified by refugee consumers as key market gaps include: eggplant (small round Indian variety), okra (small green Middle Eastern variety), cowpea (fresh green pods, not shelled), cranberry bean, pumpkin greens, chili (Nepali round variety), leeks, and melon (Afghan honeydew variety).

The production and consumption of culturally appropriate specialty crops is a significant determinant in refugee health and food security, and significant barriers exist that affect healthy food access. The IRC will continue to support specialization in producing culturally appropriate specialty crops in the farm and garden sites and address access issues through produce sales at locations that are within walking distance at affordable prices.

Education and training:
The IRC developed curriculum and administered trainings to support nutrition and food education among 1,349 newly arrived refugees and farmer education among 50 refugee farmers.

Farmer training:
The IRC developed farmer training curriculum provided training and technical assistance to 50 enrolled farmers, including 40 currently active farmers and additional waitlisted and independent farmers. The training program was administered year-round with 1-2 monthly workshops on topics including but not limited to: food safety, crop planning, market preparation, soil management, irrigation, farm safety, postharvest handling, and pest management. Workshops were provided with language interpretation to help ensure understanding among many English language learners.

Nutrition education and healthy food access training:
The IRC developed and administered nutrition and healthy food access workshops to 1,349 individuals on topics including, but not limited to: nutrition and healthy diet composition, role of food in diet-related illnesses, common processed foods in the U.S. new to many immigrants, how to read ingredient labels, where to find culturally appropriate specialty crops, and how to utilize CalFresh benefits in shopping. Workshops were provided with language interpretation to help ensure understanding among many English language learners.

Food Production:
The IRC supported production of specialty crops at 4 farms (1 IRC-operated, 3 independently operated) and 3 community gardens (2 IRC-operated, 1 independently operated).

Farm:
The IRC secured land and prepared the field for farming, including developing a lease, installing temporary irrigation, tilling and amending the field for planting. 40 individual farmers were assigned farm plots and produced over 50 different specialty crops across 4 seasons. The IRC supported additional production and marketing activities through technical assistance provision to 3 farmers on independent leaseholds.

Garden:
The IRC secured land and developed 2 community gardens to support household production and consumption of culturally appropriate specialty crops. IRC provided 60 refugee households with garden access through the 2 IRC-operated community gardens and referrals to a 3rd independently operated garden.

All outcomes were met during the project. Comparison of actual accomplishments with the goals established:

Outcome measure	**Goal**	**Actual**
**Number of individuals that received nutrition education	1100 = 400 per year * 2.75 years	1,349
**Total value of crop sales	$550,000 = $200,000 per year * 2.75 years	$638,000
**Number of farmer training program graduates	50	50
**Number of community garden participants	30-40	60
Number of retailers interviewed	40-50	50
Number of partnered market retailers	10	15
Number of consumers surveyed	250	259

**Outcome measures were long-term. Each of these outcome measures represented ongoing and longstanding activities that were completed over the course of the full program period. For example, nutrition education workshops were held on a weekly basis, and the number of individuals that attended those workshops over the 2.75 years was 1,349. Similarly, the total value of crop sales reflects sales activities that took place over 2 years.

Additional outcomes that were less quantitative include the following:
- Farmer training: develop new farmer curriculum and deliver trainings and technical assistance
- Farm development: secure land, develop lease contract, prepare field for planting, install irrigation and apply soil amendments, onboard farmers, and support production of 50+ crops on newly cultivated land
- Garden development: secured land, develop MOUs with landowners, prepare land for planting, install irrigation and build garden beds, onboard gardeners, and support production of 20 crops
- Food production: support the production of 50+ specialty crops grown by 110 individuals on 7 different farm and community garden locations that were used for both market sales and household consumption

- Market research: conduct market research with 3 university research partners among 50 market retailers and 259 consumers to identify gaps and barriers to accessing specialty crops

Key findings that support the program activities include:
- There are many challenges and barriers refugees face upon arrival that impact their ability to access and consume fresh fruits and vegetables they desire, including transportation, finances, childcare, language, confidence, and cultural familiarity. For example, many consumers are able to find certain culturally significant produce items in ethnic markets that are not available in mainstream grocery retailers, but it is often more expensive to shop at those small ethnic markets, which is a significant barrier for low income consumers enrolled in CalFresh benefits. Meanwhile, discount grocery stores have the best prices, but poorest availability of diverse specialty crop offerings.
- Food insecurity was identified among a majority (62%) of head of household farmers surveyed, and key stressors included feeling a loss of cultural identity and difficulty accessing culturally significant fresh fruits and vegetables since coming to the U.S., among others. All (100%) of surveyed farmers indicated the IRC program could provide benefits that would help address these issues. With this information, the IRC continued to support farmers in the production of culturally significant crops to support food insecurity and cultural preservation. The IRC will use this report to help inform and guide future activities and decisions and re-evaluate impacts in the future.
- An abbreviated list of 5 top crops is detailed below:
    - Corner store association: strawberry, melon, carrot, onion, and tomato
    - Restaurant: broccoli, chard, tomato, lettuce, and kale
    - Ethnic retail market: fava bean, parsley, cowpea, chive, and basil
    - Consumers: eggplant, fresh cowpea, okra, chili pepper, leeks

Beneficiaries

Direct beneficiaries of the program include:
1. Diverse, low-income communities in Sacramento seeking improved access to culturally appropriate specialty crops
2. Diverse, low income communities in Sacramento seeking farmer training and land access
3. Fresh food retailers and restaurants attracting customers based on locally produced and diverse cultural cuisines

The number of direct beneficiaries include:
1. 50 individual farmers who received farmer training, technical assistance, and land access to support the launch of a small farming business
2. 1,349 individuals who received nutrition and food education to support their ability to access culturally appropriate specialty crops in U.S. markets and understand diet-related health implications
3. 15 market retailers with partnership agreements to receive in-demand specialty crops
4. 60 households who received access to a community garden plot to grow in-demand specialty crops

Lessons Learned

The IRC learned many lessons through the course of the program period, including the following:
1. Land access – the IRC underestimated the time it would take to find, secure, and develop a new farm operation. Particular delays resulted from administrative timelines required to secure a land lease with the landowner (California State Parks) and install temporary irrigation materials.

2. Farmer development – the IRC underestimated the time it would take to adequately train new farmers and prepare them to sell specialty crops to market
3. Market interest: the IRC underestimated the level of interest many markets and restaurants have in partnering with the IRC and purchasing specialty crops grown on the IRC farm. At this time, the IRC has great market penetration and more business interest than can be fulfilled.
4. Farmer and gardener interest: the IRC was surprised at how many individuals were interested in participating in the community gardens and farm activities. Upon the first intake cycle, all available farmer plots were filled and a waitlist was created and has been in effect ever since. All community garden plots were immediately filled within one week of completing the garden construction. More land is needed to accommodate the large and growing interest.
5. Community support: this project received extensive support from private individuals and community partners, including donations, volunteer hours, technical assistance, research support, and market connections.

The IRC did not anticipate the delays in land access and farmer development, or the positive responses received from retailer markets, farmers and gardeners, and community partners. No significant unexpected outcomes or results were a direct effect of these occurrences.

Despite delays in land access and farmer development, outcome measures were achieved, though not as high or in the same manner as was initially envisioned. In the future, the IRC would include additional time at the beginning of the program period to find and secure land and develop the parcel to support crop production, including administrative times to support contract development and legal review of the land lease. The IRC would also extend the training window before farmers are ready to sell crops to market, since many farmers were not at an advanced enough level to successfully produce and sell crops in the beginning, despite reporting farming experience during intake.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
21	California Specialty Crops for California Kids	
Grant Recipient: Oakland Unified School District	**Grant Agreement No.:** SCB14021	**Date Submitted:** December 2017
Recipient Contact: Alexandra Emmott and Amy Glodde	**Telephone:** (510) 434-3334	**Email:** alexandra.emmottt@ousd.org amy.glodde@ousd.org

Project Summary

Though California is a rich source of agricultural products for the entire country, many of the leading California specialty crops were not reaching the Oakland Unified School District (OUSD) students in 2014. As a department serving almost 40,000 meals every day, Nutrition Services (NS) had an important opportunity to partner with local specialty crop producers to make positive systems changes, support student health, and promote the local economy and environment. In the past decade, the OUSD NS became a leader in school food reforms, which culminated in November 2012 when the Measure J bond was passed, $44 million of which was earmarked for food system infrastructure improvements including the construction of a new central kitchen. While this was a significant accomplishment, the bond did not fund the necessary research and planning to ensure a maximal benefit for the OUSD students and the local economy by producing meals centered on California specialty crops. To address this need, the OUSD NS undertook a menu redesign and staff training program to expand access to, and expand the market and marketability of California specialty crops. To increase access, the OUSD NS developed student-vetted recipes which highlighted California specialty crops, restructured the salad bar program to be sourced entirely from California, and researched an in-house produce processing program to reduce reliance on expensive and/or imported pre-cut fruits and vegetables. To expand the market and marketability of California specialty crops, the OUSD NS undertook a recipe testing and marketing program targeted at students and families, coupled with professional development for the OUSD staff.

The project expanded access to California specialty crops for over 37,000 students in the OUSD, 71% of whom qualified for free or reduced priced lunch under federal guidelines. Many students relied on school meals for breakfast, lunch, snack, and sometimes supper every day. NS strives to produce meals centered on local produce that are nutritious, student-vetted, and environmentally sustainable. The menu and salad bar redesign accomplished under this project significantly increased the volume of local produce (California specialty crops) served in the OUSD (39% increase between 2013 and 2017), a direct benefit to Oakland's students. The OUSD accomplished this transformation by substituting frozen imported produce for locally grown fresh produce in recipes and increasing recipes featuring California specialty crops on menus. As a result, $2.4M was directed to local specialty crop growers over the three year grant period, a direct benefit to both farmers and the local economy.

While the project was important because of the immediate accomplishments listed above, it was also important because of research and staff training, which will benefit the OUSD for years to come. The OUSD NS worked with The Community Alliance with Family Farmers (CAFF) to conduct a comprehensive feasibility study for in-house produce processing to reduce use of imported frozen vegetables and pre-cut fresh produce. The Local Produce Processing Feasibility Study, see Attachment 1 showed that in-house processing would allow the OUSD NS to take advantage of favorably priced local seasonal crops, which

could be processed, stored, and served year round. This study, along with the recipes developed ensured that the new Central Kitchen would maximally benefit students by producing cost-effective meals centered on California produce. Also, during the three year grant period, the OUSD invested 63 hours into professional development for frontline staff on new recipes, equipment, California specialty crops and seasonality. As a result, 100% of staff were able to correctly identify California specialty crops on the OUSD menus and 86% reported their knowledge had increased since 2013; it was expected that this staff knowledge will be sustained long term.

Finally, the project resources developed (recipes, cycle menu patterns, feasibility study, research, and surveys) were shared with partner school districts and the California Farm to School Network. This resource sharing was expected to have far reaching benefits to the California specialty crop industry because recipes and menu patterns developed as part of the program were transferable to any United States school district following the United States Department of Agriculture (USDA) meal pattern.

The project did not build on any previously funded Specialty Crop Block Grant program.

Project Approach

The project team underwent the following tasks in order to achieve the project's objectives:

Activities	Results/ Accomplishments
Expanding Access to California specialty crops in the OUSD	
Develop 15 new or modified entrée recipes and 15 new or modified side recipes (cooked vegetables, salads, composed fruit dishes) which highlight (over 50% by weight) California specialty crops – convene four focus groups with stakeholders to identify recipes.	Fifteen entrées and 21 side recipes were developed during the grant period. The entrée recipes included: pizza sauce, vegetable pizza, bean & cheese burrito, pinto bean taco, veggie nacho/taco meat, veggie chow mein, pasta sauce, veggie chili, pozole, bean tostada. Side recipes include: brussel sprout slaw, sweet mashed and mashed potatoes, peacmole (guacamole made with peas), baked beans, balsamic beets, delicata squash smiles, fiesta bean salad, brown rice lentil and garbanzo bean pilaf, red beans and rice, salsa, refried beans, black beans, edamame salad, cucumber and tomato salad, carrot salad, greek salad, spinach strawberry, taco salad, asian salad, and Cesear salad. Four staff focus groups were convened during to gather staff input on recipe development and implementation. These were helpful in modifying recipes to meet the individual facility operations. All recipes were over 50% by weight, California specialty crops. See Attachment 2 for examples.
Scale all recipes for bulk production and test recipe yields.	All aforementioned recipes (15 entrée and 21 sides) were scaled for bulk production and yield tested.

Activities	Results/ Accomplishments
Establish menu cycle which aligns with USDA meal pattern and maximizes use of California specialty crops.	Developing menu cycles with student preferences in mind was ongoing. Several new menu cycles were developed using the recipes and sides developed. It was anticipated that the OUSD would continue to develop menu cycles using all recipes and sides that were developed as the move was made into the new Central Kitchen. Additionally, new recipes would continue to be developed even after the grant duration had ended. These would include California specialty crops as students preferences change and menu cycles were developed based on seasonality.
Identify procurement sources for all California specialty crops and cost recipes.	Procurement sources were identified for all 36 recipes. 18 of the procurement sources were implemented. The remaining sources will implemented once the Central Kitchen has been opened in 2018.
Develop strategy and training plan to count California specialty crops in entrees towards USDA meal pattern.	California specialty crops that credit as protein (beans and legumes) were credited towards USDA meal pattern; whereas California specialty crops that credit as fruits or vegetables were only credited towards the meal pattern in side dishes.
Modify salad bar program to establish a "California Bar" which maximize use of California specialty crops and rotates seasonally, featuring appealing and culturally relevant options for students.	The modified salad bar recipes (100% seasonal and local California specialty crops) were developed and implemented in 2014 – staff were trained on three rotating seasonal recipes.
Include Harvest of the Month (HOM) promotion on all the OUSD Salad Bars four times per year, aligning with menu cycle. All HOM items will be sourced from a family farmer less than 500 acres and within a 250 mile radius of Oakland.	HOM was promoted on all Salad Bars four times per year (12 times in total). This helped increase student knowledge and preference for California specialty crops. Featured farmers included: Tomahawk Farms in Santa Maria, California (snap peas); Capay Organics, in Capay California (mandarin oranges); Coke Farms in San Juan Bautista, California (strawberries); Top 10 Farms, in Salinas, California (Persimmons).
Research, plan, and implement in-house fruit and vegetable processing for the new Central Kitchen to maximize use of California specialty crops and eliminate use of frozen vegetables sourced from outside California.	Local Produce Processing Feasibility Study, including the Central Kitchen and supply chain research findings, cost analysis, external sales survey. The study was completed in partnership with the CAFF between 2014 and 2017. The results were shared with School Districts in California and nationwide.
Implement Staff Development Program to train staff on new recipes, ordering procedures, and seasonal eating. Year 1 and 2 – one 7.5 hour training and three 4 hour trainings for cooks and managers; Year 3 – one 7.5 hour training and three 4 hour trainings for cooks, managers, and satellite leads.	Prior to the grant the OUSD offered minimal development and training hours for frontline staff. Through the course of the grant duration, the OUSD increased staff development and training. These trainings included menu production, hands on recipe creation and testing. These trainings also included information on the HOM promotions and salad bar improvements.

Activities	Results/ Accomplishments
Expanding the Market and Marketability of California Specialty Crops	
Peer-to-peer recipe testing with the OUSD students. Health For Oakland's People and Environment Collaborative (HC) Youth Action Board to facilitate four taste tests in Year 1 and Year 2.	The HC assisted with peer-to-peer taste testing during the summer of 2014 and 2015. During this time, 26 recipes were evaluated at ten school sites. Over 1,700 student votes/surveys were tabulated.
Design and implement marketing program to promote California specialty crops.	Marketing materials, including aprons, line tags, salad bar banners, and flyers, were developed and used to increase the OUSD community knowledge and preference for California specialty crops.
Design and implement "California Bar" marketing program for salad bars and quarterly HOM promotion.	Marketing materials were developed and used for the OUSD California Salad Bar and promotion of HOM.
Design and implement business plan for selling the OUSD processed California specialty crops.	The Local Produce Processing Feasibility Study was completed in partnership with The CAFF between 2014 and 2017.
Design and implement pre/post surveys for students and families to measure recognition and consumption of California specialty crops.	Surveys implemented in Fall 2015 and Spring 2017. Though an across-the-board increase in knowledge of California specialty crops was not demonstrated by surveys administered in 2015 and 2017, surveys showed a significant increase in positive school meal perception from 2015 to 2017 among both students that ate school lunch regularly, and parents with children at low income/high participation schools. These results reflected the OUSD's efforts to improve school meal quality and freshness.
Analyze current menu cycle and recipes for number of recipes and recipe frequency containing over 50% California specialty crops by weight; compare against new recipes/menu cycle.	Between 2013 and 2017, the number of recipes served that contained more than 50% California Specialty Crops increased by over 39%. Menu analysis from 2013 showed that 38% of recipes contained over 50% by weight California specialty crops. The 2017 analysis showed that more than 50% of current menu cycle recipes were over 50% by weight California specialty crops.
Collect and assess purchasing data to determine percent specialty crop purchases from California.	Purchasing data was collected monthly and analyzed biannually. Analysis showed an increase of 16% between baseline and 2017.

Activities	Results/ Accomplishments
Design and implement retrospective surveys for the OUSD frontline staff.	Sixty-five of the OUSD Staff completed a retrospective survey about their knowledge and communication of California specialty crops in May 2017. 100% of respondents correctly identified at least one local fruit or vegetable used in the OUSD recipes. Additionally, 100% of respondents stated their school used at least one promotional item to communicate/market California specialty crops to students. Staff were asked to evaluate changes in their own and the students' knowledge and behavior between 2014 and 2017. 86% reported their knowledge of California fruits and vegetables had increased during this period; 73% reported that the students' knowledge of California fruits and vegetables had increased; and 68% reported students' consumption of California fruits and vegetables had increased during this period.

This project did not enhance the competitiveness of non-specialty crops. All grant expenditures were tracked to ensure that grant funds solely enhanced the competitiveness of specialty crops. This project focused on shifting district purchases of non-California grown specialty crops to California grown specialty crops and increasing purchases of California specialty crops overall. All of the recipes created were comprised of over 50% by weight.

The project leveraged partnerships as follows:

- The HC: The HC's youth convened peer-to-peer taste tests of new recipes.
- Center for Ecoliteracy (CEL): CEL partnered with the OUSD to identify new recipes for development which highlighted (over 50% by weight) California Specialty Crops.
- The CAFF: The CAFF partnered with the OUSD to conduct a feasibility study for in-house processing of local produce at the OUSD's new Central Kitchen, establish a specialty crop local supply chain with area farmers via a Request for Information (RFI), and research future potential markets for external sales of local produce processed by the OUSD .
- Pacific Rim Produce: Pacific Rim Produce partnered with the OUSD to track and increase California specialty crop purchases.

Goals and Outcomes Achieved

Aggregate specialty crop purchasing data from the 2013-2014 school year was used as a baseline against which to compare each grant year. Data was collected and tracked monthly via sourcing reports prepared by the Pacific Rim Produce company. The data was analyzed biannually by the OUSD to assess progress towards increasing the OUSD purchasing of California specialty crops.

The OUSD made significant gains in local purchasing from 2013 to 2017. Between October 2014 and June 2017, the OUSD NS spent a total of $2,696,427.32 on California specialty crops. In the first two full project implementation years, purchasing of California specialty crops increased by 24.1%, with an increase in annual purchases by $188,893. The overall percent of the produce budget directed to California specialty crop growers was also increased from 55.02% to 64.98%. Though this achievement was slightly below target of a

50% or $200K annual increase, the overall gains were fairly significant given the delay in opening the Central Kitchen. These targets are expected to be met after first year the Central Kitchen has become operational.

Menu analysis was completed for baseline, mid-term and final by evaluating each recipe by weight, tallying weight and then calculating percentages for California specialty crop content. Individual recipe data was then applied to the OUSD's menu cycles using sample months in 2014-15 (baseline) and 2016-17 (comparison) to assess overall California specialty crop menu content. More than 300 recipes were evaluated.

The OUSD increased California specialty crop recipes by 39%. In the baseline menu analysis, 38% of recipes on the menu were at least +50% by weight California specialty crops, and by 2017, more than 50% of recipes were California specialty crop dense. These results exceeded the target of 20% by 19%.

Pre/post surveys for students and parents were designed and implemented to evaluate general perceptions of the OUSD meal program, knowledge of California specialty crops and seasonality, as well as average consumption of California specialty crops. Surveys were conducted in fall 2015 and again in spring 2017. Eight hundred and fifty students were surveyed at 13 diverse the OUSD schools in spring 2017 and baseline survey data was collected in fall 2015 from 670 students at nine schools. One hundred and fifteen parents were surveyed at 39 schools in 2017, a significant increase from 59 parents surveyed at 13 schools at baseline (2015).

The target 15% increase in knowledge of California specialty crops was not demonstrated by surveys administered to students and parents in 2015 and 2017. Results were likely impacted due to increased end-of-year apathy among students, and dramatically different demographics among parent respondents. Surveys showed a significant increase in positive school meal perception from 2015 to 2017 among both students that ate school lunch regularly (23% increase), and parents with children at low income/high participation schools (33% increase); results which reflected the OUSD's efforts to improve school meal quality and freshness. Surveys showed a decrease in average number of California specialty crops consumed by both parents and students between 2015 and 2017 (14% decrease for students and 28% decrease for parents.) These results were below the target 5% increase, but survey timing and parent demographics likely impacted these results.

Prior to the start of the grant, the OUSD offered 15 hours of professional development funded via a USDA Farm to School grant during the 2012-13 school year. Since then, over 60 hours of professional development covering more than 15 topics and 25 recipes were conducted. Overall, staff training increased by 90%; exceeding the target increase of 50% (see Attachment 3). Hours and attendance were tracked using sign-in sheets. The training investment in the OUSD frontline staff (primarily low-income women of color) not only allowed the OUSD to increase produce on the menus, but also empowered staff to recognize their important role in fulfilling the OUSD NS' vision to create an equitable food system for the Oakland community.

A retrospective survey was developed and implemented in May and June 2017 to measure staff's knowledge and communication of California specialty crops. Sixty-five the OUSD kitchen staff completed surveys regarding their knowledge of California specialty crops and materials used to promote these crops at school sites. Of the staff surveyed, 86% reported their knowledge of California fruits and vegetables had increased during this period; exceeding the target of 10% increase in knowledge.

The OUSD expected to make ongoing progress by continuing to increase California specialty crop purchases, recipes and menus, marketing, and staff training. This project will be sustainable beyond the grant because of its focus on system development, best practice and supply chain research, staff empowerment, and marketing. The menu structure and recipes will be used long-term. Also, because the project leveraged previously committed bond measure funds, it will maximize the impact of facilities improvements by recommending viable models for in-house produce processing and supply chains, with an option to generate future income through the sale of processed produce.

Outcome	Target	Baseline	Progress to Date
Increase purchases of California specialty crops.	50% increase from baseline or $200K per year.	2013-14 school year (Oct-Sept): $782, 265 purchased and 55.02% of total produce spent.	October 2014 – September 2017: $2.7 Million purchased and 64.98% of total produce spent. 16% increase from baseline.
Increase quantity of California specialty crops on the OUSD cycle menus.	20% increase from baseline.	2013-14 school year: 38% of recipes on menu are California Specialty Crop dense (50% or higher by weight).	2016-2017 school year: 53% of recipes on menu are California specialty Crop dense (50% or higher by weight.) 39.5% increase from baseline.
Increase knowledge of and consumption of California specialty crops among the OUSD students and parents.	15% increase in knowledge from baseline and 5% increase in consumption from baseline.	2015 student survey results: 47% of students answered California specialty crop questions correctly. 2015 parent survey results: 53% of parents answered California specialty crop questions correctly. 2015 student reported average consumption: 2.9 California specialty crops the day prior. 2015 parent reported average consumption: 5.9 California specialty crops the day prior.	2017 student survey results: 40% of students answered California specialty crop questions correctly. A 17.5% decrease from baseline. 2017 parent survey results: 40% of parents answered that California specialty crop questions correctly. A 32.5% decrease from baseline. 2017 student reported consumption: 2.5 (California specialty crops consumed the day prior) 14% decrease from baseline. 2017 parent reported consumption: 3.5 (California specialty crops consumed the day prior) 28% decrease from baseline.
Increase positive school meal perception among students and parents	No target set.	2015 student survey results: 39.3% of students who regularly ate school meals answered school meal perception questions positively 2015 parent survey results: 36% of parents with students at low-income schools answered school meal perception questions positively	2017 student survey results: 48% of students who regularly ate school meals answered school meal perception questions positively, 23% increase from baseline. 2017 parent survey results: 48% of parents with students who attended low-income schools answered school meal perception questions positively, 33% increase from baseline.

Outcome	Target	Baseline	Progress to Date
Increased professional development hours for the OUSD frontline staff.	50% increase from baseline.	2013-14 school year: 15 hours professional development for staff	2016-17 school year: 28.5 hours professional development for staff 90% increase from baseline
Increase the OUSD frontline staff knowledge of and communication about California specialty crops.	10% increase	Retrospective survey administered in May and June 2017, covering 2014-2017	86% of staff surveyed reported their knowledge had increased since 2014, 76% above target.

Major successes of this project included:

- Development of 36 innovative and healthy school lunch recipes that were greater than 50% by weight California specialty crops. Recipes were student-vetted, credited to the USDA meal pattern standards, and were scaled for bulk production.
    - Implementation of 18 recipes on the OUSD menus at 85 schools and 20 child development centers.
- Increase of 39% in California specialty crop content of the OUSD school menus between 2014 and 2017.
- Conversion of the OUSD salad bar to seasonal program via development and implementation of three seasonal salad bar recipes.
- Purchase of 32 Robot Coupe food processors to enabled the OUSD kitchens to process fresh, local produce for recipes and salad bars.
- Over $2.7 Million spent on local produce in three years.
- Over 60 hours of professional development for the OUSD staff over three years.
- Twenty-six student taste tests (see Attachment 4), which tabulated over 1,700 student votes.
- Increase in positive school meal perception from 2015 to 2017 among both students that ate school lunch regularly (23% increase), and parents with children at low income/high participation schools (33% increase.)
- Published Local Produce Processing Feasibility Study summarizing central kitchen and supply chain research findings, cost analysis, and external sales survey.

Beneficiaries

The CAFF and the OUSD partnered to research and write a Feasibility Study for in-house produce processing in the new central kitchen. The findings were beneficial to both the OUSD and the CAFF; and could be applied to any district currently processing produce or exploring processing options for future. The study was released to over 30 school districts and partners as an initial "preview" and was fully released and promoted in late 2017, on the California Farm to School Network's listserv and the CAFF's blog, as part of back-to-school 2017.

The HC, an Oakland-based social justice and youth development organization, benefited from the student taste tests conducted in 2015 and 2016 as part of the OUSD's project. The taste tests were a professional

development and work opportunity for members of HOPE's Youth Action Board and helped educate and inform youth about school meals, health, and local produce.

Between 2014 and 2017, the OUSD invested over $2.7 Million into the local economy by purchasing specialty crops grown in California, mainly within a 250 mile radius of Oakland. In just two years, the OUSD allocated an additional 16% of its produce spend to local growers. This not only boosts the local economy, but ensured students in Oakland had access to fresh, locally grown fruits and vegetables at all meals. The OUSD expected to build upon this investment as the food services moved into the new Central Kitchen in 2018. Research conducted in partnership with the CAFF as part of the Local Produce Processing Feasibility Study, demonstrated the potential to shift up to $500,000 annually to local growers. Sixteen farms and aggregators, representing a total of 55 items available locally, responded to the OUSD's Request for Information in 2016. Over 100 local California farms were represented by farm and aggregator respondents, at least 90 of which were family farms, which demonstrated the tremendous interest among local growers in selling produce to the OUSD.

Lessons Learned

The OUSD learned several important lessons:

- Despite widespread stigma associated with school meals, improving both student and parent perceptions of school meals with the addition of more fresh produce was possible within a short period of time.
- Significantly increasing produce on all menus (39% in three years) was made possible using existing facilities and equipment through creative recipe development, staff training, and vendor partnerships.
- The OUSD NS staff learned from training provided and saw firsthand the positive impact menu changes had on students: 86% reported an increase in knowledge since 2014; 73% reported that the students' knowledge had increased since 2014; and 68% reported that the students' consumption of California specialty crops had increased since 2014.
- Surveying over 1,600 students and parents at more than 60 sites was challenging and required precise methodology and experience. (See below for an expanded discussion)
- Very few institutions in California and nationwide were processing produce in-house, even if they had the capacity to do so, hence there were few best-practice production models from which to draw in this area.
- Produce processing equipment was widely variable in capacity and ability. Extensive research was necessary before selecting processing equipment.
- Research confirmed the assumption that in-house processing would save money and increase local produce options for some produce items, while for other items, it was found to be more cost-effective to purchase pre-processed items.
- Local growers were overwhelmingly interested in selling produce to the OUSD - over 30 growers responded to the OUSD's Request for Information.

The OUSD's most significant implementation challenge was the delay in opening the Central Kitchen and Instructional Farm, which was originally scheduled to open in summer 2016 (project year 3), and was re-scheduled to open in 2018. While the project team was initially anxious about achieving all project outcomes without the Central Kitchen in place, the unexpected outcome as a result of this delay was the project team's ability to successfully implement the project using existing facilities and equipment. In three years, the

OUSD increased spending on local California produce by 16% and increased the California specialty crop content of menus by 39%.

The student and parent survey results generated through this project were disappointing: neither knowledge nor consumption of California specialty crops was shown to have increased among parents and students surveyed in 2015 and 2017. However, surveys showed an increase in positive school meal perceptions among both students that ate school lunch regularly, and parents with children at low income/high participation schools; results which reflected the OUSD's efforts to improve school meal quality and freshness during this time. The project managers suspected that these poor results may have been a result of flawed survey methodology as different groups of students and parents were surveyed in 2015 and 2017, and surveys were administered at different times during the school year. "I don't know" responses were significantly higher among students surveyed in spring 2017, suggesting increased end-of-year apathy. Also, parents surveyed in 2015 had higher average income than parents surveyed in 2017, and this demographic variance likely skewed results.

In retrospect, the process of surveying over 1,600 people across 60 plus schools in two years was somewhat beyond the OUSD's capacity. To better measure changes in perceptions, knowledge, and consumption, grantees should consider contracting an evaluator specializing in this type of assessment or conducting smaller, more meaningful focus groups with stakeholders to assess project impact.

Additional Information

See attachments 1-4.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
22	Farm to School Project	
Grant Recipient: North Coast Opportunities, Inc.	**Grant Agreement No.:** SCB14022	**Date Submitted:** December 2017
Recipient Contact: Terry Logsdon	**Telephone:** (707) 994-4474 ext. 127	**Email:** tlogsdon@ncoinc.org

Project Summary

Lake County (population 63,983) is scenically beautiful, but suffers economically. At the beginning of this project, unemployment stood above 12 percent, the poverty rate was 24 percent, the median household income was only $38,147, and 71 percent of students participated in free school meal programs. By 2015, that participation rate had risen to 73.3 percent. Health outcomes are dire as well, placing Lake County at 57th overall, worse than all but one other California county, which does not report. Lake County rose to 56th out of 58 counties this year, the first upward trend in over a decade. While most local schools reported to staff that they had policies in place prioritizing use of local produce in school meals, they did not, although many were purchasing some specialty crops from local farmers. However, efforts to expand farm to school activities face numerous barriers. Specifically:

- Most fruits and vegetables currently used in school meals were purchased from food service companies in pre-prepped and packaged forms.
- Food service staff lacked training in using field-fresh produce and time to process it.
- School kitchens lacked kitchen supplies and adaptations to facilitate prep and processing.
- Farmers needed information on school produce needs and purchasing policies.

North Coast Opportunities, Inc. (NCO) has worked with communities to reinvent local food systems since 2001, generating increased specialty crop production, greater demand for local fruits and vegetables, and thriving farm to school programs. Based on former farm to school programs NCO operated in neighboring Mendocino County, this project increased utilization of specialty crops by:

- Assessing needs and purchasing items to support preparation, storage, and processing of specialty crops.
- Training food service staff in best practices for incorporating specialty crops into meals, menu planning, and on-site prepping.
- Working with farmers to help them understand institutional market needs and purchasing policies, developing market relationships with schools, and planning production to meet school needs.
- Training youth to prep, process, and preserve specialty crops during the summers.

With support on the national and state level, coupled with growing specialty crop production in Lake County, this project was able to raise not only the awareness of the impact farm to school can make in the lives of children, but the positive impact financially it can make for local specialty crop producers who tailor their production to meet the needs of schools. Most importantly, with national and state-level resources in place, the local school districts have multiple ways of finding support to improve the quality of meals they serve to students, increase participation in school meals, and ideally – help improve the health outcomes for students in Lake County.

This project built upon 2011 Specialty Crop Block Grant Program Project 46: *North Coast Opportunities Farm2Fork Project.* Farm2Fork provided training and support to Mendocino County producers, schools, and

wholesale buyers to increase local specialty crop purchasing in Mendocino County and to increase the number of specialty crop producers selling to local markets in Mendocino County. The Farm2Fork model provided some of the structure that was subsequently replicated in neighboring Lake County through the Lake County Farm to School Project.

This project also built upon 2013 Specialty Crop Block Grant Program Project 5: *NCO Food Hub Project.* Working with local specialty crop producers, the MendoLake Food Hub created a distribution hub that facilitates more efficient aggregation, processing, distribution, and marketing of specialty crop produce, increasing the efficiency of marketing to local schools and supermarkets.

Project Approach

A press release announcing the kick-off of the project was released to local media with an estimated circulation of over 12,000 reaching nearly 20% of the population of Lake County. Additionally, the announcement was distributed by project partners in member newsletters, social media, websites, and more.

Monthly meetings of Project Manager (PM) and participating school food service directors (FSDs) were scheduled, and a data collection plan for specialty crop purchases was implemented.

A Training Consultant (TC) completed the kitchen assessments at all kitchens in five school districts and held one round of trainings at four of the districts. Two rounds of in-kitchen trainings were completed, as well as a hands-on salad making workshop at the 2016 Feeding Our Future all school food service staff training.

To introduce FSDs to local specialty crop producers, a farm tour was held in 2015, allowing FSDs to meet the farmers, discuss produce needs, and build relationships. The farmers were able to hear directly from FSDs their concerns over size, quality, and most importantly, quantities each kitchen would need. It was through this farm tour that the FSDs learned that there were very few specific items grown in a quantity at an affordable price that they could purchase from Lake County farms – but they committed to do so. In 2016, the Kelseyville Unified School District (KUSD) could not attend the Feeding our Future event as their district was still in summer school session. Therefore, a farm tour for their entire school food service staff (nine) was arranged. This was very successful, as it allowed not just the FSD to meet farmers and see where their local produce was coming from, but because the school food service staff work together on a daily basis, they were more comfortable asking difficult questions and describing their challenges to the farmers. The PM would recommend taking entire school food service staff teams on farm tours instead of just all FSDs in a county.

The primary specialty crops schools purchase locally include apples, pears, tomatoes, and winter squash. Winter squash of all varieties are grown in Lake County in abundance. However, it was not a specialty crop that schools had purchased whole and unprocessed, except for one district (who only made soup with it). Thanks to the purchase of knives and sharpeners, in-kitchen trainings in 2016 and 2017 focused on developing recipes and training staff how to quickly and easily utilize this abundant crop, and all school districts have added these recipes to the school menus, and winter squash is now one of the Harvest of the Month (HOTM) selections, and will continue to be promoted in schools.

In-kitchen trainings were held three times in each participating school district and focused on knife skills, learning to use the kitchen supplies purchased, recipe development focusing on utilizing the HOTM selections (all of which are field-fresh specialty crops), and taste-testing the recipes. What was unplanned, is that with

each training, staff grew more comfortable using the kitchen supplies and preparing field-fresh produce, which allowed them to continue identifying additional supplies needed. Therefore, purchasing additional kitchen supplies has been ongoing throughout this project. For example, several schools initially said they would never need a salad spinner decided by year three that they did need one for the kale they are now purchasing.

Trainings for specialty crop producers focused on food safety, working with institutions, and production planning. In 2015, farmers toured the wholesale market in San Francisco, then at an all-day workshop learned about GAP (good agricultural practices) and selling wholesale. In 2016, specialty crop producers participated in an all-day workshop on "Wholesale Success: A Farmer's Guide to Food Safety, Selling, Postharvest Handling, and Packing Produce," which was co-sponsored by the University of California Hopland Research and Extension. Also in 2016, an all-day conference was held with workshops on topics such as learning how to use amendments on your farm, farm financing, and getting ahead of the Food Safety Modernization Act. In 2017, another conference for farmers was held with workshops on keeping crop records, composting techniques, drought resistant crops, value added wholesale; which brought together specialty crop producers and institutional buyers that helped to form relations and expand the market reach for Lake County farmers. In total, about 15 Lake County specialty crop producers attended these workshops.

One of the difficulties has been coordinating collaborative purchases of specialty crops directly from producers. The new MendoLake Food Hub, which aggregates specialty crops from Lake and Mendocino Farmers, and delivers, had what the FSDs felt like a confusing ordering system for the schools. The MendoLake Food Hub provided one-on-one training with each FSD at the beginning of year 3. Another concern was identifying which box of produce came from which farm. Thanks to the purchase of new supplies, the nodes where Lake County specialty crop producers drop-off their produce will be equipped with label printers that address this issue. All FSDs are committed to ordering via the MendoLake Food Hub on a regular basis with the start of the 2017/2018 school year.

Outreach and education to promote local specialty crops in school meals was assisted by the purchase, distribution, and installation of white boards with "farmer cards" that the school cafeterias used to update what was purchased locally and promote which farm it was from. Additionally, through the partnership with the Lake County Public Health, which implements the HOTM curriculum in all elementary schools, the monthly presentations that teachers use before giving a taste of the specialty crop highlights the farm the produce came from.

During the project time, the PM attended two California Farm to School Conferences, presented at one of them about the project, and attended the National Farm to Cafeteria Conference with one FSD. All three of these conferences were educational, informative, and inspirational on expanding ways to incorporate locally grown specialty crops into school meals.

In the summer of 2016, KUSD hired 20 youth, via a summer youth jobs program, throughout the summer to maintain the school gardens and harvest produce. Then in the KUSD central kitchen, they learned to clean and process it for storage to use during the upcoming school year. They harvested and processed a total of 562 pounds of specialty crops, preserving 517 pounds for future use, and utilizing 45 pounds in summer meals. KUSD originally planned for the youth jobs program for three years, however year 1 did not occur due to lack of staffing, and year 3 did not occur due to the summer program being outside the grant period.

All trainings focused on specialty crops, all kitchen supplies purchased are for use in preparing and processing specialty crops, and each FSD signed a statement that they would only use the supplies with specialty crops. (See attachment A).

There was a considerable amount of staff turnover and organizational changes with initial project partners, as well as forming new partnerships that had great impact.

- Upper Lake Union Elementary School merged with the High School District, creating a larger opportunity to serve more students in that district. The FSD at the elementary school became the FSD for the new Upper Lake Unified School District and was deeply committed to the project, which she was able to implement district-wide.
- Konociti Unified School District applied for and was awarded a Farm to School Planning Grant from the United States Department of Agriculture (USDA) during year two of this project, which allowed them to put policies and procedures in place to institutionalize Farm to School in their district.
- KUSD had a change of FSD late in the first year, which reduced their capacity to participate in the project. However, they were able to complete all of their committed goals of the project and continue to commit to farm to school.
- Middletown Unified School District had a change of Superintendent early in the first year, and then was greatly affected by the 2015 Valley Fire, which was declared a national disaster; Lake County is still a declared National Disaster area. This district was not able to participate since early year 2.
- The Lake County Farm Bureau had a change of Executive Director after a lengthy search. They remain supportive of the project and have always disseminated information to their member via newsletters.
- Farmer/owner of Leonardis Organics experienced a massive crop loss due to flooding in year 1, then suffered a health set-back in the spring, so did not plant summer crops. Their focus shifted to managing and planting certified organic walnut orchards instead of producing other specialty crops.
- Lake County Public Health's SNAP-Ed program committed to purchasing locally-grown specialty crops for their HOTM program, which serves a taste of a different specialty crop each month to all qualified elementary school students (schools with more than 51% free and reduced lunch rates). Through this commitment, NCO created a HOTM calendar that reflects what is grown in Lake County each month. In addition, in year 3, the SNAP-Ed Director formed the “Eat Well Lake County” collaborative to bring together HOTM providers/promoters in other agencies (NCO and Lake Family Resource Center) to extend HOTM education to the community.
- Lake Family Resource Center's Be Fresh program serves families who qualify for SNAP by creating healthy recipes focused on specialty crops and serves tastes of these recipes at grocery stores, food pantries, and more. In just January – May of 2017, they served 600 tastes at food pantry distributions and 556 tastes at grocery stores – tastes which included the recipes either developed by NCO or from the USDA website.

Goals and Outcomes Achieved

To ensure that purchase of local specialty crops increased in the participating school districts, the PM provided training and opportunities for FSDs to learn procurement rules, take FSDs on a tour of local farms to meet the farmer in person and discuss future purchasing needs, get FSDs signed up to local farmer email lists of product availability, and provide training on how to purchase via the MendoLake Food Hub.

In order for school food service staff to adequately process, prepare, and store field-fresh specialty crops, the PM provided supplies for school kitchens that would enable staff to handle fresh produce quickly, as well as provide a series of trainings on how to use the kitchen supplies, recipe development that featured specialty crops, and stipends to attend the trainings to increase participation in the trainings. FSDs were also able to attend conferences such as the National Farm to Cafeteria Conference, the California Farm to School and Garden Conference, the North Coast Regional Farm to School Network Conference and webinars, as well as a school garden training. Additionally, a summer youth training program was completed that taught 20 students how to plant and harvest specialty crops from school gardens then bring it to the school cafeteria to clean, process, and store the crops for use in school lunches throughout the school year.

It was planned and anticipated that school FSDs would be able to track specialty crops separately from other food items in order to establish the amount of locally grown specialty crops they had purchased. Although the FSDs initially signed on to do that, it immediately became apparent that it would be impossible – they would have to create an entirely separate and manual process that would be extremely vulnerable to mistakes. Therefore, FSDs reported quarterly on the amount of food purchased and the amount of local specialty crops purchased.

The most challenging aspect of the project was to increase the capacity and number of specialty crop producers. Numerous trainings and workshops were offered free of charge or at a nominal fee for farmers on how to work with schools, food safety requirements, delivery options, planting schedules, and much more. If a farm could not hire enough qualified farm hands, they couldn't ramp up to meet demand. Lack of qualified farm labor remains a major stumbling block in Lake County, and has only gotten worse throughout the project period.

The proposed project outcomes, and the extent to which they were achieved, are discussed below.
Measurable Outcome #1: Purchase of local specialty crops will increase (goal), thus increasing consumption by local students. Schools will increase expenditures on local specialty crops by 100% (target) from 15% of produce budget. Lake County schools do not track a separate “produce budget” from all food items, (to do so would require manual tabulations of each individual invoice, and all FSDs stated they do not have the time, and unintentional errors and omissions would occur). Instead, the percentage of the total food budget vs. purchase of local specialty crops was tracked (See Attachment B). Therefore, the PM and FSDs tracked percentage of locally grown specialty crops purchased of entire food budget, and used the 2013/14 school year as the benchmark. The performance measure, increasing the amount of locally grown specialty crops by 100% by year 3 was maintained. However, the overall average at end of project was a 75% increase without Middletown, or a 60% increase with Middletown, who did not participate.

	2013/14 Benchmark	2014/15 Project Year 1**	2015/16 Project Year 2	2016/17 Project Year 3	Total
Kelseyville	8.00%*	8.00%*	3.00%*	1.00%*	-100%*
Konocti	1.00%	1.00%	2.00%	4.00%	100.00%
Lakeport	3.00%	3.00%	3.00%	2.00%	0.00%
Middletown	0.00%	0.00%	0.00%	0.00%	0.00%
Upper Lake	1.00%	1.00%	5.00%	5.00%	300.00%

*Kelseyville – 8% does not include specialty crops from school gardens, which FSD estimates that if paid for, would raise percentage to 10%, however, it also includes specialty crops purchased for use in catering programs outside of school meal programs. Therefore, there is no way to determine an accurate benchmark. The incoming FSD could not gather former paperwork to determine an actual number.
**2014/15 School year is missing first quarter reporting as project had not yet started.

Measurable Outcome #2: Number of specialty crop producers with the capacity to sell to the institutional market will increase (goal), by 150% (target) from the current 10 vendors. Six of the initial 10 had gone out of production/retired before the project began. Although the benchmark at the beginning of year 1 (benchmark) actually was four farmers, the PM had hoped to have at least 10 farmers by the end of the grant with the capacity and training to work with schools. The Lake Farm to School project has been working with nine farmers in Lake County and one food hub that represents over 30 farmers in Lake and Mendocino Counties, therefore, the original performance measure of 25 has still been met. While this outcome was not primarily addressed directly through the Lake Farm to School Project as training and technical assistance was primarily being provided by the Food Hub Project. Currently, the number of vendors selling through the MendoLake Food Hub has risen to 32 farmers, representing an increase of 220%, not including the Lake County farmers that do not participate in the food hub, which includes an additional five farmers, for a total of 37.

Measurable Outcome #3: Increase skills and knowledge of food service staff (goal), by providing them with a range of trainings. On average, skills and knowledge will increase by at least 25% (target), assessed by retrospective pre/post testing conducted at the Feeding Our Future all-county training, as well as in-kitchen trainings (performance measure and benchmark). According to training evaluations, overall gains in knowledge saw an increase of nearly 38%, with 59% of school food service staff reporting increased gains in knowledge. Food service staff that participated in trainings were asked to complete assessments of their experience, including assessing how much they learned. Results of these assessments can be seen in Attachment C.

Year 1: Surveys were not collected during Year 1 as no trainings occurred in the first year due to setbacks in securing a Training Consultant, and then due to the series of devastating wildfires impacting Lake County in 2015.

Year 2: Surveys collected after the first round of “Mini Feeding Our Future” in-kitchen trainings (held January – April 2016 because the larger event had to be cancelled three times due to wildfires) and responses to surveys collected after the Feeding Our Future all-staff training (in July 2016) showed that participant knowledge increased overall, and for all of the training topics. The assessments in Attachment C show aggregate pretest results, aggregate posttest results, percent change, and the percent of participants that reported a gain in knowledge. For questions 6-8, those participants who had benefited from in-kitchen trainings prior to the event were asked to report their knowledge gain. Note that some questions were not answered by all respondents. The highest possible rating = 5.0.

Additionally, during year 2 the program surveyed participants in the second round of school-based in-kitchen trainings. As seen in Attachment C, for the first five questions on the survey, participants used a 5-point scale (1=did not learn anything new, and 5=learned several new ideas) to rate the extent to which they learned from each component of the training. As the following table shows, the overall training as well as each of the five training components were all rated highly by participants, with the lowest rating going to the “knife skills”

module and the highest rating to the "how to use/expand farm to school" module. All but four of the respondents said they would definitely return for future trainings, and those four thought they would "maybe" return.

Year 3. During year 3, the program again surveyed participants after two rounds of school-based in-kitchen trainings. As the final assessment in Attachment C shows, participant knowledge increased overall, and for each of the topics.

Successful outcomes of the project include:

- The smallest school district in the project, Upper Lake Unified School District, has increased their purchase and serving of locally grown specialty crops by 300%.
- The largest school district in the project, with the highest rate of free and reduced lunch qualified student (85.9% in the 2015/16 school year), Konocti Unified School District, has written a Farm to School implementation plan and highlights the HOTM selection each month on their school menu. (See Attachment E). They also host the FoodCorps Service Member in their district to work with elementary schools in taste-testing of specialty crops, recipe development highlighting locally grown specialty crops, and school garden development.
- The major farm to school producer, Seely Farm Stand, has expanded production enough to hire another full time farm hand, tailors crop production to coincide with the school calendar, and now is a top seller via the MendoLake Food Hub.
- Over 30 Lake and Mendocino County specialty crop producers have received training on how to successfully sell their produce to schools.
- The MendoLake Food hub now has the capacity to comply with individual farm tracking that is required by schools thanks to purchase of equipment that allows printing of labels for each case ordered, instead of just one invoice from all farmers.

Beneficiaries

- Specialty crop farmers: Through direct sales to schools and partnership with the MendoLake Food Hub, local specialty crop producers benefitted from a variety of training opportunities and by having the opportunity to develop market relationships with local schools. At least 25 farmers increased their capacity to market specialty crops to schools and other institutional buyers. One participating farmer increased sales enough to hire an additional full-time farmhand. Although schools are just beginning to increase their purchase of local specialty crops, if just $1 was spent on local food for each of the 8,959 public school students in Lake County per month throughout the school year, those purchases would generate at least $80,631for local specialty crop producers.
- Students: Lake County's depressed economy means that many students do not receive the nutrition they need at home. During the 2015-2016 school year, three out of four (75.7%) students were enrolled in the free and reduced price meal program. Improving school meals through the utilization of local specialty crops can increase student consumption of these healthy foods. More than 7,450 students had increased access to local specialty crops and 3,234 participated in HOTM taste tests.
- Schools and food service staff: Food service programs benefitted from upgrades and training tailored to each district's needs and situation, building their capacity to utilize local specialty crops in school meals. Thirty-six food service staff working in 15 schools in four school districts benefitted from training delivered through the project.

Lessons Learned

The major lesson learned was that everyone – students, schools, parents, community members, stores, restaurants, and more – is excited about farm to school and farm to table. They want local produce, to know and support their farmers, have local produce served to their children at school, and have farmers' markets in their own community. However, there are not enough farmers to meet the demand, and then if a farm can meet the demand, schools and other institutions balk at the prices. When that hurdle is overcome (primarily by purchasing at peak of season then processing and storing for future use) it is a win-win.

Another insight is that if the idea isn't getting traction or support, be open to where the momentum is. For this project, it was collaborating across programs and organizations to promote HOTM with a locally grown/seasonally available calendar. Start with HOTM and go from there. Additionally, getting the commitment of HOTM providers to purchase local specialty crops is a great opportunity for local farmers to have a secure market opportunity.

One major unexpected outcome was the synergistic efforts across agencies and programs to promote HOTM not just at the schools, but also out to the community. In year 1, the PM brought together all HOTM providers in Lake and Mendocino Counties, the MendoLake Food Hub manager, and local farmers to create a HOTM calendar that reflected what grew locally that farmers could provide in quantity (See attachment D). Armed with a calendar that reflected seasonal and local specialty crops, the PM garnered the support of the HOTM provider in Lake County to source all specialty crops via the MendoLake Food Hub.

Therefore, through this project:

- All elementary students in Lake County get a taste of a locally grown specialty crop, from a local farm, and learn about a local farmer each month.
- One participating district highlights the HOTM selection each month on their school menus, (See Attachment E), other participating districts use HOTM cling stickers on their salad bars to denote the HOTM selection.
- The Partnership to Improve Community Health program utilized recipes from this project, and created recipe cards highlighting HOTM selections and are distributed at local grocery stores, and encourages area restaurants to utilize HOTM on their menus. (See attachment F).
- The Lake Family Resource Center’s Be Fresh program offers HOTM recipe taste testing at local food pantries and grocery stores.

It was planned and anticipated that school FSDs would be able to track specialty crops separately from other food items in order to establish the amount of locally grown specialty crops they had purchased. Although the FSDs initially signed on to do that, it immediately became apparent that it would be impossible – they would have to create an entirely separate and manual process for each and every invoice for different vendors that would be extremely vulnerable to mistakes. The PM would encourage others to work in-depth with FSDs and their vendors to develop a system for tracking. Having the relationship with vendors that are outside of the scope of the project may be key.

Additional Information

See Attachments A-F.

USDA Project No.:	Project Title:	
23	Improving Nutrition and Increasing California Specialty Crop Sales: Implementing Collective Buying in K-12	
Grant Recipient: The Regents of the University of California, Santa Cruz	**Grant Agreement No.:** SCB14023	**Date Submitted:** December 2017
Recipient Contact: Tim Galarneau	**Telephone:** (831) 459-3248	**Email:** tgalarne@ucsc.edu

Project Summary

This project addressed nutrition issues, specifically the under-consumption of fresh fruits and vegetables, and the health problems arising from this trend. Studies show that small percentages of adults and children are eating enough fruits and vegetables, which are important for preventing obesity, diabetes, high blood pressure, certain types of cancer and digestive problems. Further, many schools in California have worked alone to procure and market more specialty crops in their institutions, and many don't just focus on California sourced specialty crops. Center for Agroecology and Sustainable Food Systems' (CASFS) experience working with Food Service Directors (FSDs) has shown that there is demand for collective buying, shared problem solving and buying locally. There is clear dedication to improving nutrition by increasing consumption of California specialty crops in schools, yet barriers challenge many of these efforts. Problems include the cost and time to understand and coordinate sourcing specialty crops as well as inadequate structures to jointly do menu planning and promotions. Facilitating a collective buying, menu planning and promotional effort will make specialty crops more affordable and allow FSDs to buy more of them.

This project was timely because it built on existing efforts to increase local and regional produce sourcing in the Central Coast of California. CASFS has helped facilitate ongoing conversations since winter 2010 with school districts in the Central Coast to increase consumption of fruits, vegetables, and healthy options in school meal programs. This project established institutional purchasing and life-long consumption patterns for California specialty crops. This will reduce escalating public health care costs caused by the current increase in diabetes and heart disease in California. The overall objective of this project was to assist and support school districts in developing collective buying and marketing efforts to increase the consumption of specialty crops.

This project built upon the 2010 Specialty Crop Block Grant Program (SCBGP) Project 44*: Fresh Fruit and Vegetables: A Centerpiece for a Healthy School Environment (FFVCHSE*). The 2010 SCBGP Project 44 focused on catalyzing school administrators and garden educators to increase consumption of fresh fruits and vegetables (FFVs) in schools through one or two day workshops serving over 2,000 professionals and 40 trainings across the state. The current project, 2014 SCBGP Project 23, intensified the work with FSDs in the Central Coast, fostering strategic group problem solving and providing technical assistance with buying and marketing resources.

Project Approach

The primary purpose of this project was to enhance participating FSD's ability to increase the procurement and consumption of California specialty crops. The project staff conducted assessments of district partners and their produce distributors utilizing purchasing invoices to track the quantity of specialty crop and meals

purchased, tracking how much was spent on specialty crops, menu planning practices, and promotion activities. This information provided project staff with baseline data, which did not exist prior to the start of this project. Assessment surveys were created to identify needs to help plan the workshops, identify issues, and create better contracts for purchasing California specialty crops. The project staff gathered materials to highlight innovations in procurement, recipe sharing and development, and promotion/marketing best practices for California FFV's.

The first expected measureable outcome was that 15 FSD partners would increase the purchase dollar amounts of California specialty crops. For the 2015/16 school year, project staff had a majority of data for the project participants, which included 11 purchasing collaborative members, two project member districts, and five other districts receiving the benefit of the purchasing collaborative's buying influence (they are currently with Watsonville coast). This is a total of 18 districts. All but one currently have a primary distributor of Watsonville Coast. Data currently comes from the primary distributer and the Department of Defense (DoD) Fresh Fruit and Vegetable (FFV) Program and Gizditch Ranch.

The project staff gathered materials to prepare and highlight innovations in procurement, recipe sharing and development, and promotion/marketing best practices for California FFV's. Workshops were conducted to focus on collective buying and menu planning and focused on review and analysis of sourcing practices, examined methods to increase sourcing through collective buying, menu planning, and effective promotions. The projects staff conducted regular check-ins; both phone and in-person meetings that helped assess progress, offered insights, addressed challenges and offered new opportunities in implementing collective buying strategies.

The second measurable outcome was to have an increase of meals purchased by students due to new menu items and promotional efforts focusing on fresh fruits and vegetables. Baseline data has been collected for the 2014/15 school year for 11 districts and follow-up 2015/16 data has been collected for seven districts. In addition to data collection, activities to advance this outcome included in-district interactive California FFV juice taste tests, California FFV crop posters placed across partner cafeterias, as well as Harvest of the Month cafeteria promotions and parent mailings.

The project staff monitored data through surveys and follow-up interviews that asked the FSD's to identify how they plan to use provided resources and collective buying concepts to increase their California specialty crop sourcing. The project staff continued to collect data and analyze specialty crop and meals purchased, and provided ongoing technical assistance to implement collective buying, promotions, and menu planning.

Third measurable outcome summarized results from trainings that took place in the third year of the program. The trainings took place through hosting a statewide webinar in partnership with the Office of Farm to Fork and the California Farm to School Network, the bi-annual California Farm to School and Garden Conference in Modesto, California as well as a Central Coast regional farm to school training that brought regional leads across the entire California Farm to School Network to Santa Cruz, California with the Office of Farm to Fork and California Department of Education (CDE) participation. All participants were provided project findings, joint-district and collective buying process documents, marketing and promotion materials, as well as an opportunity to learn from the FSD partner leads as continuing points of contact in the farm to school field. Over 100 stakeholders representing districts across 14 counties as well as California specialty crop producers and distributers participated. Multiple district FSDs from out of region have been repeatedly reaching out to

the district partners for guidance as they explore collective buying advances. Community Alliance with Family Farmers (CAFF) has also included this project outcomes in their ongoing collective buying and farm to institution trainings and will continue to draw upon this project districts' leads as FSD resources for their projects across the state.

The overall scope of this project did not benefit other commodities and was specifically focused on California specialty crops. All activities conducted were aimed at ensuring the procurement of California specialty crops and were solely focused on this effort.

The cohort district project partners have advanced substantial sourcing of California FFVs, partnered on in-district California FFV promotion tasting events led by University of California, Santa Cruz (UCSC) student project interns and project staff, as well as helped shape priority marketing materials to further engage kids in a healthful cafeteria environment that promotes California FFVs. CAFF has worked specifically on enhancing the promotion and involvement of regional small and mid-scale California FFV farm products through direct marketing, distributor supply partnerships, and promotion materials on featured farms.

Goals and Outcomes Achieved

The first goal was that 15 FSD partners would purchase more California specialty crops than they did before this project started. The performance measure and target was to increase the purchase of California fruits and vegetables by 30%.

The project included 12 school districts that were part of the Central Coast Purchasing Collaborative (Alisal, Gonzales, Greenfield, Live Oak, North Monterey, Pacific Grove, Pajaro Valley, Salinas, San Benito, San Lorenzo, Santa Cruz, Scotts Valley, and Soquel). There was another district that participated actively with this project, a second that was active for half of the project and another five who benefited from the prices set by the collaborative. In total, 19 districts benefitted from the project.

Baseline data was not available when the project was proposed. It was hoped that project staff would acquire baseline data from the school year before the start of the project (2013/14), or at least the starting year of the project (2014/15), but this was not possible. The baseline data was collected in the second year of the project, school year 2015/16.

These districts did make notable advances however did not meet the targeted outcome of 30% increase in California produce purchases. This situation was likely due to a few factors. First, project staff were unable to get actual baseline data, and thus missed potential changes that might have taken place in the first two years of the project that would have indicated the target of 30% being met. Second, many of these districts have been active in purchasing more California and locally grown produce, so it's harder to make such a bold increase in the period of time project staff measured. Third, there are limits to the amount of California produce that can be purchased throughout the year. Fourth, there are staple fruits that are easy to ship, store, sell and eat that are always or often from regions outside California (oranges and bananas, in particular).

Overall, project staff consider the improvements in the first three quarters of the school year to be a success, given the factors listed above. While there was a smaller increase in California produce sales for October through December 2017, the baseline percentage was very high (55%), and thus it would not be expected to make as much of a gain.

The project staff did not include data for the last quarter as it is incomplete due to the truncated data collection period as a result of the project ending on June 30, 2017. Thus, it is not quite appropriate to compare April through June data from 2015/16 to 2016/17. One large district's purchases were only available for April and May by the end of June 2017. Other data is through mid-June 2017, and thus didn't include summer school schedules. It is quite likely that there were more California produce coming on line as the summer started into full swing at the end of June 2017.

The second goal was through promotional efforts focusing on FFVs, students would consume more specialty crops. The performance measure and benchmark was the percentage of meals purchased by students would increase, on average by district, by 10%.

Baseline data was taken from the first year of the project, school year 2014/15. Since promotion activities did not start until the second year, this seemed an appropriate starting point. Usable data included average daily meals for breakfast and lunch (excluding a la carte, supper and summer meals). There were nine districts who provided this information at both the benchmark and final year of the project.

On average, the increase in meal purchases between the years was 3%. This statistic did not meet the target. There are likely several reasons for this. First, as the project started, project staff were told by the FSDs that this was a problematic measure to use. There are many factors that impact the purchase of meals. For example, students don't have very much time to each lunch, so if there is a long line, they won't get in it. Additionally, several changes in the National School Lunch Program were mandated during the project, requiring more whole grains in foods, which many students find unappealing. Thus this measure was not necessarily the best to use to assess the impact of promotion activities for California FFVs.

Other data collected as part of the juicing promotion activity pointed to the success of that particular effort. This effort served over 5,000 participants across seven districts during the project. As part of the juicing engagement strategy, students were asked to respond to a short survey about the juices they tried. Although the questions were often worded somewhat differently, they generally asked how much they liked to juice, if they would eat it again, and if they would buy lunch at school if this product was available.

Students from seven districts were asked how much they liked the California FFV juice, and some students were asked to compare their satisfaction with two different juices (one just fruit, and the other with a green vegetable in it). In all instances but one, over 80% of students thought the green juice was good or very good. Students in five schools overwhelmingly reported that they would eat the green juice again (84%) or that they would buy lunch at school if this was in it (87%). These numbers are significant as the interns conducting the taste testing reported that students consistently found the green juice unappealing by sight and needed to be encouraged to try it.

Although this data only looks at satisfaction and intent, and does not identify follow-up behavior (changed future eating patterns), it points in a very positive direction. It shows that the promotion activity of juice taste testing was considered a positive activity by the students. It also showed that it gets students to like something they may not have liked before or thought they didn't like. Having a change of mind about something being good opens the door to trying them again, and potentially eating them on a more regular basis. Lastly, going forward, some of the districts have taken on the juicing taste test program with their own staffing given the student receptivity.

The third goal was that participants in the statewide trainings would be more likely to increase the purchase of California specialty crops at their institutions following the trainings. The performance measure and target was that 70% of attending FSDs would report that they planned to implement something. Another performance measure and target was that 10 districts would join a collective buying effort.

Participants who attended the webinar on June 8, 2017 were asked to complete a survey to identify their plans based on attendance and their interest in joining a collective buying effort. The request to take the online survey was stated at the end of the webinar, and an email was also sent to all participants immediately after the webinar with a survey link. Unfortunately, the post-workshop evaluation request had a poor response rate. The two other in-person statewide trainings received 30 evaluations with 23 FSDs, four California FFV producers, two FFV distributors, and one non-governmental organization affiliate. Ninety percent of respondents reported that they felt more informed and prepared to support collective buying efforts in-district or as a partner. In addition, 65% noted they are looking to advance collective buying efforts over the next two years.

Although project staff hoped that the statewide trainings would encourage other districts to join a collective buying effort, it became clear that this target could not be assessed as part of this project since the trainings were so late in the project effort. However, multiple district FSDs from out of region have been reaching out to the district partners for guidance as they explore collective buying advances. CAFF has also included this project outcomes in their ongoing collective buying and farm to institution trainings and will continue to draw upon this project district leads as FSD resources for their projects across the state.

Overall, this project has had several successful accomplishments:

- There was $2,859,853 spent on California fruits and vegetables for all 19 districts who were part of the collaborative, active with the project, or benefitted from the price discounts of the collaborative.
- For this same group, $2,102,395 was spent on local fruits and vegetables.
- Increases in local fruits and vegetables were exceptionally high. Overall, the percentage of local produce increased 41% from 2015/16 to 2016/17 in the first three quarters of the school years.

	2015/2016	2016/2017	Percent Change
Jul-Sep	36%	52%	44%
Oct-Dec	40%	50%	25%
Jan-Mar	22%	36%	63%
Total	**32%**	**45%**	**41%**

Percent of local produce purchased for two school years.

Beneficiaries

Impacted beneficiaries include students at K–12 school districts in the Central Coast and across the California state. FSDs from partner districts serve over 87,000 students. Nine of the initial 15 school districts serve vulnerable populations, where 61% to 91% of students lack access to California specialty crops. The other six sites are smaller districts serving 5,000 students or fewer. Since small districts account for nearly 73% of all school districts in the state, insights from the smaller district sites will enhance the impact of the statewide trainings. Project partners are also active in their peer associations, and are committed to increasing purchase

and consumption of California specialty crops in their operations and sharing best practices within their peer associations. Lastly, the California FFV producers themselves benefit from the intentional supply chain work undertaken as well as student promotion of California FFVs.

Lessons Learned

Collective Buying Processes:
District FSDs require technical assistance to help establish collective buying efforts due to the demanding work environment of their profession. The Office of Farm to Fork and CDE may want to consider future ways to provide technical consultation and assistance in convening regional FSDs in order to increase California FFV procurement and streamline contract processes for improved efficiency. In the interim non-governmental organization and third-party partners will continue to advise and work with districts on collective buying.

Collecting and Using Purchasing Data:
The best way to get purchasing data is to request it in the initial contracting process. Distributors were not necessarily willing to share this information otherwise. Providing purchasing data summaries to FSDs was very useful. There were some who thought they were purchasing large amounts of local and California produce, and did not realize the actual situation until they saw the numbers in a graph. This encouraged them to explore what was happening and improve the situation.

Promotion and Marketing Efforts:
The project staff learned that interactive cafeteria based promotion efforts provided a positive impression in increased interest in California FFVs for students. FSDs and their cafeterias require additional resources to scale up California FFV posters and promotions. The pilot efforts indicated there is a significant opportunity to inspire eaters by shifting the visual landscape of the built environment.

As stated previously, project staff did not meet the desired outcome of increasing the purchases of California produce by 30%. One particular item to consider, especially for future projects using similar measures, is that there may be a natural cap to the amount of California produce that can be purchased by districts. Since most of the school year generally takes place when fewer crops are grown in California, it is not possible for schools to purchase 100%. Additionally, there are a few fruits that students regularly eat that are either just sometimes grown in California (oranges and apples), or are never grown in the state (bananas). It is not clear from this project what the upper limit might have been. However, the largest percentage of California produce purchased over a period of time (first three quarters of the most recent school year) was 65% for one district. However, for other schools, percentages in the high 50's were the upper limit for this block of time.

Another reason project staff did not meet the identified target to increase purchases of California produce by 30% may be due to not having measured the actual baseline year. The distributor for those years could not produce this information – they did not track product origin data in their computer system. This situation is important to consider for others measuring similar outcomes. While new food safety regulations require that any product be traceable back to the farm on which it is grown, this information has not been kept in the distributors database in any way that can be used to aggregate it. It appears to take extra work on the distributors part to identify where the food comes from. It will be important for others to clearly check with distributors to see if they can offer a report identifying the location of the products, and ask for a sample report. Additionally, many wholesalers, or shipper/packers, get produce from a variety of places, mix it

together, and send it out to buyers. Just because the shipper/packer is from a specific location in California does not necessarily mean the produce is from there. This is another item to ask about when tracking this information. As there is more demand to know the origin point of food, it is hoped that this information will start to be more available by distributors.

The other outcome goal that was not met was having a 10% increase, by district, in meal purchases as a way of identifying successful promotion strategies. Given the information received, looking for changes in meals purchased may be too general of a measure, as many things impact meal purchases. Since it is an easy item to measure (FSDs have easy access to this information), people might be inclined to use it. However, project staff would suggest finding another measure. Utilizing student surveys that get at the promotion intervention more specifically is likely more appropriate way to go. Of course, that often just gets at immediate outcomes (changes in knowledge, attitudes or intensions) and not the more sought after intermediate outcomes (changes in behaviors).

Additional Information

The webinar, trainings materials, and outcome documents will be shared on the California Farm to School network site: http://www.cafarmtoschool.org

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
24	Farms to Seniors: Improving the Vitality of Special Crop Farmers and Senior Adults	
Grant Recipient: California State University, Chico Research Foundation	**Grant Agreement No.:** SCB14024	**Date Submitted:** December 2017
Recipient Contact: Maria Giovanni	**Telephone:** (530) 898-4023	**Email:** mgiovanni@csuchico.edu

Project Summary

The goal of this project was to increase the purchase and consumption of locally grown specialty crops by rural senior adults through promotion and serving of food made with these foods as part of the Senior Nutrition Program (SNP), similar to the popular "Farm to School" model used in many school districts. Good nutrition is important to supporting healthy aging and consumption of specialty crops is linked to better health. However, the seniors in rural Glenn County have limited shopping options due to four grocery stores in the county and the distance of these stores from many homes. Those seniors participating in the SNP, which provides meals both at a congregate site that provides transportation or to the home for seniors who are not able to travel, said that the lunch they received was their primary meal of the day. Specialty crop farmers need additional market outlets as the agricultural production in this county is primarily almonds, walnuts, and commodities that are sold to processors and distributors, then shipped out of the area. Although Glenn County's primary revenue source is agriculture, very little production reaches its residents.

Two factors shape the importance of this project at this point in time: 1. The decreasing numbers of specialty crop farmers in rural Northern California's north valley; and, 2. The increasing numbers of older adults who live in these counties and have limited services available to them, such as grocery stores, restaurants, and in-home and medical care. As the older adult population grows, the need for these services will increase as will the importance of eating a healthy diet.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

In year one, meetings were held with four stakeholders to discuss the project: Glenn County SNP, University of California (UC) Cooperative Extension in Glenn County, Passages (Area Agency on Aging), and two specialty crop farmers. The Glenn County SNP is part of the county Office of Education, and the Human Resource Director was engaged in the project. Job descriptions were written and four students joined the project in year one, with two students serving as the primary contact with either the farmers or the SNP staff. All students worked well together and participated in various aspects of the project. Farm to Fork models were evaluated and a plan was developed that included reaching out to farmers, with four farmers selling to the project. A payment system of invoicing and check requests was established. One problem identified was distribution to transport the specialty crops to the SNP. Most produce was picked up by the project staff and brought to the SNP.

The seniors who ate at the SNP were engaged in the project by asking which specialty crops they would like to eat. Key findings were that most of the seniors ate at the SNP four or more times a week and they were

supportive of the project, particularly if the quality of the fruits and vegetables could be improved. In summer 2015, fresh specialty crops were used in various recipes and feedback from the seniors was mixed, as they preferred familiar foods. The team began to work with the SNP staff to prepare small amounts of new recipes that were given to the seniors in a "taste test" to determine acceptability. The recipes that were accepted were incorporated into the SNP menu or if they were not well accepted, attempts were made to improve them or the recipe was not made again. Project staff provided 10 new recipes to the SNP, whose staff also began to incorporate specialty crops into food preparation. A promotional card was prepared about kale and received favorable responses. No stakeholder concerns were expressed.

Year two continued with few changes. The student who worked with farmers identified a new farmer who was producing leafy greens, broccoli, kohlrabi, and other winter vegetables, providing these specialty crops to the SNP during the winter of 2016. A second new farmer was added in June 2016. The addition of these two farmers plus increased purchases from a third farmer resulted in an increase of specialty crops purchased from year one to year two.

At the end of year two, the grant was extended for a third year. Farmers were contacted and initially, two farmers agreed to plant 10-20% more of their spring and summer crops to sell to the SNP. However, they were not able to implement this additional production because they both were not able to continue farming on the land they were leasing. Another setback was that the two students who did much of the work for the first two years of the grant moved on to other work. The project manager did not have time to seek other farmers or to take on the purchasing of specialty crops, delivering them to the SNP, and training SNP staff. This resulted in no activity on the project during fall 2016 and winter 2017. In spring 2017, new students were recruited. One of them contacted the farmers who had participated in the past and found that two of them would have enough to sell some specialty crops to the SNP.

This project solely benefited California specialty crops. All kitchen supplies, educational materials, and promotional items purchased were for the purpose of preparing and promoting specialty crops. Every purchase was linked specifically to a specialty crop. When recipes were made, the ingredients that were not specialty crops were purchased by the SNP from their budget.

The manager of the Glenn County SNP said that the ability to "provide fresh produce rather than canned or pre-packaged has been wonderful" and the seniors appreciate the efforts. The SNP is not able to purchase much fresh produce from their supplier due to cost and they would not use all of the produce because the pack size is too large from them, so the frequent delivery of fresh produce works well for them. Passages (the Area on Aging center for Glenn and four neighboring counties) was very supportive of the project and explained the requirements of the program, such as nutrition and budget.

Goals and Outcomes Achieved

Stakeholders were engaged, including the senior adults. UC Cooperative Extension provided a list of farmers in Glenn County and the "Buy Fresh, Buy Local" guide was reviewed to identify farmers. Specialty crop farmers were contacted to determine interest in the project and determine specialty crops that were planned for spring and summer. A focus group was held with the seniors to engage them in the project and learn what would be most helpful to them. Eight regular participants in the SNP said that the program provided their main meal and also provided socialization. Other meals were generally microwaveable meals and they did not prepare vegetables very often. They would eat fruit when available. They noted that most of the specialty

crops eaten as part of the SNP were canned or frozen. While the food was good, some of the meals were not satisfactory but because few other dining options are available, the seniors would eat at the SNP. They were excited to learn about using local food in the SNP, not just for better taste but many of them had been involved in farming and wanted to support local farmers. The types of foods suggested were fruit salads and better vegetables, but nothing too different. A baseline survey of 31 participants found that 19 of them (61%) ate at the SNP every day and only 23% ate specialty crops at least three times a week, with 41% eating fruit and vegetables once or twice a week, which is less than the amount of specialty crops recommended in the Dietary Guidelines for Americans.

Eight farmers participated in the project in the 2015, with four of those growing enough produce to regularly sell to the SNP. The other four farmers had one crop, e.g., watermelon or herbs, that was grown in enough quantity for the SNP. The first specialty crops introduced into the program were in spring 2015 and included stone fruit (peaches and plums), cucumbers and tomatoes. Although zucchini is generally an abundant crop, the yields were very low in summer 2015. In the first year, 456 pounds of specialty crops were purchased, resulting in $675.50 additional income to specialty crop farmers. Winter 2015 and spring 2016 were also limited due to only two farmers producing winter or early season crops (one was just herbs). The specialty crops purchased were primarily salad greens, winter greens, and herbs providing $426 for 117 pounds of produced purchased and used by the SNP.

The summer of 2016 was very successful, with 1,386 pounds of specialty crops purchased from five farmers on a regular basis, and three farmers occasionally, adding $2,511 to their sales. In fall 2016, the one farmer who had kept the SNP supplied with winter vegetables in 2015 had to relocate, and did not continue farming. A second farmer who had supplied produce in summer 2016 was not able to continue farming on the land he had leased. These closures resulted in no produce purchased in fall 2016 or winter and spring 2017, despite the project for another year.

Two farmers consistently provided products in summer 2017, with 552 pounds purchased for a total of $653 in sales to the farmers. Over the three year period, 2,511 pounds of produce were purchased for a total of $3,790 to specialty crop farmers.

One key limitation for the use of specialty crops by the SNP was lack of adequate kitchen supplies. Knives, a mandolin, and a commercial salad spinner were purchased and training of SNP staff was conducted. Another limitation was staff turnover. The kitchen staff was in transition due to a new hires and retirements, which impacted the staff's ability to be trained. Five staff were exposed to the use of specialty crops and the students had opportunities to train people with limited culinary skills, which they enjoyed and may lead to increased use of specialty crops as these staff moved to other jobs. Fall 2016 a permanent head cook with a culinary background was hired and enthusiastically used the specialty crops provided, primarily winter vegetables and herbs.

One long term outcome that will continue beyond the scope of the project is the improved preparation methods of fruits and vegetables by the SNP, which should increase consumption of specialty crops by the seniors. The cost of the local specialty crops was comparable to buying fresh or processed fruits and vegetables from a national distributor that may have been imported or from other parts of the United States, particularly the summer vegetables. Winter vegetables, for the one winter they were available to the project, were more expensive.

The primary goal of the project was to increase the purchase and consumption of locally grown specialty crops by rural senior adults through promotion of specialty crops, in collaboration with the SNP. This project did increase the purchase and consumption of specialty crops, but not to the extent intended when the project started. The proposal planned for the specialty crops farmers to realize an increase in revenue of $15,000 in year one and $20,000 in year two. Over the three year period, 2,511 pounds of produce were purchased for a total of $3,790 to specialty crop farmers. Thus, the original grant grossly overestimated the amount of specialty crops that would be purchased both in terms of how much fresh fruits and vegetables would be produced and available for purchase and how much specialty crops can be prepared by a limited staff. A second goal was to increase revenue to the farmers by 10%; however, farmers did not provide specific sale numbers, so the accomplishment of this goal is based on subjective perception from the farmers who told staff that the project did increase their sales. A third goal was to improve consumption of specialty crops by the SNP participants. While plate waste was not measured for accurate assessment, a visual examination of the plates by the student employees and the project manager found that less food, particularly fruits and vegetables, was being discarded each day when the fresh specialty crops were used. The fourth goal was to train the SNP staff to incorporate more specialty crops into their menu, and this goal was reached. A fifth goal was to create promotional material for specialty crops, which has been reached with six different crops displayed with varietal information and recipes, for farmers to use during markets.

The farmers who sold to the project did not provide sales numbers for either baseline data or to quantitatively assess the impact of the project. However, when asked if the project had increased their revenue, two of the farmers who participated in year two indicated that the sales to the project increased their revenue by at least 10%, which was the goal for the project. The other three farmers felt they could have sold the produce through their regular channels (farmers' markets and farm stands). In year three, one of the farmers acknowledged that the project contributed to selling their fruit, rather than not selling the fruit.

A baseline survey of 27 seniors who were eating at the SNP in fall 2015 indicated that 56% ate fruit and vegetables at least once or twice a week. At the end of the project in summer 2017, the 38 seniors who responded to the survey indicated that they were eating more fresh fruit and vegetables daily and 34% said they were eating more fruit and vegetables now as compared to a year ago. Several commented that the food served in the SNP contributed to their consumption of specialty crops, with satisfaction scores for salads increasing from 2.1 to 2.3 (on a four point scale). Although comments indicated that the quality of both the cooked vegetables and the fruit served was better with the use of fresh local specialty crops, the satisfaction scores did not increase for either of these foods.

The major successful outcome was the purchase of 2,511 pounds of produce were purchased for a total of $3,790 to specialty crop farmers over the three year grant period. Ten farmers were engaged in the project. A post-project survey of the seniors (N=38) who participate in the SNP found that 34% were eating more fruit and vegetables, 53% the same amount, and only 8% reported eating less. The impact of this project on actual specialty crop purchasing by older adults cannot be measured, as many of the seniors have other people shop for them. Seven SNP staff were trained in quantity production of specialty crops in various meal items. While three of these staff remain to continue providing high quality fruit and vegetables to the seniors, the other four are likely to continue to use what they have learned from this project in other jobs. Ten students were involved in the project, developing recipes using specialty crops, training SNP staff on use of specialty crops, informing farmers about the opportunity offered by the SNP to expand their production and sale of specialty crops, and developing promotional materials for specialty crops.

Beneficiaries

Two groups were directly benefited from this project, the specialty crops farmers who supplied the produce and the SNP staff and participants. The specialty crop farmers had a new market channel and increased revenues, plus promotional material to use at farmers markets and at their farm stands and the satisfaction of providing healthy food to people who are at nutritional risk. The SNP staff learned valuable skill in quantity production of specialty crops and preparing them in a variety of ways. They also gained supplies that will help them continue to use fresh fruits and vegetables in the program, which was very well received by the seniors. The SNP participants benefited from increased exposure to specialty crops, new ways to prepare them, better nutrition from consuming more specialty crops, and an opportunity to engage with the students, project director, and SNP staff.

Three other groups benefited from the program. First, the students who participated in the program learned important skills in using specialty crops in quantity food preparation, recipe development and scale-up, budgeting, logistics, and "soft skills" of interacting with both the SNP participants and staff. Second, the Area Agency on Aging gained ideas and support for the five-county rural area to increase their use of specialty crops and some of the student employees served as unpaid interns to assist with their program as needed. Third, residents of the county benefited by increased exposure to specialty crops both through promotion of the project and the farm event held in June 2017, and also the needs of older adults in the community, resulting in an increased awareness of the types and amounts of specialty crops that are available in the county.

The SNP in Glenn County feeds an average of 120 seniors five days a week, except holidays. With turnover, a conservative estimate is 150 seniors benefited from the project by having fruit and vegetables served to them in an appetizing manner, thus increasing their consumption of specialty crops and improving their likelihood of continuing to consume specialty crops. Having better food should result in higher numbers of older adults participating in the SNP, thus increasing the amount of specialty crops consumed.

Lessons Learned

Many lessons were learned in this project. Farmers face many barriers to profitability, including labor shortages, and the ability to produce enough produce to sell institutionally rather than at a farmers' market or farm stand. These limitations are due to a shortage of labor and production costs, seasonality, pricing. Farmers, particularly small specialty crop farmers who produce enough only for a small farm stand or a local farmers market, must be engaged early in the planting season so they can plant enough specialty crops for the SNP to use, while still having enough specialty crops to sell via their traditional channels. The farmers were understandably reluctant to plant additional crops without a guarantee of purchase, but the establishment of a contractual agreement was beyond the scope of this project. Additionally, the farmers often ran their operation by themselves or with assistance from family members, so growing more produce would mean hiring additional employees.

Most of the farmers did not have time to drive the produce to the SNP. One farmer did deliver as part of his delivery route to restaurants in the town. On a few occasions, another farmer set up a farm stand in town one day a week to sell his produce and was able to bring produce for the SNP. One solution to this would be a food hub.

Labor issues also affect the kitchen, as the amount of labor needed to clean and prepare the specialty crops is high, compared to commercially frozen or canned fruit and vegetables, which is the primary form of specialty crops used by the SNP and the crops may be imported, so increasing the use of fresh and local specialty crops will increase sales for local farms.

The project manager learned that money needs to be budgeted for administrative assistance, data collection and tracking, and report preparation. The time and energy involved in hiring students, tracking timesheets and activity logs, arranging pick up of specialty crops with farmers, and appropriate use of the specialty crops in the SNP menu was much larger than the project manager anticipated. The staff of the grant were of invaluable assistance in this project and their support is greatly appreciated.

The older adults appreciated the opportunity to have a wider variety of dishes made with specialty crops, and enjoyed trying some new crops such as kabocha melon, donut peaches, or Armenian cucumbers. To introduce a new menu item required a “taste test” of the item to determine how well it was liked, then add it to the menu with any suggested changes. They also appreciated the support of local farmers because they know the source of the produce.

Several important lessons resulted from this project. First, ensure that the farmers in the area that would supply the SNP produce enough specialty crops to ensure a consistent supply. The second lesson is to explore distribution channels that would transport the produce from the farm to the SNP. Third, kitchen staff must be trained and available for preparing the fresh specialty crops in a form that most of the seniors can eat, as dentition is a problem for many of them, making foods such as lettuce and greens, or tomatoes and fruits with peels, difficult to eat.

Several ideas were explored to increase the purchase of specialty crops but were not implemented for various reasons. First, canning fruit was considered to be used in the winter, but the SNP requires processed food to be commercially canned. Second, seniors were asked to provide recipes to be used in the SNP but they were not interested.

This idea may be more successful in an area with a larger SNP and more specialty crops farmers particularly if they were able to deliver the produce to the SNP site. Another idea, which may be more successful in a rural area, is to partner the food preparation with the local school district who may have more staff and access to more equipment that will expedite cleaning and piecing the fruit and vegetables. The nutritional requirements for the SNP are not as stringent as those for the National School Lunch Program and focus primarily on minimum amounts of Vitamin A and Vitamin C, both which are abundant in specialty crops.

Additional Information

The design and learnings from the project were shared via two venues. In March 2016, the two students who provided leadership to the project presented a talk at “This Way to Sustainability” on the California State University, Chico campus. In October 2016, the project director presented a poster about the project at the Sixth Annual International Conference on Food Studies in Berkeley, CA. A publication about this project is planned in an appropriate peer-reviewed journal for 2018.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
25	Cultivating Community North Valley	
Grant Recipient: California State University, Chico Research Foundation	**Grant Agreement No.:** SCB14025	**Date Submitted:** December 2017
Recipient Contact: Karen Hansen	**Telephone:** (530) 898-6286	**Email:** kthansen@csuchico.edu

Project Summary

With the purpose of strengthening nutritional and agricultural literacy, food security and self-reliance of the community, as well as protecting the environmental quality of regional food sheds, the Cultivating Community North Valley project (CCNV) was designed to address core access barriers contributing to low resident participation in the regional specialty crop economy.

The primary objective of CCNV was to increase consumer, buyer, vendor, and grower investment in the local specialty crop economy with methods developed to boost food security, help reverse poor diet-related outcomes; and to preserve soil health and fragile ecosystems. The North Valley region had been facing persistent drought and associated soil degradation, a non-replenishing farmer population, 23 urban/rural food deserts, a 10 percent unemployment rate and a much higher underemployment; 60 percent of residents suffering from diet-linked illness, and 21 percent of residents facing food insecurity.

A 2013 study by the Northern California Regional Land Trust found that the region's rural food shed alone, if developed to its potential using specialty crops, would be capable of employing scores of additional farmers and answering over 70 percent of regional food needs, while adding urban and suburban plots would increase this percentage further. A different 2012 North State study, applied exclusively to Butte County, showed that while less than three percent of residents' fresh food purchases were determined to be locally sourced, if residents were persuaded to spend just $5 per week on North Valley crops, the regional farm economy would receive a $57.5 million annual infusion, with expected economic multiplier effects boosting the projected annual increase beyond $80 million.

The CCNV project aimed to expand direct markets and improve local specialty crop availability and marketability, thereby increasing healthy eating awareness, local food security and strengthening the (chiefly organic) regional specialty crop economy. As a core part of this effort, CCNV sought to increase the region’s specialty crop growing capacity by adding cultivated acreage and teaching bio-diverse, water-efficient, sustainable specialty crop growing skills among Butte County's 221,500 residents, and particularly among least-served community members (students, small/new farmers, and low-income consumers). This project solely enhances specialty crops.

This project built upon the 2011Specialty Crop Block Grant Program (SCBGP) Project 48: *Cultivating Community North Valley*, by utilizing its successful demonstration model and its EBT enablement of eight regional farmers’ markets and three Community Supported Agriculture (CSA) Programs. This allowed project staff to better market local specialty crops to low-income participants, and to expand training assistance to direct marketers with whom the project team had developed connections.

This project also enhanced the number and quality of participant relationships previously established by hundreds of culinary demonstrations, thousands of tastings with a mobile bike kitchen constructed as part of the 2011 SCBGP Project 48, and its 300 farming workshops which featured a Learn-and-Earn program that gave matching farmers' market incentive coupons to low-income workshop attendees, thereby increasing consumer awareness of, and continued shopping at, farmers' markets. CCNV's project also expanded upon and up scaled Project 48's thriving network of 22 community gardens and their farm stewards and teams of volunteers. Finally, CNNV's project built upon the networking capacity developed by Project 48's partnerships with 20 service agencies, farmer networks, conservation organizations, neighborhood revitalization groups and schools.

Project Approach

Throughout the project, CCNV's team performed the following tasks/activities:

Task: Coordinate Effective Project Management: CCNV's Management Team met twice monthly throughout the course of the project. The team included the Project Director, farm managers, evaluator, representatives of the lead contracting organization, and other relevant players. Each meeting involved collecting and sharing progress reports and upcoming event needs from all players, messaging coordination, identification of concerns, and post-meeting distribution of notes and action items.

To coordinate and manage events and participants, CCNV Management Team members contributed to a common internal Google spreadsheet which indicated: upcoming dates for events/activities, locations, whether the event/s would be open-to-the-public or private/site-specific (e.g., for a classroom or unique served population); team member/s responsible for each event's successful execution, and relevant results of the event(s) after-the-fact, and a post-event number/description of participants (e.g., "24 students, 2 teachers and 5 adult volunteers"). Project management activities also included maintaining a spreadsheet of names and contact information of event participants, and the dates and titles of the events in which they participated.

Task: Convene Stakeholders Regularly: CCNV brought together its diverse and expanding stakeholder coalition to share project progress, look at future directions, explore avenues of collaboration, maximize networking, strategize cross-promotion, and explore new sources of support, with the aim of strengthening a healthy food system consortium. (For a list of Stakeholders, see Attachment 1 Part 6.)

Task: Perform Ongoing Project Outreach and Event Promotion: CCNV's media team maintained a monthly farming newsletter and weekly-updated website with event calendars and daily-updated social media page (1,025 followers as of June 2017), and also advertised project events via radio/newspaper calendars.

Task: Provide University-Farm-based, Hands-On Farming and Directing Marketing Training for Students and Community Members: Project team members working with Chico State's Student-Run Organic Vegetable Project Farm (OVP) hosted dozens of workshop and field day events designed to bring the farming community together with high school students, university students and educators around the sustainable growing of specialty crops.

CCNV's Project Director and team members also utilized the OVP farm site as an instructional platform for California State University (CSU), Chico courses involving student work and learning (for a list of classes involving OVP's farm site, please see Attachment 1 Part 1.)

Additionally, the OVP's project-linked CSA program engaged and trained CSU farming students in a.) Ongoing crop input, care and harvest; b.) Providing instructional events and tours for marketers, growers and K-18 students; c.) Marketing OVP crops to campus staff, faculty, fellow students, CSUC dorms, cafes, as well as campus community and institutional buyers; d.) Implementing logistics of a CSA program—crop planning, membership recruitment, member communications and feedback, processing, tracking, delivery, and running a U-pick.

Task: Provide Direct Farming Support for New/Existing School/Community Gardens: CCNV's team provided consulting, outreach and instructional activities in support of the ongoing success of 21 gardens built or otherwise supported by CCNV's previous 2011 SCBGP Project 48, and also provided labor, materials, consulting and event support for the input and maintenance of 21 new specialty crop growing sites. CCNV's team also assisted with finding stewards, volunteers, resources and information. CCNV's team coordinated garden-builds at schools, housing projects, help-agency and church sites, as well as dedicated neighborhood and private urban farm site properties. CCNV also organized instructional workshops for teachers, students, school staff and volunteers, community housing residents, agency recipients and staff, neighborhood community members and garden enthusiasts. (For a list of CCNV gardens, please see Attachment 1 Part 2.)

Task: Provide Specialty Crop-based instructional events for students, farmers, community: CCNV's farm instruction team utilized its project-supported growing sites serving community/agency/neighborhood/ school/housing-projects to offer hundreds of private (site-dedicated--e.g., for students or housing residents) and open-to-the-public educational events and workshops for community members to develop and hone specialty crop farming skills.

For these weekly events, CCNV's team published and promoted seasonal event calendars, recruited presenters; established relationships with venue hosts, garden stewards, agency leads and farmers' market managers. At each event, team members tracked participant attendance, and distributed and collected pre/post surveys. In the days and weeks after events, team members followed up with participants to advertise new events, conduct longitudinal surveys and recruit volunteers and stakeholders.

Finally: the Glean Team. CCNV's instructional events were not confined to growing produce. CCNV's scope encompassed teaching participants to take full advantage of seasonal and local harvests by identifying over-producing local farms, gardens, fruit trees/orchards, nut trees/orchards and wild berry and grape grows suitable for harvest. CCNV's Glean Team recruited volunteers and participants for biweekly gleaning in the Chico area, and maintained a Fruit/Nut Tree Registry and a Farm/Garden registry for participants and community members who wanted help with their harvest. Upon invitation, CCNV's Glean Team would show up with tall ladders, boxes, poles and bags, and harvest. CCNV's Glean Team and participant volunteers also learned to keep a lookout for fruit/nut trees on public land open to harvesting. (For a list of CCNV Specialty Crop Instructional Farming Events, please see Attachment 1 Part 3.)

Task: Provide Consultation & Training for Direct Marketing & Cottage Industry Ventures: At the start of CCNV's project, CSU Chico's project-supported OVP created its own student-run CSA program, consisting of pre-paid shares to students, staff, faculty and community members, and also day-of purchases from the CSU, Chico campus-based OVP market; its field-based farm stand and u-pick. OVP's CSA program and farmers' market consistently exceeded 50 customers per week throughout the project.

In 2015, CCNV's team provided consultation, planning and construction support for a local farm stand that sold produce to neighborhood families from a combined church and Hmong garden, and also helped plan and construct a mobile farm cart operation that sold produce from three garden sites in a densely populated but low-income, unincorporated part of Chico. Also in 2015, CCNV's team provided organizational support to a small farmer's market hosting five small-scale farmers in South Chico.

In 2016, CCNV's team provided extensive planning and consultation to a membership-based CSA program (35-plus subscribers to date) supplied by the Jesus Center Farm, which trained homeless residents in farming and marketing.

Finally, CCNV's team partnered with several local community and commercial kitchens to train participants to safely prepare, preserve, store and sell specialty crops in accordance with health standards and laws. (For a list of Cottage Industry and Value-Added partners and workshops, see Attachment 1 Part 4.)

Task: Provide Culinary Demonstrations & Tastings Featuring Specialty Crop Produce: Throughout the course of the project, CCNV team members utilized partners' commercial, agency, school, and fraternity/sorority kitchens to provide specialty crop cooking and food drying/preservation demonstrations to target participants (K-18 students, help-agency served populations, Community Housing Improvement Program (CHIP) housing residents; community members in food deserts). These classes focused on using garden and farmers' market fare for family and group cooking, cooking with and by children, cooking when on a tight schedule and budget, prepping food on a busy, starving student schedule; preparing food for maximum energy, health and flavor.

Team members also utilized a bicycle-powered mobile kitchen constructed by the 2011 SCBGP Project 48 called The Edible Pedal, to provide weekly culinary demonstrations and tastings at schools, CHIP housing sites, farmers' market sites, garden sites and at help-agency sites. Edible Pedal events averaged a minimum of 750 tastings per reporting period. (For a list of CCNV's culinary demonstration events, see Attachment 1 Part 5.)

Task: Disseminate Results and Share Project Model: Throughout the project, CCNV's team presented its project model and key results at local regional, state and national events in support of regenerative specialty crop farming, sales, and incorporating specialty crops into healthy diets. In the North State, CCNV presented its project at annual events such as: the Sierra Oro Farm Trail Tour, This Way to Sustainability North State conference on the CSU, Chico campus (2015, 2016, and 2017), the Far Northern Healthy Aging Summit, the North Valley Wellness Fair, Butte County's Environmental Film Festival, Respectful Revolution "Re-Conquering Food Systems," and the Sierra Nevada Sustainability Fest. Nationally, CCNV's director presented CCNV's project model at the 2015 and 2017 American Society for Horticultural Science Conference.

Roles and contributions of unpaid project partners included, but were not limited to: stakeholder meeting attendance, cross-promotion of the project, advertising project activities/events among served populations, providing volunteers, hosting of project events/participants (beyond or not-including the hosting agency's served population), providing meeting and storage space, donation of seeds & starts, technical support, donation of printing and building materials, free radio and publication advertising, providing interns, providing consulting and expertise, loaning of vehicles, tools and equipment, and providing free produce,

starts and seeds to the project gardens, workshops, the Glean Team and the Edible Pedal. (For a list of partners, please see Attachment 1 Part 6.)

Goals and Outcomes Achieved

To achieve the goal of increased networking capability and response capacity throughout the food system, CCNV convened a specialty-crop-focused stakeholder coalition of partners in each reporting period to share results, coordinate efforts, and to explore needs and solutions. CCNV's team added a minimum of three new member organizations per meeting, for a 2017 total of 40. Stakeholder project partners included farmers, conservationists, service providers, educators, vendors and commercial buyers. Eighteen additional agencies and organizations acted as resource-contributing partners in other ways on the project.

To achieve the goal of strengthening the competitiveness and ecological sustainability of, and local participation in, the regional specialty crop economy--specifically, increasing regenerative local growing, eating, buying, preparing, preserving, marketing and nutritional knowledge of specialty crops, CCNV's team performed the following activities:

a) Provided material, labor, construction, consulting and instructional workshop support for water-conserving, soil-organic-matter-building demonstration gardens to 42 schools, service agencies and housing projects; which in turn provided organic specialty crop produce to thousands of residents and students.
b) Provided direct marketing and cottage industry training and material support to students and small farmers, value-added entrepreneurs and caterers.
c) Provided specialty crop farming instruction events to small/new farmers and community members.
d) Provided culinary demonstrations and tastings to target participants at multiple venues.
e) Utilized the project-supported OVP as an instructional platform for specialty crop-focused college courses, as well as for OVP-based farm and community events.
f) Trained CSU, Chico agriculture students in management of a member-based CSA program.
g) Directly sold OVP-grown specialty crops weekly from campus and the CSU, Chico farm via a farm stand, U-Pick and membership-based CSA program.
h) Promoted the project model at multiple venues locally, in the North State, and out-of-state.

Neighborhood/school/agency garden networks were designed for sustainability, longevity, and propagation. The project team expect input gardens to continue producing an average of five years into the future post-project, with served populations cultivating, consuming, preparing and (in some cases) selling produce.

A main projected outcome for CCNV's project was long-term behavioral change: a significant and enduring increase in participant engagement in the specialty crop economy via more cultivating, buying, preparing, consuming and selling of specialty crops as a function of project participation.

For educational event attendees, reported behavioral change with longitudinal surveys of large representative samples of event participants were tracked. These surveys were taken informally in classrooms, in-person at housing projects and help agencies (whose served populations were consistent enough to be re-contacted), and online via email and Facebook, using SurveyMonkey.

The project goal/outcome target was to see a large representative sample of CCNV event attendees reporting a 70% or higher increase in specialty crop related activity.

The actual outcome was higher: 80% of representative project participants surveyed (500 over the course of the project) reporting increased activity in one or more of the following: growing, preparing, preserving, consuming, buying, or selling specialty crops. Compared to non-participants (80 surveyed in 2014), CCNV participants reported being more than twice as likely to eat, grow and buy more specialty crops as a function of project event attendance as those who had not attended project events. Incorporating the most recent surveyed sample, per activity, 82% reported preparing more produce at home than prior to attending project culinary events. 58% reported habitually eating more specialty crops than prior to attending project events; and 59% reported increased purchase of local specialty crop produce since attending project events. 62% reported growing more specialty crops than prior to attendance at project farming events, and 67% reported selling more specialty crops (fresh or value-added) than prior to attending direct marketing events.

Comparisons project goals and accomplishments are as follows:
Goal: A doubling of CCNV's stakeholder coalition membership.
Outcome Actual: Target met: CCNV's project added 20 new agency/organizational/farming members to its coalition, for a total of 40. A total of 18 additional project partners contributed in other ways to the project--with expertise, time, or materials.

Goal: A doubling of the 2011 SCBGP Project 48 benchmark of total Specialty Crop Educational Events offered; a doubling of the 2011 SCBGP Project 48 benchmark of educational units, and a doubling of the 2011 SCBGP Project 48 benchmark of unduplicated Specialty Crop Educational Event participants.
Outcome Actual: All targets exceeded, with 248 Specialty Crop Educational Events offered, 7,054 Specialty Crop Educational Event educational units, and 4,405 unduplicated participants (K-18 students, service agency participants, farmers, CSA members).

Goal: A doubling of the number of culinary demonstration events and tastings that the 2011 SCBGP Project 48 had offered.
Outcome Actual: Target for culinary demonstration events exceeded. CCNV provided 127 culinary demonstration events. Educational unit target of was also exceeded: CCNV provided 4,698 tastings.

Goal: 70% of post-event participants will indicate increased specialty crop skill/facility/knowledge, and conversance with specialty crop benefits.
Outcome Actual: Target exceeded by 22%. In the 1,097 post-event surveys collected in the performance period, 92% of respondents reported increased knowledge and skill in the event's covered topic as a result of the attended CCNV event.
Note: Please see previous section for long-term and longitudinal goals and results.

Goal: CCNV will provide substantial project support to at least four new CSA and/or direct marketing operations (e.g., membership-based, institution-based, or onsite farm, farm stand or cottage industry sales) with a minimum of 50 weekly members/customers, and provide a minimum of 40 cottage industry product training workshops for value-added vendors and caterers.
Outcome Actual: The project exceeded direct marketing targets. OVP's year-round traditional CSA and farmsite/market weekly sales exceeded 50 consistent members/customers in the performance period. CCNV's project team also provided start-up and ongoing consultation support to one year-round CSA effort connected to a homeless shelter (35 weekly memberships feeding over 50 people), as well as to a small farmers' market in South Chico that operated for two years, and a farm stand and mobile food cart operation, both of which

still operate in the summers. The team also provided 40 specialty crop based cottage industry/value added trainings to 295 unique participants during the project.

Goal: CCNV will double its number and acreage of supported gardens/farm sites. Specifically, CCNV project will provide labor, materials and consultation support to the 2011 SCBGP Project 48's network of 21 supported gardens on seven acres, and will input and provide support for another 21 farm sites of similar collective acreage, increasing the amount of specialty crops produced for served populations by approximately double.
Outcome Actual: The project met supported farm site targets. CCNV's team provided material, training and consultation support to the 2011 SCBGP Project 48's existing gardens, and also provided workshop training, installation, seeds and organization in support of 21 new sites on an additional seven acres. (See description of garden efforts in section one, and a list of supported gardens in Attachment 1 Part 2.)

Goal: CSU, Chico Farm OVP's farm sales will show a 55% increase.
Outcome Actual: CSU's student-run OVP farm fell short of its final year revenue target by 2.8% (about $315, the difference of a few days' sales), with OVP Farmer's Market and CSA member produce-sales to students, faculty and community members. However, the OVP received an additional $4,000 purchase commitment for 2017-18 from Chico State Associated Students Association, on behalf of low-income students who wish to participate in the CSA membership program. These guaranteed funds push the OVP sales substantially over-target.
Note: Baseline/benchmark data is given below for outcomes for which baseline data was obtained/used.

Goal: A doubling of the number of active stakeholder coalition members to 40.
Baseline/Benchmark established by the 2011 SCBGP Project 48 for stakeholder coalition membership: 20 agencies.
Outcome/Actual: Goal met: CCNV's project drew 40 agency/organizational members.

Goal: A doubling of Specialty Crop Educational Events offered; a doubling of educational units; and a doubling of unduplicated Specialty Crop Educational Event participants.
Baseline/Benchmark (2011 SCBGP Project 48) for
Specialty Crop Educational events: Benchmark 108; Target 220; Outcome exceeded goal by 11% with 248
Educational Units: Benchmark 2,000; Target 4,000; Outcome exceeded by 44% with 7,054
Unduplicated participants: Benchmark 1,000; Target 2,000; Outcome exceeded by over 200% with 4,405

Goal: Double the number of project-provided culinary demonstration evens and tastings.
Culinary Demonstration Events: Benchmark 41; Target 83; Outcome exceeded by 45% with 127
Culinary Demonstration Tastings: Benchmark 2,062; Target 4,125; Outcome exceeded by 13% with 4,698

Goal: A doubling of the farm site number and acreage installed/supported by the project.

Number of farm/garden sites: Benchmark 21; Target 42; Outcome 42
Farmed Acreage: Benchmark 7; Target 14+; Outcome 14-plu farmed acres

Goal: 55% increase in OVP farm sales by the final project year.
Benchmark of $7,282 for sales in July-June 2013-14; Target of $11,287 for sales in July-June 2016-17;
Outcome: missed by 2.8% with $10,972 in sales.
Note: when factoring in the additional $4,000 in guaranteed sales revenue from a Chico State Associated Students grant providing CSA shares to low-income students for 2017-18, target is substantially exceeded.

CCNV further developed the capacity of the region's specialty crop industry, as evidenced by: 1.) A 100% membership increase of a regional-food-system stakeholder coalition to 40 members 2.) A 53.2% increase in production output and sales of a university student-run organic specialty crop farm; 3.) A doubled network of community and school specialty crop gardens, facilitating: 4.) A doubled amount of fresh specialty crops to institutions, service agencies, and housing projects; 5.) More than doubling of the number of project workshops in bio-intensive specialty crop growing provided to a more than doubled number of participants; 6.) A doubling of the number of culinary preparation/preservation demonstrations to workshops and farmers' markets; 7.) The addition of direct marketing and cottage industry workshops and consulting support, increasing the sustainability of urban farms and the number of local direct marketers; and 8.) Expanded promotion of the project model throughout the North State and at national conferences. 9.) Over 16,000 educational units/direct participant contacts in the project.

Beneficiaries

The primary beneficiaries of CCNV's project accomplishments include:
Those receiving onsite community garden support, consulting and garden-based workshops, and that also received fresh produce from these farm sites, including:

- Small and new specialty crop farmers
- K-12 students, parents, faculty and staff of 15 public and charter school gardens;
- Residents of 11 CHIP and senior Housing Complexes,
- Served communities of 13 nonprofit service agencies including disability-support centers, rehabilitation centers, teen centers, shelters, churches; recreation, wellness and community centers
- Residents of three neighborhoods with formerly derelict properties enlivened as new community gathering spaces dedicated to cooperative specialty crop growing/eating/promotion

Those receiving direct-marketing, cottage industry and value-added-product workshop instruction and consultation, including:

- Small and new specialty crop growers and farmers' market vendors
- CSU, Chico Students
- Community entrepreneurs

Neighborhood and community residents benefitting from the purchase and consumption of specialty crops from the project-supported farm stands, mobile food cart, and CSA membership programs, as well as those benefitting from produce harvesting from the Glean Team program.

Those receiving culinary demonstrations and tastings of specialty crop products, including:

- CSU, Chico students
- Farmers' market customers at three markets
- Participants in neighborhood and community wellness and sustainability events

- Public and charter school students
- Service agency beneficiaries and residents of CHIP housing communities

CSU, Chico students receiving farming and marketing instruction through workshops, college courses, and the CSA training program at the OVP site at the CSU, Chico farm.

High school students in the North State who visit and receive instruction at the OVP during the CUS, Chico farm's OVP Fall and Spring Field Days.

Participants at conferences, farm and wellness events who viewed presentations of the project model.

Stakeholding organizations and their served populations, as well as other cooperating partners achieved greater networking, service capacity and response-capacity as a result of partnership with the project.

It is estimated that the number of beneficiaries of the CCNV project to be over 20,000, including:

More than 2,000 K-18 students and over 2,500 lower-income residents, small farmers, direct marketers gaining vocational and health-saving skills to cultivate, prepare, preserve, purchase, or sell an estimated $500,000 of specialty crops per year.

Over 40 stakeholding organizations (attending stakeholder meetings) and 52 partnering organizations showing increased response-capacity, augmented resources from improved networking, and magnified capability to assist up to 50,000 regional low-income and high-need residents.

The project estimate of the potential economic impact of the project combines the 14 acres of bio-intensively grown produce currently being farmed on project cultivation sites, and the 500-plus growers recently trained to cultivate or increase production of specialty crops for their own use or to direct-market, added to the 200-plus cottage industry participants trained to prepare and sell value-added specialty crop products.

The project team estimate the project has added a minimum of $755,000 worth of newly-grown specialty crop activity over 2.75 years and will see an ongoing $350,000-plus per years' worth post-project, anticipating: a.) 30% of cottage industry trainees go on to sell value-added specialty crop products; b) Community garden/farm sites experience 20% or less per-year attrition post-project; and c.) 25% of trainees who reported increased cultivation upon their own/shared plots average one-fifth acre per person per year during and post-project, with estimated attrition rate of 30% post-project (numbers derived from a 2008 United States Department of Agriculture National Agriculture Statistics Service specialty crop study's ratio of 3,100 acres of specialty crops at UPV of $20 million = $6,451 per acre, scaled down to $5,000 per acre for new/individual growers); d.) Participants' reported increases in personal specialty crop purchasing and consumption habits remain consistent. Additionally, it is anticipated the regional specialty crop economy receiving the added benefit of a 100-150% multiplied economic effect of local specialty crop spending.

Lessons Learned

A university-based, student-run CSA program is difficult to implement sustainably because of the ways it differs from a commercial CSA program: 1) neither unpaid student interns nor hourly-paid students feel the kind of ownership of the business that they would if profits and losses directly impacted their pocketbook; 2)

students come and go--they graduate, so institutional knowledge is difficult to retain in CSA workers; 3) there is not a direct relationship for students between the amount of effort and ingenuity invested, and the amount of compensation they receive.

The project team hope to solve the issue of preserving continuity of accumulated-knowledge/lessons in the future by having a dedicated non-student staff member running the CSA program and training students. Opportunities for students to receive bonus pay based on increases in CSA revenue, to more closely tie the reward-for-effort typically associated with the kind of private enterprises for which the project team are training students is also being explored.

Also, the project team learned that radically simplifying surveys (shortening them to 4-6 questions) made it much easier to obtain participation and cooperation. The surveys for the 2011 SCBGP Project 48 gave much more detailed information, but the respondent pool was smaller and more reluctant.

This project mainly offered workshops to “captive audiences” (e.g., at schools, help agencies, assisted living centers, etc.) that had requested project team efforts, and it was required from the hosting organizations to provide a minimum number of participants. Often these hosting organizations would open the events to anyone interested, so the events were advertised to the general public, with the focus on target populations to guarantee an audience. Though available funds for this project were less than the 2011 SCBGP Project 48, it was surprisingly easy to exceed target numbers with this new strategy.

The OVP fell just short of its completed sales goal for the project’s final year, not counting guaranteed funds from Chico State Associated Students. The project team believe that having a consistent staff member overseeing student farming and marketing training for the OVP’s CSA will create continuity of institutional knowledge and smoother transitions when students graduate and/or leave for the summer or winter break, which should make revenue targets easier to meet.

Additional Information

Please see Attachment 1 for project lists of events and partners.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
26	Los Angeles Farm to School: Developing a Network of Local Practitioners	
Grant Recipient: Occidental College	**Grant Agreement No.:** SCB14026	**Date Submitted:** December 2017
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Project Summary

The Los Angeles Farm to School (LAFS) Network project was designed to support the development and continuation of robust and sustainable Farm to School (F2S) programs throughout Los Angeles (LA) County by creating a network of local practitioners, providing training and technical assistance (TA) opportunities, expanding traditional F2S models to childcare settings, and advancing innovative best practices.

For a number of years before the grant period, instances of childhood obesity and diet-related illnesses were reaching epidemic levels, particularly in low-income LA communities. To mitigate this trend, experts recommended increased consumption of fresh fruits and vegetables in lieu of high-calorie low-nutrient fast foods. At the same time that diet-related illnesses were on the rise, it was documented that a growing number of children were eating the majority of their meals at school, indicating that schools could be the ideal venue to improve access to fresh nutritious foods. Interest in F2S programs had also been growing over the years, and so it was an ideal time to introduce the F2S concept to a wider LA County audience. Not only do F2S programs provide children with healthful food options, but they also teach lessons about nutrition and how food is grown, instilling a life-long appreciation for local California agriculture.

With many years of experience in F2S, the Urban & Environmental Policy Institute at Occidental College (UEPI) saw that a LA F2S Network had the potential to support new and existing programs with local procurement resources, LA-specific training and TA opportunities, networking events, assistance with gardening and nutrition education programming, and centralized communications that could build relationships across synergistic programs to maximize their effectiveness.

As was described above, at a time when instances of diet-related illness and children relying on school food for basic nutrition were steadily increasing, F2S presented a potential solution that could increase access to fresh nutritious foods in schools. Because F2S programs can be difficult to coordinate and implement, particularly for first-time operators, UEPI saw the LAFS Network as an opportunity to highlight best practices and simultaneously support multiple programs struggling with similar challenges. As the founder of the National F2S Network (NFSN), a Regional Lead within the California F2S Network (CFSN), and leader of the California Farm to Preschool (F2P) Initiative, UEPI already had extensive expertise in addressing F2S barriers, and building dynamic networks for coordination and resource sharing, so was well equipped to take on the development of the LAFS Network.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Over the entire grant period, UEPI performed the following activities and tasks to create a robust F2S Network in LA County that increases awareness of and demand for California grown specialty crops and serves F2S program operators, farmers, students, and other stakeholders throughout the region.

Network Development:
Over the course of the grant, UEPI took numerous steps to develop the membership and structure of the LAFS Network. These included building a listserv, tracking F2S programs, and recruiting practitioners, farmers, and nonprofit support organizations to join the Network. UEPI also designed a website to house all of the LAFS Network resources and partner information to make it easily accessible for members and stakeholders. (*note – the abbreviation "F2S" is also inclusive of Farm to Preschool programs)

Listserv:
The simplest way for LA County F2S stakeholders to become involved in the LAFS Network is to join the LAFS Listserv. This listserv allows UEPI to communicate with Network members about relevant events, activities, and opportunities. The listserv also includes several different filter categories, such as "program operator," "farmer," and "support organization" so that communications can be catered to a subset of Network members. At the start of the project, UEPI set up the framework for a listserv and database to track all Network stakeholders. Within the first year of the grant, UEPI had 80 listerv members, and by the end gained an additional 181, for a total of 261 listserv members.

Survey & F2S Program Database:
A primary goal of the LAFS Network is to develop a way of documenting and tracking the progress of F2S programs throughout the County. Over the first year of the project, UEPI focused their efforts on outreach. Staff sent a preliminary survey to 75 school districts and nonprofit F2S/preschool service providers to gauge interest in and status of F2S programs. Staff also recruited several known F2S practitioners and to be advisory partners who would help to inform the development of a more comprehensive F2S program tracking survey and database.

In Year 2 of the project, UEPI used the results of the United States Department of Agriculture (USDA)'s F2S census (from the 2013-2014 school year) to establish a baseline of 36 LA County F2S programs. Staff also worked with partners to identify meaningful F2S indicators that would align with the USDA's F2S census as well as data collected by members of the national and statewide F2S networks. Crafting a survey and database that was compatible with national and statewide statistics took longer than anticipated but set the Network up to collect more significant and useful data in the long term.

In the final year of the grant, UEPI identified and gathered information from a total of 53 active F2S programs in LA County for the program database. This database is not only used to track F2S statistics over time, but is also linked to a program map on the F2S website. The map shows each school site with a F2S program, the type(s) of F2S programs offered (i.e. procurement, school garden, or classroom education), and the program operators, which are often distinct from the school or district. UEPI's partners consistently emphasized that this map would be an extremely valuable feature of the website and a key function of the LAFS Network, as it allows Network members to easily identify similar programs and connect with peers.

Some of the F2S programs in the database are particularly innovative and/or successful. UEPI has designated programs that exhibit F2S best practices as "model programs." In addition to being included on the program map, these programs are given a case study profile on the website so that others can look to them for inspiration and to learn about replicable best practices. By the close of the grant, UEPI identified and recruited eight model F2S programs to join the Network and develop program summaries.

Farm to School Farmers:
After 20 years of experience in F2S, UEPI observed that one of the most challenging aspects of achieving successful F2S programs is engaging the right farmers; those who can meet the supply needs of a given program, have the necessary infrastructure to work with schools, and/or have the desire to engage (in the case of field trips or classroom visits). F2S program operators consistently run into challenges arising from a mismatch between farmer and program. For example, large districts often contact small farmers about local procurement programs. In these cases, all parties tend to end up disappointed and generally discouraged about F2S. UEPI saw that if F2S practitioners were simply connected to appropriate farmers, many of these common barriers could be avoided. For that reason, a key function of the LAFS Network is a system to streamline the process of directing interested F2S program operators to farmers who are willing and able to meet their program needs.

To develop this system, UEPI first conducted extensive outreach to prospective "F2S Farmers." This included 55 local and regional specialty crop producers (who either have the capacity to sell to schools/districts, host field trips, or visit classrooms to engage students in learning where their food comes from). Within the LAFS Network, "F2S farmers" also include distributors selling source-verified California specialty crops and non-traditional field trip hosts such as urban gardens and farmers' market operators. Outreach efforts resulted in 20 F2S farmers committing to join the Network. Of those, UEPI identified eight "advisory farmers" who would provide feedback on the Network's "find a F2S farmer" search tool and assist with recruiting other interested farmers.

The "Find a F2S Farmer" searchable database is housed on the LAFS Network website and allows F2S practitioners to search for F2S farmers based on program type (i.e. procurement, field trip host, classroom visit), as well as product type (fruits vs. vegetables), and "order size," which is defined in terms that are familiar to school food service directors. Users are then directed to appropriate F2S farmer profiles that describe the farm, products grown, and F2S services offered. The goal of the database is to make an initial connection rather than to conduct a transaction or negotiate a formal commitment. Successful F2S programs are all built on strong relationships and communication, so this tool is designed to be a first step that gets initial conversations and relationships off to a promising start.

In addition to the information described above, the F2S farmer profiles also include a section highlighting the operation's "Good Food Purchasing" values. The Good Food Purchasing Program (GFPP) created by the Los Angeles Food Policy Council (LA FPC) and now run by the Center for Good Food Purchasing (CGFP) is a comprehensive institutional purchasing standard that includes the "good food" values of local, sustainable, fair, nutritious, and humane. UEPI partnered with the CGFP to create a profile feature that enables California specialty crop producers to differentiate their products by highlighting their growing and/or business practices that align with the good food values. Because school districts (such as LAUSD) are signing on to the GFPP, this feature has the potential to make F2S farms more appealing to school districts, as buying from them will contribute toward their good food purchasing commitments.

The farmer profiles are populated using a F2S farmer survey that phrases questions in terms that are clear to farmers. To ensure that the survey questions were phrased appropriately for the farmer audience, UEPI worked very closely with the eight advisory farmers on all of the survey details. The survey went through several iterations, and though the process took longer than anticipated, the advisory farmers were satisfied with the results. Once the survey was finalized and tested by the advisory farmers, UEPI staff followed up with the 12 additional farmers committed to joining the Network (20 total). Farmers were enthusiastic about the Network in general and no major issues were reported with the survey.

Farm to School Support Organizations:
Though UEPI has been working on F2S for many years, it is not the only organization in LA County that is operating or supporting F2S programs. The other F2S "support organizations" are independent nonprofits that provide technical assistance and/or run F2S programs for multiple school sites. For the LAFS Network to be inclusive of all F2S programs in the County, UEPI understood that it was critical to develop a role for support organizations within the Network. UEPI invited six support organizations to advise the LAFS project on the development of a support organization directory to be housed on the website. Like the "model programs," each organization has a profile page, describing the F2S services that they offer, and specific populations they serve. By the close of the grant, UEPI had collected information from seven support organizations to be featured in the directory. Feedback from partners and stakeholders indicated that there is a strong interest in this resource.

Website & Promotion:
Over the last two years of the project, UEPI focused significant effort on designing and building a LAFS Network website that unites all of the project activities and components of the Network, and will serve as a foundation for the Network's continued growth into the future. The website is designed to support F2S program development and growth by providing practitioners with a wealth of resources catered specifically to the LA region.

The LAFS Network website has three primary features. First is an interactive map of existing F2S programs in LA County, which is informed by the F2S Program Survey and database described above. In addition to the map, this feature highlights a series of "model programs," allowing stakeholders to learn about F2S best practices in the region. Second is a search tool to identify appropriate "Farm to School Farmers" for a given program. All F2S farmers in the Network are interested in selling California specialty crops to schools and/or offering F2S services (field trips or classroom visits), and can be found in the database. Other local procurement resources relevant to the LA area are also included in this section. And third is a "support organization" directory that lists all of the organizations in the area that operate or provide assistance to F2S programs. After working closely with a diverse group of partners and organizations, UEPI believes that making all of these resources easily accessible to practitioners and other stakeholders will greatly strengthen the F2S movement in the region moving forward.

At the close of the grant the website was fully completed on the back-end, and with only a few exceptions, all of the preliminary program survey information, resources, and profile data had been assembled. However, some minor details and issues around gathering partner information still remained, so UEPI formally launched the website for the public in October http://lafarmtoschool.org/. The overall delay was mainly due to adjusting the website features based on partner feedback and gathering detailed information from over 80 partners (*see

"lessons learned" section for additional description). Though the project has concluded, UEPI remains dedicated to maintaining the LAFS Network.

Network Programs and Projects:
In addition to developing the structure and membership of the LAFS Network, UEPI conducted several programmatic activities and projects for the Network including meetings and events, trainings and direct technical assistance (TA), and pilots designed to identify best practices.

Meetings and Events:
Over the course of the grant, UEPI held eight stakeholder meetings with a total of 141 attendees. The LAFS meetings were designed to provide networking opportunities, gain stakeholder feedback on the vision for the Network and aspects of its development, share best practices, and assess common F2S challenges and priorities. The meetings also provided a space to explore ways in which the Network might help address common F2S barriers through resources, trainings, events, or other coordinated efforts.

From mid-May to early June 2017, during the final reporting period, UEPI held three Network meetings with stakeholders from throughout LA County. These events were hosted by active LAFS Network partner organizations; Growing Great, Pasadena Unified School District (PUSD), and Social Justice Learning Institute. They were held at locations across the County for attendees' convenience and to foster more localized networking. The events introduced attendees to the resources and opportunities offered by the Network, discussed future Network possibilities, included interactive networking and brainstorming activities, and highlighted the F2S work of host partners.

Trainings and Technical Assistance:
During the grant period, UEPI staff provided workshops, trainings, and/or direct technical assistance to 575 F2S practitioners and stakeholders, representing over 100 LA County preschool and K-12 sites. As experts in Farm to Preschool and as the leader of the Statewide California F2P Initiative, many of the training sessions were geared toward F2P practitioners. However, UEPI also offered workshops or direct technical assistance to over 20 K-12 programs.

Pilots:
UEPI worked on three pilot projects over the course of the grant to explore innovative program concepts and identify best practices that could be replicated by other programs. These included a *Garden to Cafeteria* pilot with Pasadena Unified School District (PUSD), a Local Harvest of the Month pilot with Sustainable Economic Enterprises of Los Angeles (SEE-LA) and Pacific Asian Consortium in Employment- Early Childhood Education (PACE-ECE), and a Preschool Farmers' Market Field Trip pilot with St. Joseph Center Early Childhood Education Center and the Santa Monica Farmers' Market.

Garden to Cafeteria~
Before the Garden to Cafeteria (G2C) pilot, PUSD already had a strong and well-established F2S program that integrated the three F2S components of local sourcing, school gardens, and classroom education. In addition to having gardens at nearly every school as well as a staff garden instructor, PUSD had seven "production gardens." While most of the District's gardens are used only for educational purposes, the production gardens are run by older students and can produce enough fruits and vegetables to collectively support a G2C program. Leading up to the pilot, the PUSD School Board had recently passed a non-binding

resolution to source 2% of cafeteria produce from school gardens that would serve the District's 19,100 students. In 2015, UEPI formally partnered with PUSD to help document and evaluate the pilot roll out of their G2C program.

In the 2015-2016 school year, PUSD worked with the Department of Public Health to develop a manual for garden production that would guide district-wide implementation of the G2C model and ensure that all of the specialty crops served in the cafeteria would meet food safety standards. During this time, UEPI also worked with PUSD to plan out the strategy for documenting and evaluating the pilot. UEPI's primary role on the pilot was to analyze the evaluation data, assess the program's successes and barriers, and develop a Garden to Cafeteria Best Practices Guide that could be used by other districts interested in creating similar programs.

Once the production garden sites were determined to be compliant with the safety standards outlined in the manual, the District coordinated with each of the sites to grow and harvest one specialty crop per month that would be purchased collectively by PUSD's Food Service Department as a "micro-purchase." In the 2016-2017 school year, the PUSD Food Service purchased a specialty crop item from the production gardens each month as a part of the District's "California Thursdays" program (in which all food served on a given Thursday is produced in California). The items were either offered in the salad bars or incorporated into recipes. According to interviews with PUSD staff, students were very enthusiastic about all of the G2C produce items, and consumed more of them, even in cases where a substitute item was served.

Over the course of the pilot, UEPI staff collected data, researched other best practices in G2C programs, and also conducted extensive interviews with key PUSD staff members leading the program in various departments. UEPI then drafted a best practices guide in early March and sent it out to G2C practitioners throughout the state to review and provide feedback. In the final reporting period, UEPI held a group interview with all of the PUSD staff leading the program to assess finding and recommendations after the pilot had concluded, and then synthesized all partner feedback into the best practices guide.

Some of the primary takeaways from the pilot had to do with preparation, communication, and flexibility. PUSD staff emphasized that having established production gardens and food safety standards in place before the start of the pilot was essential. This eased the relationship with the Food Service Department by guaranteeing safe produce and a (relatively) consistent supply. Staff also agreed that the most important factor in a successful G2C program is buy-in from and communication between all departments involved; in this case the Food Service, Student Health, School Garden, and Facilities Maintenance Departments. Key staff communicated regularly throughout the pilot and also convened bi-monthly Farm to School meetings. PUSD staff also reported that flexibility and the ability to troubleshoot was key to their success. Produce was not always available on precise dates and some crops thrived beyond expectations while others did poorly. In all cases, Food Service had to improvise and adjust, and sometimes use backup sources. One month, this improvisation resulted in a "pumpkin-peach crisp" due to the unexpected availability of 400lbs of pumpkins. Though the cafeteria staff had to change plans on short notice, it was the students' favorite G2C dish all year.

Local Harvest of the Month (Farmer in the Classroom) ~
At the beginning of the project, many sites expressed an interest in participating in LA F2S Local Harvest of the Month (Farmer in the Classroom) pilot. In 2015, UEPI solidified plans with two strong partners; SEE-LA and PACE-ECE for a local Harvest of the Month (HOTM)/Farmer in the Classroom pilot. The goal of the

pilot was to examine the educational value and feasibility of a HOTM/Farmer in the Classroom model that pairs farmers' market operators with school/preschool sites.

In the 2015-2016 school year, all PACE teachers and site directors were trained on the Farm to Preschool HOTM curriculum (developed by UEPI). Teachers also received a refresher training the following year, as the majority of pilot activities were conducted in the 2016-2017 school year.

Beginning in May 2016, SEE-LA, a LA farmers' market operator, arranged for four local farms to participate in the pilot. These farms delivered seasonal specialty crops to PACE's central kitchen. From there, it was distributed to PACE's 14 sites with 69 classrooms (1,087 preschoolers) for in-class HOTM taste tests and snacks. The pilot began in May with a smaller-scale launch at only eight school sites. Although UEPI initially thought the pilot would only be able to provide taste test experiences to some classrooms, the springtime launch proved successful, so the pilot was expanded to all of the school sites and classrooms for the 2016-2017 school year, beginning in September and running through May of 2017. Over the course of the school year, preschoolers tasted California grown avocados, tomatoes, sweet potatoes, squash, persimmons, carrots, kiwi, tangerines, grapefruit and cucumber. Preschool teachers were also provided with the HOTM curriculum and any materials needed for pilot activities.

The SEE-LA HOTM coordinator, PACE Nutrition Director and PACE kitchen staff met periodically with UEPI staff to evaluate the pilot's progress. Pilot feedback forms were also distributed in spring 2017 to all teachers and site directors, and slight changes were made along the way to improve the pilot. For example, the produce list for the year was changed to include more ready-to-eat fruit and vegetable items that did not need to be cooked (i.e. Kiwis replaced cooking greens in February).

Initially UEPI envisioned this project would incorporate a Farmer in the Classroom visit, but due to the recent passage of SB792: Vaccines for Day Care Workers, effective September 2016, (which mandates that all childcare employees and volunteers must have a recent vaccination for influenza, pertussis, and measles), PACE-ECE now requires that all volunteers (including day time visitors) have adequate titers (antibodies) to Measles and Pertussis. The Famers that work with SEE-LA's Farmer in the Classroom program are screened for TB and undergo a criminal background screening to visit local school district classrooms but this additional testing is unfunded and an extra step that the farmers were not prepared to take. Therefore, this part of the program was cut. SB 792 is also affecting plans for parents to participate in the building and maintaining of school gardens. Most parents do not have the means to pay for the titer and therefore participation has dramatically decreased at PACE-ECE sites in general.

Despite this issue, the pilot was successful overall and PACE plans to continue collaborating with SEE-LA for the 2017-2018 school year without UEPI's support. This demonstrates that the program is sustainable and can potentially be replicated by other Head Start sites. Full pilot findings are presented in a final write up of best practices for Local HOTM programs.

Preschool Farmers' Market Fieldtrip ~
Over the 2014-2015 school year, UEPI worked with five ECE sites to develop a farmers' market field trip curriculum. Though all partners expressed interest in participating in a pilot program, various logistical and scheduling issues set the project timeline back, and it became apparent that the best partners for the pilot were the City of Santa Monica (which administers the Santa Monica Farmers' Market) and St. Joseph Center Early

Childhood Education Center, a preschool in Venice, California (near the Santa Monica Farmers' Market) that serves low-income families.

During the summer of 2016, UEPI staff trained teachers on the HOTM curriculum, which was implemented in the 2016-2017 school year, and also met with St. Joseph Center staff to share specific lesson plans created by other sites in LA County that would complement the Farm to Preschool HOTM curriculum. In addition, UEPI worked with Santa Monica Farmers' Market to develop a specific curriculum for the Farmers' Market pilot that took place in April 2017 with 32 preschoolers. Teachers interviewed after the pilot reported that preschoolers greatly enjoyed the field trip and accompanying curriculum and activities, and many demonstrated increased enthusiasm for trying new fresh fruits and vegetables.

After the field trip, UEPI also compiled the final curriculum and lesson plans into a best practices manual for preschool sites and farmers' market operators. Santa Monica Farmers' Market has adopted this manual and now uses it for their school field trip program for young children.

The overall scope of the project benefitted no commodities other than specialty crops. Throughout the grant period, increased procurement, consumption, and promotion of California-grown specialty crops in schools, districts, and early childhood education sites has remained the primary focus of the LAFS project. All LAFS program activities, including F2S pilots, trainings, data collection, and promotion efforts were designed to advance these goals and to develop strategies and tools that would streamline the purchasing and consumption of California specialty crops for school children in LA County. Additionally, all of the F2S farmers in the Network database grow (or sell) California specialty crops.

The LAFS Network is made up of project partners, so it could not exist without their participation. Throughout the grant period, partners have also played integral roles in all aspects of the Network's development including survey creation and data collection, member outreach and recruitment, website development, hosting of Network events, and participation in pilots. Each component of the Network has benefitted from advisory partners' expert advice as well as insights from model program, support organization, and farmer partners. The role of LAFS partners even extends to other supporting Networks such as the California Farm to School Network, in which UEPI is the LA Regional Lead, and the Los Angeles Food Policy Council, in which UEPI has taken on leadership of the Farm to School & Garden Working Group. The structure and resources provided by these partner Networks will also contribute to the continued development and growth of the LAFS Network into the future.

Goals and Outcomes Achieved

Over the course of the grant period, UEPI made continual progress toward achieving the expected measurable outcome of increasing demand for California specialty crops through the creation of the LAFS Network. UEPI, along with project partners, met the project's performance goals and corresponding targets in the following ways:

1) 25% Increase in F2S Programs:
UEPI surpassed the performance goal and target of a 25% increase in the number of LA County Farm to School programs. UEPI first used data from the USDA's F2S census (2013-2014 school year) to establish a baseline. At the start of the project, there were a reported 36 F2S programs in LA County. Through extensive

outreach, recruitment, and technical assistance efforts, UEPI increased this number to 53 programs by the close of the grant, achieving a nearly 47% increase.

2) 500 Individuals representing 30 F2S Programs Receive Training &TA: UEPI also exceeded the target of training 500 individuals representing 30 programs on F2S best practices to facilitate program development. Through workshops, trainings, and direct technical assistance offered over the course of the grant, UEPI trained 575 individuals representing over 100 LA County preschool and K-12 sites.

3) Increase Network Membership among Farmers, School Programs & Support Organizations: To ensure that all F2S stakeholders would have opportunities within the Network, UEPI established a variety of ways for different types of partners to engage. All stakeholders are encouraged to join the listserv and attend events and meetings. Additionally, practitioners can register and highlight their programs through the F2S survey. Programs that demonstrate best practices or lessons learned can be featured as “model programs,” California farmers (or distributors selling source-verified California specialty crops) can join the farmer database, and nonprofits operating or assisting F2S programs can sign up for the “support organization” directory.

Over the course of the grant, UEPI signed up 261 listserv members, 53 F2S programs (including eight model programs), 20 F2S farmers, and seven local support organizations. LAFS gatherings and events were also attended by 141 stakeholders over the grant period. All of these performance measures indicate that Network membership among famers, school programs, and support organizations increased significantly over the grant period.

4) Increase Number and Quality of Experiential F2S Education Programs:
Experiential education, in which a student has the opportunity for hands-on learning in the field, is an important aspect of F2S. Experiential F2S education programs include field trips to farms or urban gardens, as well as garden education at school. Of the F2S programs in the LAFS Network, 34% have an experiential component. Thirty-five percent of the F2S farmers in the Network offer to host field trips, and UEPI staff worked with several of these farmers on strategies to better communicate their services to a school audience. One hundred percent of the F2S support organizations offer assistance with experiential education programs. And additionally, over 500 of the practitioners trained by UEPI staff received instruction on best practices for running experiential F2S education programs. A significant portion of programs and activities added to the Network over the grant period include an experiential component, demonstrating an overall increase in both quantity and quality of experiential F2S education programs.

5) Increase awareness and use of F2S resources and materials by 50%:
UEPI conducted several activities to increase awareness of F2S resources and best practices. These included writing up best practices from the three F2S pilots, developing program summary profiles for 15 model programs and support organizations, gathering data and information from 20 F2S farmers, and collecting over 20 F2S resources produced by Network members, all to be shared on the LAFS website. Though the primary mechanism for disseminating all of these resources is the website, UEPI also shared resources during the grant period at practitioner trainings (575 individuals), and Network gatherings (141 attendees). Moving forward, the website is set up to significantly increase awareness of all of these F2S resources and streamline access to them.

Though the majority of targets identified for the project period were met or exceeded, all of UEPI's LAFS Network goals are long-term. Though there was a 47% increase in F2S programs over the grant period (surpassing the 25% target), UEPI plans to continue outreach and recruitment efforts into the future. Though 575 individuals received F2S technical assistance and training, UEPI is also continuing efforts to help practitioners expand programming through trainings on an ongoing basis. While Network membership among farmers, support organizations, and program operators –including experiential education programs– increased (from 0-80), UEPI plans to continue actively engaging all project partners, expanding the LAFS listserv, and emphasizing the importance of experiential education in future projects. And finally, though the website –the primary means of increasing awareness about the LAFS Network– was not utilized during the grant term, UEPI still raised awareness by training 575 individuals and hosting 141 attendees at Network meetings. Additionally, UEPI collected data and program information from 80 partners to feature on the website.

UEPI met or surpassed the targets outlined for the majority of project goals in the final reporting period. Increasing awareness and use of F2S resources and materials by 50% was not accomplished through the website as originally anticipated but conducted through trainings and Network meetings that promoted resources and provided instruction on their use. Significant data, information, and resources were also collected during the reporting period to be shared via the website moving forward.

Because the LAFS Network did not exist before this project, many of the baseline numbers for achieving goals were "0." However, the baseline data gathered and progress toward achieving targets is outlined as follows: (*note- see response above for more detailed descriptions)

1) 25% Increase in F2S Programs:
- Baseline = 36 programs (based on USDA F2S Census data from 2013-2014 school year).
- F2S programs in Network = 53 (47% increase).

2) 500 Individuals representing 30 F2S Programs Receive Training &TA:
- Baseline = 0 Network trainings, workshops, or direct TA
- Individuals trained = 575
- F2S Programs represented = 100+

3) Increase Network Membership among Farmers, School Programs & Support Organizations:
- Baseline = 0 Network members
- Listserv members = 261
- F2S programs in Network = 53
- Model programs = 8
- F2S farmers = 20
- Support organizations = 7
- Network meeting attendees = 141

4) Increase No. and Quality of Experiential F2S Education Programs:
- Baseline = 0 experiential F2S education programs in Network
- Experiential F2S education programs in Network = 18 (34%)
- F2S farmers offering experiential education services = 7 (35%)

- F2S farmers who received TA on marketing experiential education services to school audience = 4
- F2S stakeholders trained on experiential education best practices = 500+

5) Increase awareness and use of F2S resources and materials by 50%:
- Baseline = 0 individuals aware of LAFS Network resources and materials
- Individuals introduced to LAFS Network resources and materials through trainings or TA = 575
- Individuals introduced to LAFS Network resources through meetings = 141

The expected measurable outcome of the LAFS Network project was to increase demand for California grown specialty crops through the development of the LAFS Network and associated activities and programs. The major successful outcomes of the project included; creating a listserv with 261 members, identifying and collecting data from 53 F2S programs, recruiting 20 F2S farmers, developing program summaries for 8 model programs and 7 support organizations, training 575 F2S stakeholders representing over 100 school and preschool sites, and hosting 141 stakeholders at Network meetings.

Beneficiaries

The LAFS Network is designed to benefit California specialty crop growers, all partners, members, and other F2S stakeholders in the LA area. UEPI also considers direct beneficiaries of the project to include listserv members, F2S program operators and participating students, model programs, F2S Farmers, support organizations, training attendees, Network meeting attendees, and pilot participants. Additionally, partner networks, including the CFSN and LA FPC, also benefitted from the LAFS Network as it supports their work and overarching goals.

UEPI estimates that 21,014 individuals (California specialty crop growers, school-aged children, and organizations benefitted directly from the LAFS Network project activities. This estimate adjusts for duplicates and includes 53 F2S programs (including 8 model programs), 20 F2S farmers, (*note- this group includes 1 farmers' market operator representing over 30 specialty crop producers and a food hub with 5 specialty crop members, so the estimate could be expanded) 7 support organizations, 575 training attendees, 141 meeting attendees, 261 listserv members, and 20,219 school-aged children participating in pilot programs. It should be noted that this assessment includes only direct beneficiaries of LAFS program activities. Factoring in all of the children benefitting from F2S programs at schools within the Network would bring this number to over 800,000 students.

UEPI looked to the number of F2S programs in the County as an indicator of demand and economic potential for CA-grown specialty crops. The 47% increase in F2S programs over the course of the grant implies that demand for specialty crops has also increased, strengthening the California specialty crop industry as a whole. Each component of the Network was also developed to showcase California specialty crops as a key element of successful F2S programs. Therefore, as the Network grows and develops, so will demand for California specialty crops.

Lessons Learned

After completing the project, the primary insights and lessons learned by UEPI staff had to do with partners' buy-in, feedback, and contributions. When working with practitioners and representatives from other networks to develop the F2S program survey and database, partners provided excellent insights and

suggestions. However, incorporating their feedback and reworking the survey several times did delay the project timeline.

Similarly, the process of outreaching to and engaging F2S farmers was extremely time consuming, but ultimately worthwhile. Because farmers are so busy, it can be very challenging to get in touch with them. Additionally, in terms of outreach, it was often difficult to locate current contact information, and UEPI staff found that farmers were significantly more likely to respond to a call or email from someone they already know. Therefore, the most successful outreach efforts extended from existing contacts and relationships.

In the end, UEPI staff agreed that these working relationships with partners were critical to the project's success. However, in the future staff would also make sure to allot more time for any project components that involve coordinating with multiple partners or that require partner feedback.

The most unexpected outcomes or results of the project all came out of conversations with F2S farmers that run small-scale specialty crop operations. UEPI staff were surprised to learn about several aspects of the website profile and Network functions that appealed to these partners. Though UEPI staff designed the presentation of F2S farmer information to benefit school audiences, the farmers contributing information reported that the format and questions helped them to frame their businesses and services in a way that would benefit them even beyond the F2S audience. UEPI staff were particularly surprised by farmers' enthusiasm for the section of the profile highlighting "good food purchasing" values. UEPI assumed that farmers might view this section as a chore, but farmers reported that the breakdown of values helped them to articulate many of the ideals that drive their small-scale operations and differentiate their products.

UEPI staff were also surprised by the number of small-scale farmers who expressed interest in hosting field trips, but felt that they needed additional guidance from the Network before doing so. Though small-scale growers may be able to sell their products to schools as snacks/taste tests or to small schools and preschool sites, most do not have the volume of product or capacity to partner with large districts on procurement. Therefore, F2S services such as field trips or classroom visits are frequently the best way for small farmers to engage in F2S.

The only deliverable that was not accomplished according to the original project schedule was the launching of the Network website. Due to the complexity of several of the website features, the development process took longer than anticipated. Though the site was fully developed by the end of the grant period on the back-end, UEPI was delayed in formally launching the site due to the process of gathering and finalizing information from all of the many partners involved. Given the situation, the LAFS Network partners all agreed that it would be better to make the website public once all of the information was up to date, so they suggested that the best opportunity to launch the site publicly and highlight their work would be October 24, 2017, which is "food day," and also in the midst of "Farm to School Month." The website was successfully launched in October http://lafarmtoschool.org/. Partners have given good responses thus far, and since the launch several more have expressed interest in joining, so adding and updating profiles and growing the Network continue.

The primary lesson learned was that the website is a highly ambitious project with many partners to coordinate, which turns out to be a recipe for a slow process requiring many revisions. However, despite the

delays, the website and resources offered on it have consistently been the aspect of the Network that partners are most enthusiastic about and excited to engage in. Over 80 partners have contributed information about their F2S programs or specialty crop businesses to be shared on the website, which formalizes their membership and creates a sense of buy-in that a simpler format could not have achieved. Additionally, member participation makes the resources offered much more comprehensive and useful to all stakeholders. Though a simpler project could have been completed more quickly, UEPI believes that investing in partners and a thoughtfully developed system for sharing information will significantly bolster the LAFS Network and F2S movement in the long term.

Additional Information

See Attachments 1-3

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 27	**Project Title:** Increasing the Awareness and Profitable Use of High-Performing Grafted Varieties by California Fresh Market Tomato Growers	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB14027	**Date Submitted:** December 2017
Recipient Contact: Minghua Zhang	**Telephone:** (530) 752-4953	**Email:** mhzhang@ucdavis.edu

Project Summary

The specific need addressed by this project was to fill a gap in the information on the performance of grafted fresh market tomatoes in California production systems. Data from around the world have fueled a widely-held perception that grafted tomato plants can be economically viable in commercial production systems. The grafted tomato plants use in commercial production is extensive in Europe and Asia, and promising results have been obtained recently in eastern United States (US). However, California's production systems differ from others in several important respects:

- The tomato varieties used are uniquely adapted to California's growing conditions
- Tomatoes are grown predominantly in open-field systems, rather than protected culture
- Harvesting is typically performed only once, while the fruit are green

Because of these differences, the results obtained in field trials elsewhere do not necessarily apply to California's production systems. Therefore, the main goal of this project was to obtain data on the performance of standard California fresh market tomato varieties as scions grafted onto high-performance commercial rootstocks and grown in commercial field settings in San Joaquin and Merced Counties.

This project is important because it provides, for the first time, data on the suitability and potential profitability of using selected grafted tomato plants in growers' fields in California. It is timely because of the recent surge of interest in grafted tomatoes in the US. One of the key factors in the commercial success of grafted tomatoes is keeping the per-plant cost down, and the increasing interest in grafted tomatoes in the US in the past decade has implications for the future of the US grafted plant industry infrastructure, and, therefore, pricing. Specifically, broader adoption of grafted tomatoes may allow the industry in the US to achieve the same "economy-of-scale" that now facilitates the affordability of grafted plant use on a commercial scale in Europe and Asia.

This project did not build upon a previously funded Specialty Crop Block Grant Program (SCBGP) project.

Project Approach

The activities and tasks performed throughout the project fall into three categories:

1. Literature Review and Meta-Analysis:

A thorough review of current knowledge about the performance of commercial rootstocks in prior field and greenhouse trials was conducted by surveying published literature.

Queries of three standard bibliographic databases and two online sources yielded 163 studies that reported either yield or fruit quality data from both grafted tomatoes and either the non-grafted or self-grafted scion varieties in the same experiment.

This task helped project staff to choose a key rootstock (Maxifort) among the dozens of available commercial rootstocks to use in the field trials. Maxifort is, by far, the most widely used rootstock in field trials around the world. In dozens of trials with 43 different scion varieties, it has produced an average yield increase of 29%, and it is resistant to seven different soil-borne pathogens (see rootstock table at: http://www.vegetablegrafting.org/tomato-rootstock-table/). Based on these features, project staff decided to include it in their field trials.

A summary of data on the widespread use of Maxifort in previous field trials is presented in a table on the project's website (http://agis.ucdavis.edu/Research/tomato/literature.html). The performance data for Maxifort in the 2016 Merced and San Joaquin trials funded by this grant are presented both in that table and in the Growers Guide to Grafted Tomatoes (Attachment 1). The graph on the website shows that in the San Joqauin trials, Maxifort-grafted plants performed well, giving a yield boost typical of trials elsewhere, while their performance in the Merced trials was extremely poor—suggesting that conditions in Merced County may not be optimally suitable for this rootstock.

2. Conducting field trials with grafted tomatoes in San Joaquin and Merced Counties:

Field trials were conducted in the 2015 growing season, but problems with the grafted plants prevented project staff from obtaining useful data from those trials.

These issues were avoided in the 2016 growing season. The 2016 trials were carried out in commercial fields near Vernalis (San Joaquin County) and Le Grand (Merced County) in cooperation with growers at Pacific Triple-E and Live Oak Farms, respectively. Detailed descriptions of the experimental design and results are elaborated in the Growers Guide to Grafted Tomatoes (Attachment 1) and on the website dedicated to this project. The rootstock and scion varieties included in the project's trials are shown in Table 1 below.

In the published literature on grafted tomatoes, statistically significant yield increases are not always achieved, and often vary from scion-to-scion within an experiment. For example, of 105 field trials with data on yields obtained with non-grafted versus Maxifort-grafted plants, 79 indicated whether the two were statistically significantly different (see the graph on project's website). Less than half of them, 33 of the 79 (42%), found a significant yield increase in Maxifort-grafted plants. The project's trial results also showed variation among scion varieties. Only one grafted combination, Bobcat/Maxifort, produced a significantly higher yield (60% increase) than the non-grafted scion (Bobcat) in the San Joaquin trial, and none did in the Merced trial (Table 1).

Table 1. Yields obtained from grafted and non-grafted varieties in the 2016 San Joaquin and Merced field trials.

#	Vdq#Mrdtxlq#Frxqw#wldq#						Phufhg#Frxqw#wldq#				Frpelqhg#	
VFIRQ#	Wrwdo#lhog[v]#			Pdunhw#lhog[v]#			#	Wrwdo#lhog#	Pdunhw#lhog#		Pdunhw#lhog#	
URRWVWRFN#	lhog#	#	(#glii[v]#	lhog#	#	(#glii#	Q#	lhog#	\lhog#	(#glii#	lhog#	(#glii#
EREFDW#	#		#				#	#	#	#	#	#
PD[IIRUW#	5;53#	def#	84(#	#5573#	d#	93(#	6#	679<#	5845#	(:(#	56:9#	49(#
GU346;W[#	57;;#	defg#	66(#	#4<35#	def#	69(#	7#	6;8;#	5988#	04(#	#55:<#	45(#
EV34876:89#	5677#	defg#	58(#	#49<:#	def#	54(#	7#	7535#	6539#	4<(#	#5785#	53(#
QRQQJUDIWHG#	4;:3#	#fg#	#	#4735#	ef#		7#	69;<#	59;:#	#	#5378#	#
KP4:<7#	#		#	#			#	#	#	#	#	#
PD[IIRUW#	65:9#	d#	64(#	#5557#	de#	4:(#	6#	6:99#	5;<6#	049(#	#588<#	07(#
GU346;W[#	5:53#	def#	;(#	#5457#	de#	45(#	7#	695<#	5948#	057(#	#56:3#	044(#
QRQQJUDIWHG#	583<#	defg#	#	#4<37#	def#		7#	7999#	675;#	#	#5999#	#
EV34876:89#	5:5;#	def#	<(#	#4:99#	def#	0:(#	7#	7;76#	69:4#	:(#	#5:;4#	5(#
GL[IH#UHG#	#		#	#			#	#	#	#	#	#
GU346;W[#	6369#	de#	73(#	#5335#	def#	64(#	6#	8349#	689<#	0;(#	#5:;9#	6(#
PD[IIRUW#	5::;#	def#	5;(#	#4<9:#	def#	5;(#	6#	6<7;#	548;#	(77(#	#5396#	057(#
EV34876:89#	6388#	de#	74(#	#4<77#	def#	5:(#	7#	7;4<#	69:8#	(8(#	#5;43#	7(#
QRQQJUDIWHG#	5499#		#	#4866#	def#		7#	8646#	6;97#	#	#59<<#	#
JDOIOHD#	#		#	#			#	#	#	#	#	#
PD[IIRUW#	5395#	#efg#	57(#	#4:48#	def#	56(#	7#	6:58#	55;4#	0<(#	#5333#	5(#
GU346;W[#	48:6#	#fg#	08(#	#4747#	def#	4(#	7#	659;#	53<<#	(4:(#	#4:8:#	043(#
QRQQJUDIWHG#	4996#	#fg#	#	#46<<#	ef#		7#	679<#	5849#	#	#4<8;#	#
EV34876:89#	4874#	#fg#	0:(#	#45;5#	#f#	0;(#	7#	6;:6#	5858#	3(#	#4<37#	06(#

Values represent the means of 4 observations in San Joaquin and either 3 or 4 in Merced as indicated. Means in the same column followed by the same letter are not significantly different according to Tukey's HSD test (San Joaquin) or Fisher's protected LSD test (Merced).

[v] Yields in 25 lb-boxes/A. Total yield includes culls and undersize fruit, while marketable yield excludes these two categories.

[w] Percentage difference in yield of grafted plants compared to the non-grafted controls.

An economic analysis accounting for costs and returns in California fresh market tomato production was performed to assess the economic viability of grafted plants in the project's trials (see Table 1 in Attachment 1). The results suggest that the yield increases in the San Joaquin trial for Bobcat/Maxifort (60%), and possibly those for Bobcat/DR0138TX (36%) and Dixie Red/DR0138TX (31%), may be sufficient to achieve economic viability. However, additional trials in 2017 and 2018, funded by non-SCBGP projects, will help the project staff to determine the consistency of the results of the 2016 field trials for the California production systems.

3. Outreach and education:

The results of the field trials were communicated to various stakeholders through workshops, field days, and printed and online media. The following outreach materials were produced to communicate the results of the project activities to growers, regulators, researchers and other stakeholders:

- Two peer-review articles were submitted for publication in the following scientific journals: *Agronomy for Sustainable Development* and *European Journal of Agronomy*. Unfortunately, the articles are still in the review process.

- A dedicated website for project results and for downloads of outreach materials by stakeholders such as http://ucanr.edu/sites/veg_crop_sjc/Grafted_tomatoes/
- Growers Guide to Grafted Tomatoes, 1st Edition, 10 pp. (Attachment 1)
- Quick Guide to Grafted Tomatoes, 1st Edition, brochure (Attachment 2)
- Article for growers newsletter *Field Notes, San Joaquin County* (Attachment 3)
- Article in the Merced County Farm News, May 2017. Vol. 112 No. 5. www.mercedfarmbureau.org.

In addition, four outreach events were held to further communicate results and facilitate face-to-face discussions of the relevant issues with growers and other stakeholders. Announcements for the three events, and the sign-up sheet for the Field Day are included in Attachment 4.

- Thirty-three attendees signed the sign-up sheet at the Fresh Market Tomato Field Day on August 9, 2016 in Le Grand, California. This event involved field tours by a variety of stakeholders, as well as answering their questions about grafted tomatoes in general and the trials.



- Presentation titled “Influence of Grafting on Fresh Market and Processing Tomato” was presented by University of California Cooperative Extension (UCCE) collaborators at the Vegetable Crop Research Update meeting located at the University of California, West Side Research and Extension Center in Five Points, California on February 22, 2017.
- Presentation titled “Vegetable Crop Disease and Grafted Vegetables for Disease Control” was presented by a UCCE collaborator at the Continuing Education for Pest Management Professionals, located at the UCCE in Merced, California on March 28, 2017.
- Poster presentation titled “Exploring the Potential for Grafted Tomatoes to Increase Yields, While Decreasing Soil Fumigant Use, in California” was presented at the American Society of Agronomy annual meeting on November 15-19, 2015 in Minneapolis, Minnesota.

The project involved only grafted fresh market tomatoes; therefore, it solely enhanced the competitiveness of specialty crops.

The project partners included the project's grower-cooperators (Pacific Triple-E and Live Oak Farms), both of whom contributed plots in their commercial fields for the experimental treatments. Their staff also maintained the fields, and treated the project's experimental plots of grafted tomatoes along with the main field with respect to fertilizer, pesticides, and irrigation.

In addition, with assistance from the project UCCE collaborators, the staff at Growers Transplanting Inc. (Salinas, California) produced the grafted plants. Their expertise in the "cutting and splicing" processes, as well as the healing chamber facilities and appropriate conditions for plant recovery from the grafting process, were instrumental in producing the thousands of grafted plants for the project's field trials.

Goals and Outcomes Achieved

The following activities were completed in order to achieve the performance goals and measurable outcomes of the project:

- Goal 1 (Choose Rootsocks): The appropriate data from 163 published studies were analyzed. Many published studies on grafted tomatoes were rejected because the results of various experimental treatments of grafted plants were not directly compared to results from either non- or self-grafted plants of the scion variety. Many others were rejected because they reported only data on vegetative plant growth or resistance to specific pathogens, but no data on fruit yield or quality.
- Goal 2 (Determine Field Performance): Yields and an economic assessment were performed for 12 grafted variety combinations and the four non-grafted scion varieties. Results are presented in Table 1 above, and are discussed in more detail in the Growers Guide to Grafted Tomatoes (Attachment 1).
- Goal 3 (Knowledge Transfer): The trials for Year 1 (2015) did not yield trustworthy data so the outreach effort did not begin until after the Year 2 (2016) field trials. There were approximately 40 attendees at the 2016 Field Day workshop, with 33 of them signing the sign-up sheet. The outreach efforts included printed and online media as well as stakeholder presentations.

The ultimate goal of this project was to determine the economic and environmental benefits of using grafted fresh market tomatoes in California field conditions and increase their adoption by conventional growers in California when they would offer benefits. Since a substantial increase in adoption by growers would likely be gradual and is unlikely to be achieved during the grant period, the more immediate outcome is to increase awareness among stakeholders of the new knowledge that this project generated regarding grafted fresh market tomato performance in California field conditions. By doing so, project staff hope to create less risk-averse growers who will adopt grafted fresh market tomatoes in circumstances where they make sense.

While the project's expected short-term outcomes were to increase knowledge and awareness of grafting, their expected middle- and long-term outcomes were to change attitudes among growers and to see an increase in adoption of the practice. Project staff have indeed observed the beginnings of these changes in attitude and behavior among local growers with whom they interacted with during the project. A few local growers revealed changes in attitudes or intentions in their conversations with project staff (e.g. "Maybe we'll try some grafting next year", "Where do I find rootstock seed?", and "How much do the plants cost?"). The transplant greenhouse also fielded questions from a few growers, indicating further interest or planning. In San Joaquin County, two processing tomato growers indicated to project staff their plan to plant a small

portion of their acreage with grafted plants for the 2017 season and project staff confirmed that this did happen in two local fields. While this change in behavior cannot be credited solely to the project team's efforts, project staff do know that their information was part of what the growers considered as they made their decisions. Project staff have not yet observed adoption of grafted plants among fresh market tomato growers, but they expect changes in behavior will be slow and they do know that one major grower has indicated their interest in conducting their own trials of grafted plants on a larger scale than the project's evaluations.

The actual accomplishments compared favorably with the goals established for this project.

Goal 1. Review of current knowledge on the performance of commercial rootstocks in grafted tomato production. A thorough review of all available literature on this topic was conducted; and it helped project staff to choose rootstock Maxifort for the field trials. The review also helped project staff to put the results of their 2016 field trials in the context of results from field trials conducted around the world (see Growers Guide to Grafted Tomatoes, Attachment 1) and the graph of yields obtained with Maxifort rootstock in previously published field trials on the project website. The graph on the website shows that the project's Maxifort yields in San Joaquin (the four red bars on the left) were comparable to results obtained elsewhere, with yield increases ranging from about 20-60%. In contrast, in the Merced trials Maxifort-grafted plants performed extremely poorly (the four red bars on the right), with Maxifort-grafted to non-grafted plant yields of less than one.

Goal 2. Obtain data on fruit yields from grafted tomato field trials in California. While the Year 1 (2015) trials were not successful due to problems with the plant grafting, reliable fruit yield data were obtained from the Year 2 (2016) trials in San Joaquin and Merced Counties.

Goal 3. Raising awareness of the potential for profitable use of grafted tomatoes in California among stakeholders through outreach efforts. Project staff conducted a Field Day during the Year 2 (2016) trials, gave presentations at indoor stakeholder meetings, and produced several different text-based outreach materials (Growers Guide, brochure, newsletter article, journal articles, and a dedicated website) to communicate the results of the trials to growers, regulators, industry representatives and other stakeholders. So far, the project has received positive responses to the concept of grafted tomatoes from the industry.

For Goals 1 and 2, the compilation of published grafted tomato trial data and generation of data for California field trials, respectively, set targets were achieved relative to the lack of baseline data that existed prior to this study. The results are presented in Table 1, the project website and discussed in greater detail in the Growers Guide to Grafted Tomatoes (Attachment 1). For the outreach effort (Goal 3), the lack of reliable data generated in the Year 1 field trials prevented project staff from establishing benchmarks for the outreach effort. However, a plethora of outreach and education materials (see Attachments 1-4) have been presented in several venues which reach a variety of stakeholders in the fresh market tomato industry.

The major successful outcomes of the project can be quantified as follows:

- Data on tomato yields and fruit quality were extracted from 163 different published studies on grafted tomato trials, which included 1,023 different experimental treatments (where each treatment is defined as a combination of rootstock/scion, geographic location and growing season). These data were analyzed to provide data-driven, realistic expectations of the performance of grafted tomatoes in the

production system. For example, among the 105 Maxifort-grafted combination/location/growing season treatments tested worldwide (see graph on the project website), in more than half of the 79 cases which presented statistical analysis, the grafted plants did not produce significantly higher yields than the self- or non-grafted varieties in the same experiment. That graph also shows that in the project's trials, Maxifort's performance in San Joaquin County was comparable to that seen elsewhere (four red bars with "SJ" in axis label), but was unusually poor in Merced County (four red bars with "Mer" in axis label).

- Data on yields of tomatoes from 12 grafted and four non-grafted varieties were obtained for two different locations in California and one growing season (see Table 1 above). These yields were considered in light of fresh market tomato production costs and returns in California production systems (see Table 1 in Attachment 1). The data suggests that one grafted combination (Bobcat/Maxifort) would have produced an economically viable yield increase in the San Joaquin County trial where it gave a 60% yield increase. Two others in the San Joaquin trial (Bobcat/DR0138TX, 36% yield increase, and Dixie Red/DR0138TX, 31% yield increase) showed borderline economic viability depending on the crop value in a given season. None of the grafted varieties in the Merced trial produced economically viable yield increases over the non-grafted varieties.
- The outreach efforts included: two field days, three presentations to the grower communities, one national conference presentation, a high volume of newsletter distribution to all the fresh market tomato growers, two peer review journal article manuscripts submitted for publication, and a designated website created to sustain the project outreach component beyond the life of the grant. The project also had media coverage which started as a local radio story by Valley Public Radio (http://kvpr.org/post/grafting-could-give-tomato-plants-higher-yield-tastier-fruit), but was picked up by the National Public Radio show "the salt" (http://www.npr.org/sections/thesalt/2016/07/20/486529158/an-old-trick-holds-new-promise-for-tastier-tomatoes).

Beneficiaries

The beneficiaries of this project include various stakeholders in the California fresh market tomato industry. While the implementation of incorporating grafted tomatoes into commercial production is beyond the scope of the current project, this project has generated novel field trial data that lay the foundation for further research on the plausibility of the profitable use of grafted tomatoes in this industry in California in the future. With the growers' direct participation in the research project, project staff expect that these growers will serve as a farmer-to-farmer extension model and continue to advocate for promoting the grafted tomatoes in California.

The specialty crop beneficiaries of this project will be California fresh market tomato growers, which number 2,759 (USDA 2012 Agricultural Census) and account for $353 million in annual revenue (average 2007-2012). Trials in other states similar to the ones carried out in this project have typically achieved yield and net revenue gains of 30 to 50 percent. For example, after accounting for all costs, field trials in Florida reported total net returns per acre for non-grafted Florida-47 vs. grafted Florida-47/Beaufort plants of $1,233 versus $2,499 in 2010 and $3,281 vs. $5,739 in 2011. If such increases can be achieved in California and adoption of grafted plants becomes widespread, the potential statewide economic impact could be on the order of $100 million in increased revenue.

Successful adoption of pesticide-use-reducing grafted plants, by virtue of pathogen-resistant rootstocks, would benefit the environment, field workers, and the public by decreasing pesticide use and exposure. According to the California Department of Pesticide Regulation's Pesticide Use Reports database, fresh market tomatoes currently use over 500,000 pounds of fumigants annually in California. Thus, the beneficiaries will include the thousands of field workers found on California's 2,759 fresh market tomato farms and members of the general public who live within the accidental exposure range of fumigated tomato fields.

Lessons Learned

The primary lesson learned was the importance of properly identifying the tomato varieties during the grafting and healing processes, since tomato seeds and sprouts of different varieties are indistinguishable. The Year 1 (2015) trials yielded untrustworthy data because of uncertainty regarding the identities of tomato varieties used as scions during the grafting process. This uncertainty became apparent only after the plants began producing fruit with shapes and other characteristics that differed from the characteristics of the intended varieties. This issue was rectified in the Year 2 (2016) trials, which produced the proper tomato types and allowed project staff to interpret the data obtained with confidence. One good idea which came out of the process was that in Year 2 (2016) the project collaborators went to the greenhouse, participated in the grafting themselves and oversaw the entire process of producing the grafted seedlings for field trials. This experience also underscored the importance of effective communication among project participants to perform the relevant tasks to ensure the integrity of each step in the process.

The major unexpected outcomes of this project include the lack of useful data in the Year 1 (2015) field trials which stemmed from incorrect varieties of grafted plants. Efforts to ensure that the correct varieties were used for scion and rootstock were re-doubled in the Year 2 (2016) trials. Also, the project field trials were extended for two more years, supported by non-SCBGP funds, which will allow project staff to generate reliable data across multiple years.

Although the project had unexpected greenhouse grafting errors in the Year 1 field trials, the overall goal of the project was achieved. The lesson learned from the Year 1 field trials problem was that project staff needed to be on site in order to make sure that the varieties for the grafting were correctly labeled and the technicians should also be trained before the performance of the grafting. All of these corrective actions mentioned were done for the Year 2 field trials. This meant that the data from the Year 2 field trials could be trusted for reporting and publications.

Additional Information

The following outreach materials resulting from this project are available at the project website: http://agis.ucdavis.edu/Research/tomato/main.html, and are also included with this report in the following attachments:

1. Growers Guide to Grafted Tomatoes, 1st Edition, 10 pp. (Attachment 1)
2. Quick Guide to Grafted Tomatoes, 1st Edition, brochure (Attachment 2)
3. Article for growers newsletter *Field Notes, San Joaquin County* (Attachment 3)
4. Field Day Flyer and Poster (Attachment 4)

Additional photos from our collaborator and field meetings:








USDA Project No.:	Project Title:	
28	Nitrate Leaching Risk from Specialty Crop Fields During On-Farm Managed Floodwater Recharge in the Kings Groundwater Basin	
Grant Recipient: Sustainable Conservation	**Grant Agreement No.:** SCB14028	**Date Submitted:** December 2017
Recipient Contact: Daniel Mountjoy	**Telephone:** (831) 840-2328	**Email:** dmountjoy@suscon.org

Project Summary

The future of specialty crop farming in the San Joaquin Valley is at risk due to severe groundwater overdraft and declining water quality. On-farm floodwater capture (OFFC) and recharge can significantly replenish groundwater and may improve groundwater quality by seasonally applying floodwaters to extensive areas of cropland suited to infiltration. Uncertainty remains as to whether recharge on active cropland may degrade groundwater quality through increased leaching of current and legacy agricultural nutrients and salts, or may improve groundwater quality through dilution. This project employed modeling tools coupled with field trials to assess the risk of exacerbating groundwater nitrate and salt levels and identify farm management and groundwater recharge strategies for specialty crops that reduce regulatory liability for specialty crop farmers. The increase in farmer acceptance of on-farm floodwater application following access to reliable leaching risk information was surveyed during outreach events.

Current groundwater overdraft threatens the viability of specialty crop production, especially permanent and salt-sensitive crops in San Joaquin Valley. Groundwater overdraft has degraded agricultural and community water quality as salts and nutrients are concentrated. Specialty crop farmers in the Kings Basin are spending more on energy to pump from deeper wells and irrigation wells are collapsing at accelerating rates. Subsidence is threatening state water delivery infrastructure and the reliability of local water supplies. Yet specialty crop production, especially of tree nut crops, is rapidly expanding in area and water use. A recent survey indicates that the current drought is driving farmers and water managers to consider on-farm groundwater recharge from flood flows when excess, unclaimed water is available. However, they are concerned that since nitrate leaching already contributes to degraded groundwater quality, recharge may put them at greater risk of violating water quality discharge requirements established by the Irrigated Lands Regulatory Program (IRLP). The modeling tools and flooded field trials from this project were used to: 1.) Assess whether on-farm groundwater replenishment efforts will intensify groundwater nitrate and salt contamination or improve groundwater quality, and 2.) Identify farm management and recharge strategies that minimize nitrate leaching.

Prior to the project, the project team had interviewed growers, water managers and irrigation districts throughout the Kings Basin. Most grasp the agronomic and economic benefits of groundwater recharge at the farm and regional scale, but concerns about nutrient leaching risks and liability under the IRLP need to be addressed before widespread adoption will occur. Many interviewees stated reliable modeling results and guidance on these risks are needed prior to implementing OFFC. However, since water supply issues are so dire, specialty crop growers are eager to adopt OFFC due to the immediate benefits to their farming operations.

The results of this project are of value to the 17 irrigation and water districts and groundwater water managers that are responsible for achieving balanced and sustainable water supplies under Sustainable Groundwater Management Act (SGMA) for their members, the majority of whom are specialty crop farmers. Access to reliable, high quality groundwater supports the viability of specialty crop production which benefits laborers, transportation, processing and value-added businesses, and crop storage facilities in the region. Capturing flood water on farmland to replenish depleted groundwater offers an affordable solution to reduce future water shortages caused by climate change and this approach is applicable to other counties in the San Joaquin Valley and other variable rainfall areas of the United States.

This project built upon 2011 Specialty Crop Block Grant Program Project 13: *Evaluation of Winter Cover Crops to Reduce Nitrate Leaching and Increase Yields in Drip-irrigated Tomato Rotations.* Project staff characterized root systems and modeled water and nitrate movement in subsurface drip-irrigated systems. This project built on the previous characterizations of vadose zone nutrient accumulation for some of these crops (tomatoes) to parameterize the baseline conditions for the transport models. Furthermore, this project went beyond the previous focus on irrigation and rainfall effect modeling of shallow vadose nitrate movement to simulate and field test more intensive floodwater application and leaching to groundwater. This approach extended the previous modeling efforts through the deep vadose zone to estimate the movement and concentration of nutrients and salts to groundwater under OFFC conditions.

Project Approach

This project focused on better understanding the potential impact of On-Farm Flood Capture and Recharge (OFFCR) on groundwater quality pertaining to salts and nitrate and on assessing potential management opportunities. To achieve these goals, staff used a combination of field and modeling studies. For the field study, 36 soil cores were taken to a depth of 30 feet in replicate across fields with three different specialty crops identified as important to the San Joaquin Valley (tomatoes, almonds, vineyards) and with potential suitability for OFFCR. A prime goal of the field study was to provide data for parameterizing two models developed to assess nitrate, salt and water transport through the vadose zone, prior to percolating into the groundwater aquifer. However, the field data collection also resulted in key findings that show its value as a stand-alone study:

- Nitrate concentrations are highest in the upper vadose zone and affected by texture. Those effects are not evident in the deeper vadose zone.
- Vadose zone nitrate concentrations are affected by the crop grown. These results suggest an opportunity for lower legacy mass transport for grapes and higher legacy mass transport for both tomatoes and almonds.
- Variability in individual farmers' past and present fertilizer and water management practices contributes to different legacy salt and nitrate loads in the vadose zone.

Data from the field study and other related and concurrent OFFCR field efforts were used during model development to characterize different crop types, vadose zone characteristics and groundwater characteristics. Two models were integrated to simulate nitrate and salt transport through the vadose zone to groundwater under different scenarios: a 1D Hydrus model and an analytical groundwater model (AGM).

Several significant methodological advances have occurred from this study as related to the integrated models. The project team documented a method to define typical inputs (e.g., nitrogen, irrigation, recharge) and then

put numbers to those inputs. These inputs were used to develop a Hydrus model that reasonably models nitrate and salt transport through the vadose zone, based upon a comparison to the field data and to results from other OFFCR studies. Second, an AGM was developed that allows testing of various OFFCR scenarios for different representative groundwater basins. This AGM, integrated with Hydrus, provides an important tool to widely assess OFFCR across the Central Valley and across areas interested in implementing OFFCR. This work provides an analytical tool to test OFFCR, anticipate potential outcomes to groundwater, and enable the planning and testing of mitigation measures.

For this project, a number of scenarios were identified to test the potential impacts of OFFCR to groundwater and the sensitivity of those impacts to changes in crops, cultural practices, groundwater pumping, etc. Early results from the models suggest a number of groundwater quality effects. Simulated groundwater quality effects are most noticeable near the OFFCR area at the first encountered groundwater depths. The magnitude of the groundwater quality effects decreases spatially with distance from the OFFCR area and with depth within the groundwater and temporally until they are effectively negligible. Increased quantities of recharge water applied during OFFCR events may not greatly affect groundwater quality. Rather, early results suggest the magnitude of legacy constituents flushed from the vadose zone as well as the magnitude of salts and nitrogen contributed by ongoing fertilization cultural practices are major determinants. Improved agronomic water and nutrient management practices in the future reduce long-term nitrogen loading effects. Over time, long-term legacy loading effects diminish as the vadose zone is flushed with additional clean recharge water.

Further work is needed to further test fertilizer and crop management and groundwater sensitivity to these practices, and to assess the opportunities and constraints of regionally expanding OFFCR. Work is ongoing in part funded through leveraging funds. Completion of these runs will provide important information and insight into OFFCR and groundwater quality management.

The project team has been in communication with the Regional Water Quality Control Board (RWQCB) to discuss the project methods and best management practices that specialty crop farmers would need to use when recharging groundwater in order to avoid regulatory liability. The project design also built on the work of the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) and engaged the University of California Cooperative Extension (UCCE) and Kings River Conservation District (KRCD) partners to compile nutrient management guidance for farms practicing OFFC and communicate the findings through specialty crop workshops.

The table below shows a summary of the Work Plan tasks, performance indicators and work accomplished by the end of the grant.

Tasks and Activities	Performance Indicator	Work Accomplished
1. Project Management and Reporting 1.1. Project Guidance: Integrate project design, data collection, modeling, and outreach tasks to achieve acceptance of on-farm recharge strategies in partnership with KRCD, irrigation districts, and specialty crop farmers. 1.2. Performance Monitoring: Track outcome indicators and modify project tasks if needed to achieve targets. 1.3. Reporting: Preparation of progress reports, final report.	Program partnership meeting minutes; performance indicator tracking; progress and final reports.	All activities under Task 1 are completed: - Results of performance monitoring are reported below in the section "Goals and Outcomes Achieved". - Semi-annual reports and final report submitted as required.
2. Experimental Design 2.1. Modeling Approach: Technical partners will integrate model components to describe dual domain flow and transport system and model advective transport rates and diffusion characteristics under field-capacity and saturated conditions. Approach will be used to develop quantitative nitrate/salts leaching index for integrating cropping, vadose zone and hydrostratigraphic layers; to assess on-farm flood capture effects on groundwater vulnerability and temporal salt/nitrate distributions in the vadose zone; and to assess groundwater elevations and availability changes. 2.2. Define Modeling Scenarios: Select representative specialty crops (e.g., vineyards, tomatoes, almonds, pistachios), cultural and irrigation practices, hydrostratigraphic characteristics, flood flow capture rates and methodologies. 2.3. Modeling Sites: Select sites for model calibration and validation based upon targeted modeling scenarios and other criteria including farm history of collaboration, proximity to well log data and availability of existing data sources.	2.1. Model integration completed. 2.2. Modeling scenarios selected. 2.3. 5-10 Modeling sites selected.	All activities under Task 2 are completed. Please see attached Technical Report for details.
3. Land Owner Agreements Prepare and acquire landowner agreements for farmers in which site data is being collected (e.g., well logs, geoprobe, cultural practices).	Agreements with 5-10 landowners.	All activities under Task 3 are completed: - Agreements executed with six landowners for 12 sampling sites.

Tasks and Activities	Performance Indicator	Work Accomplished
4. Data Collection for Model Calibration/Validation Includes collection, quality assurance/quality control, management, presentation of: 4.1. Hydrogeologic, Hydrologic and Soil Series Data: Existing lithology, soil texture, elevation and soil data from variety of sources, such as United States Geological Survey Central Valley Hydrologic Model, Natural Resource Conservation Service (NRCS) soil survey, KRCD. 4.2. Groundwater and Surface Water Nitrate and Salinity Data: Existing data from online databases (e.g., IRLP, Groundwater Ambient Monitoring and Assessment, CV-SALTS) and local sources if available. 4.3. Well Log Data: Existing data for wells in the area to provide lithology, water elevation, and salt and nitrate pore water and groundwater data, where available. 4.4. Vadose Zone Soil Moisture, Chemistry and Infiltration Rates: Existing data sets include NRCS Conservation Innovation Grant (CIG) study (15-min root zone electrical conductivity (EC)/moisture data; geoprobe core data for nitrate, lithology, EC, bulk density) for wine grapes; soil probe data (i.e., moisture, salts) and pore water nitrate and salinity for grape fields for on-farm flood capture. New geoprobe data planned for cropping types per experimental design and new soil probe data planned for in-situ infiltration study. 4.5. Root Zone Chemistry Data: Data compiled as available for target specialty crops. 4.6. Industry and Collaborator Cultural Practices: Fertilizer and irrigation rates.	Model data sources compiled for selected scenarios	All activities under Task 4 are completed. Please see attached Technical Report for details. Task 4.3: Well log data was initially going to be obtained from the Department of Water Resources (DWR), but due to challenges with obtaining an agency release, the project relied on Caltrans boring logs in the eastern corridors of the Kings basin and boring logs for a related recharge project within the western portion of the study area.
5. Developing and Running Modeling Framework. 5.1. Develop Model: Integrate surface water application tool (flood flow/irrigation/loading simulation), dual domain vadose zone flow model, and Groundwater Hydrology and Water Quality Model (2-D representation in groundwater hydrology and water quality). Calibrate and validate with Task 4 data subsets. 5.2. Run Model for Scenario Testing and Characterization: Nitrate / salt transport, effects of crops / practices, flood flow application strategies.	5.1. Model finalized and calibrated. 5.2. Model output runs completed for 10 crop management scenarios.	All activities under Task 5 are completed. Please see attached Technical Report for details.

Tasks and Activities	Performance Indicator	Work Accomplished
6. Outreach 6.1. Develop project outreach plan and timeline. 6.2. Present results to RWQCB and request support of practice. 6.3. Fact Sheet: Develop OFFC Fact Sheet with management guidance for using practice; distribute to agencies, universities, specialty crop commodity groups, and other stakeholders. 6.4. Specialty Crop Nitrogen Management Workshop: Present model results to workshop attendees and conduct survey of grower receptivity. Compare grower receptivity from pre- and post-workshop survey. 6.5. Presentations: Present at relevant groundwater and specialty crop conferences. 6.6. Media Outreach: Newspaper and magazine articles.	Outreach plan; RWQCB meeting minutes and decisions; Fact Sheet; 1 nitrogen management workshop; grower interest survey results; conference presentation; media clippings.	All activities under Task 6 are completed. Please see following attachments for details: - Management Practices - Outreach Plan - Guide (in lieu of Factsheet) - Workshop - Survey Results - Conference Presentations - Media Clippings

All outreach and grower recruitment events funded by this project have been targeted to specialty crop associations or companies and specialty crop production areas. All field data collection including soil samples and related agronomic data and model development have been solely focused on specialty crops, namely almonds, grapes, and tomatoes. All grower attendees at the workshop produced specialty crops. More general outreach and conference presentations used other funds.

Project partners, contractors, and consultants provided the following activities: project management, reporting, and outreach; experimental design, including modeling approach and scenarios, site selection; model development, testing and model output runs for various crop management scenarios; development of supporting root zone, vadose zone and cultural practice data; field data (soil core) collection, laboratory and statistical analyses; integration of field data with modeling results; grower recruitment for field trials; collection, processing and summarizing of grower data; OFFC nutrient and irrigation management training materials and presentation at grower workshop; data collection for groundwater model calibration and validation; and advice on outreach strategies and RWQCB communication/meeting.

Goals and Outcomes Achieved

The project had two intermediate measurable outcomes and one long-term outcome. Achievement of the two intermediate outcomes was accomplished through ongoing general outreach about OFFCR by project team members throughout the project period. Results of the grower workshop survey at the end of the grant indicated that farmers are even more likely to participate in OFFCR when they have information about managing their crops to avoid nitrate leaching and crop health risks.

The long-term outcome of the project was: Increased flood water capture to raise the groundwater level and improve water quality. The development of the nitrate leaching model has not yet directly resulted in an increase in flood water capture but related research at demonstration sites and outreach about OFFCR in general is already resulting in increased flood water capture. It is still too early to detect changes in groundwater levels or improved water quality to the limited scale of OFFCR adoption to date.

The following table summarizes progress toward intermediate and long-term goals and outcomes including progress toward measuring benchmark and target values.

Intermediate outcome 1: Increased grower and Irrigation District awareness and acceptance of OFFC		
Performance measures: (a) Number of farmers contacted through outreach meetings; (b) number of farmers expressing willingness to try OFFC as a result of the project findings		
Benchmark	Target	Status at grant end
One grower actively using OFFC	At least 30 growers agree to try OFFC	Approximately 323 (staff contacted about 300 farmers and 23 farmers volunteered their fields)

Notes and Comments:
(a) Number of farmers contacted through outreach and education: Throughout the project period outreach about OFFC was conducted with over 300 farmers reached through irrigation district meetings, agricultural associations committees and conference presentations. As a result of the drought, SGMA, and then a historically wet year, interest has grown about the findings of this project, along with related information being developed with separate funding about specialty crop compatibility and site recharge potential.
(b) Number of farmers expressing willingness to try OFFC:

- Sustainable Conservation's outreach work has identified another 25 landowners that are interested in practicing OFFC on over 15,000 acres of land in the SJ Valley.
- Field monitoring of recharge and crop response is being conducted on nine sites practicing OFFC by the University of California, Davis (UCD) or Sustainable Conservation.
- Over 100 farmers were notified about the grower workshop for this project and over 30 attended. Fifteen of the attendees reported they had already tried OFFC and as a result of the workshop, the number interested in participating increased 47% from 19 growers to 28. See additional workshop survey results in attachments.
- Two irrigation districts have entered into partnership agreements with Sustainable Conservation to evaluate recharge potential in their districts and have developed OFFC recharge programs to encourage farmer participation. The Madera Irrigation District had 85 farmers participate and take water for recharge in 2017 on 4,468 acres.

Intermediate outcome 2: Increased awareness and acceptance of OFFC by RWQCB		
Performance measures: Number of meetings with RWQCB to consider model and flood simulated field trial results and develop appropriate regulatory assurances for growers		
Benchmark	Target	Status at grant end
Current groundwater regulation and uncertainty of interpretation	Receive an assurance for growers about management and site conditions for OFFC	2 meetings with RWQCB indicating support of project methodology but requesting field data validation of model output

Notes and Comments:
Sustainable Conservation met with the RWQCB at the beginning of the project and the full project team met with RWQCB staff and a board member on March 3, 2016. The group discussed nitrate model development along with conditions for avoiding water quality impacts. There was general agreement that

application of clean surface water by farmers does not, in and of itself, violate the anti-degradation policy if current nitrogen management is meeting ILRP requirements, including avoidance of carry-over nitrogen from prior season crops. The RWQCB also indicated that the model alone will not ensure compliance and that empirical field results will be needed to validate the model. The project team will meet with the RWQCB in September to provide final project findings.

Long-term outcome 3: Increased flood water capture to raise the groundwater level and improve water quality

Performance measure (a): Acres of farmland used for applying flood water

Benchmark	Target	Status at grant end
1,000 acres at Terranova Farms	25,000 acres to capture available flow with existing canal systems	Recharge has been documented by the project team on 11,343 additional acres.

Notes and Comments:

- Recharge at field trial locations: Project staff are currently conducting field trials at nine sites in the San Joaquin Valley totaling 275 acres. UCD has an additional site where winter recharge is being tested. The results of these field demonstrations will be shared with other farmers in the vicinity to encourage broader adoption in future years.
- Irrigation district recharge programs: As a result of outreach work, two irrigation districts have initiated OFFC programs to encourage farmers to accept winter water on their farmland to help recharge the local aquifer. The program at Madera Irrigation District between January and March 2017 engaged 85 farmers to capture floodwater on 4,468 acres. The program in Tulare Irrigation District engaged 25 farmers on 6,600 acres. There are certainly additional sites where OFFCR occurred in 2017 but was not documented.

Performance measure (b): Acre-feet of floodwater captured

Benchmark	Target	Status at grant end
3,116 acre-feet were captured at Terranova on 1,000 acres	Capture at least 80 percent of available flood flows or an average of 48,000 to 100,000 acre-feet per year	An additional 1,928 acre-feet of recharge was accomplished in addition to the recharge at Terranova.

Notes and Comments:

- Recharge on an organic almond orchard in Chowchilla was measured in 2016 and a total of 94 acre-fee percolated below the root zone on 26 acres.
- In the Madera Irrigation District in early 2017, a total of 1,834 acre-feet was recharged.
- OFFCR is beginning to occur in other farms in the Central Valley but these sites are not being monitored to document total recharge.

Performance measure (c): Depth to groundwater

Benchmark	Target	Status at grant end
Groundwater in many monitoring wells in Kings Basin dropped by more than 10 feet between 2012 and 2013	20 foot increase in groundwater levels	Depth to groundwater has stabilized in 2017 but cannot be attributed to limited acreage of OFFCR.

Notes and Comments:
DWR Groundwater Information Center data on change in groundwater levels during the first two years of this contract indicated declines of more than 10 feet in much of the Kings River basin but since 2016 declines have leveled out. It is too soon to detect the effect of limited dispersed OFFC projects, especially

when considering significant recharge occurring with dedicated recharge basins and natural recharge from rivers during 2017.		
Performance measure (d): Groundwater Quality		
Benchmark	Target	Status at grant end
Nitrate and salt concentrations in groundwater at unsafe levels	Reversal and dilution of these concentrations through increased rates of recharge	Too soon to detect effect
Notes and Comments: Too soon to detect effect of limited recharge rates at dispersed OFFC sites within the Kings River basin.		

The most significant accomplishment of the project is the integration of two hydrogeologic models to simulate nitrate and salt transport through the vadose zone to groundwater under different scenarios. The other accomplishment is the characterization of salt and nitrate concentrations in soil and vadose zone profiles under three specialty crops (almonds, wine grapes, and tomatoes). The quantifiable direct outcomes of project field data analysis and model development have not yet been realized in increased use of OFFCR. However, the development of the Nutrient Management Guide will now begin to inform better management at current and expanding recharge locations. Initial farmer reaction to the content of the Guide presented at the workshop indicated that attending farmers are likely to change their management practices to protect water quality (see Attachment - Survey Results). Overall farmer reaction to information presented at the workshop resulted in a 47% increase in the number of farmer that indicated they were willing to try OFFCR on their lands. This survey result suggests that making information from this project available to more farmers in the San Joaquin Valley will further increase farmer interest and participation in OFFCR.

Beneficiaries

The groups that have already benefited from the project include farmers and agricultural business representatives in the Kings River basin and adjacent areas that attended the workshop along with water managers, crop commodity groups, agricultural lenders, and government agencies (see Attachment – Workshop).

As additional scenarios are run through the nitrate leaching model, further guidance will be available to farmers in other hydrogeological areas of the San Joaquin Valley. Further review of project results by the RWQCB and ILRP technical committees will lead to refinement of nutrient management guidance that farmers can then use to avoid leaching of nutrients during OFFCR. See Attachment – Outreach Plan for a list of other groups that have expressed interest in this project.

The long-term impact of the project could benefit specialty crop growers by providing those on optimal OFFC sites with water and nutrient management guidance and regulatory assurances to use OFFC to improve water and soil quality and increase groundwater storage. The project could also benefit irrigation and water districts and groundwater water managers in the Kings River basin and beyond that are responsible for achieving balanced and sustainable water supplies for their members, the majority of whom are specialty crop farmers. Access to reliable, high quality groundwater supports the viability of specialty crop production which benefits laborers, transportation, processing and value-added businesses, and crop storage facilities in the region.

Current groundwater overdraft trends in the Southern San Joaquin Valley have increased pumping costs, damaged infrastructure, and thus affected production economics. Capturing flood water on farmland to replenish depleted groundwater offers an affordable solution to reduce future water shortages and addresses both water supply risk as well as water quality concerns for farmers and local communities.

The availability of the nitrate leaching risk information was intended to provide specialty crop growers with greater regulatory compliance certainty so they can increase groundwater recharge to secure a more dependable water supply. The project was targeted to approximately 85 specialty crop farms on 25,000 acres of the most rechargeable soils that already have adequate water conveyance canals to capture peak flood flows in the Kings River basin. These farms could capture an average of 48,000 acre-feet and up to 100,000 acre-feet per year, thereby replenishing a sizable portion of the annual basin overdraft rate of 125,000 acre-feet per year. The long-term impact of the project could benefit over 1,500 specialty crop growers on 470,000 acres in the Kings River Basin. However, staff now expect that the project results will be welcomed by irrigation districts and GSAs outside of the Kings River basin that are already actively promoting OFFCR. These districts will each rapidly extend the findings to hundreds of local farmers on thousands of individual farm fields in their districts.

Lessons Learned

Positive experiences: It was challenging to write the grant proposal for a model development project when there was no assurance that there would be sufficient rainfall to provide water for a field trial to empirically test the effect of OFFCR on nitrate movement through the soil. As a result the proposal was written to conduct soil core analysis at a variety of crop and soil locations to calibrate the tool. Fortunately, in 2016 after three years of drought, there was some water available and Sustainable Conservation was able to fund a separate project to pay for the water and have a consultant collect soil cores on high and low recharge treatment sites as well as a control site in the orchard. The resulting data was very helpful in calibrating the Hydrus model and would not have been possible without rainfall and complementary funding to this project.

Negative experience: Staff faced several challenges – largely due to circumstances outside of their control – which in the end were successfully resolved, but they do serve as valuable lessons learned. The challenges were in the following areas: Well log data acquisition, finding appropriate fields for the geoprobe work, lack of available water due to long drought conditions, core data showing heterogeneity not explained by crop type or soil type, and complexities of model calibration.

Unexpected outcomes: Analysis of soil core data showed unexpected heterogeneity that is not explained by crop type or soil type. However, crop management data from growers indicated that past and current management choices regarding irrigation and fertilizer management is a key component to explaining soil core differences. In addition, the core data indicate that ‘short-circuiting’ or bypassing presumed impermeable layers may be occurring in the vadose zone. This sort of non-uniform situation made the Hydrus modeling plan much more difficult to develop and required calibration of a more generalized reference condition to explain the mobility of nutrients and salts in some of the soil cores.

Preliminary model outputs suggest that the amount of water applied on farmland is less of a determinant of total loads reaching groundwater than the legacy concentrations of nutrients and salts in the soil and vadose zones. Relatively low recharge rates are likely to mobilize these accumulated materials resulting in high nitrate and salt concentrations at first encountered groundwater in response to any scale intentional recharge

events. Modeling results show that the concentration generally improves with depth and time, especially in the vicinity of the recharge location. Guidance to manage the potential mobilization of legacy nitrate and salt accumulations will be important to ensure recharge benefits outweigh unintended effects. And more importantly, current management of fertilizers should take into consideration the timing of recharge events within the crop production cycle.

All intermediate term goals and outcomes for acceptance of OFFCR are being realized as a result of general outreach. It is likely that if the nitrate leaching model had been completed earlier in the contract period, the nutrient management guidance would have helped improve the water quality protection aspects of existing recharge projects but would not have contributed to significantly more recharge project participation. Farmers tend to be more concerned with crop health risks than with nitrate management though this project has increased awareness of this management component.

Additional Information

See attachmed documents.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 29	**Project Title:** Improving Irrigation and Nitrogen Management of Strawberry Production in California	
Grant Recipient: The Regents of the University of California, Parlier	**Grant Agreement No.:** SCB14029	**Date Submitted:** December 2017
Recipient Contact: Andre Biscaro	**Telephone:** (805) 645-1465	**Email:** asbiscaro@ucanr.edu

Project Summary

Strawberries are ranked as the sixth most valuable crop in California. The annual value of strawberries has increased from $0.8 billion to $2.3 billion during the last 12 years, and accounts for over 83% of the United States (US) production. In the same region where strawberry production has increased during the last decade, water quality and quantity problems have also increased. Production in the coastal valleys of California rely heavily on groundwater supplies that have been impacted by seawater intrusion and nitrate contamination. The Oxnard region where the early season crop is produced has a severely limited water supply, and with the extended drought conditions, growers are now facing a cut of 30% in water supplies. The Pajaro Valley Water Management Agency has notified growers that the charge for extracting groundwater may increase by 30% to encourage growers to further conserve water. Some of these basins have groundwater with nitrate concentrations above the drinking water standard of 10 ppm NO3-N attributed to the production of shallow rooted vegetable and strawberry crops, which require ample soil moisture and nitrogen (N) fertilizer to maximize yield and quality. Therefore, the strawberry industry needs accurate information and effective but practical tools to manage water and N in order to comply with recent changes in water quality regulations and very limited water availability.

Water quality and quantity issues have challenged the production of specialty crops in California as never before. The recurring drought throughout California and new water quality regulations have forced many farm operations to look for production practices that can address optimal water and N fertilizer use. Therefore, this project is important and timely since it aims to develop inexistent data on water and N usage of strawberries, and to provide growers with a comprehensive, free and user-friendly online decision-support tool for water and N fertilizer management: CropManage (cropmanage.ucanr.edu). This web-based software uses the most pertinent information available for creating instant recommendations of water and N fertilizer in a few seconds.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The activities in this project were divided in two phases:

- **Year 1:** Intensive field data collection for modeling the growth of strawberry canopy, root depth and N uptake was performed during the 2014/2015 season. This dataset was used for developing and modifying the algorithms used in CropManage. The results obtained during Year 1 were very concise and representative of strawberry growth (Figures 1, 2 and 3). Two of the six fields monitored in this study did not have representative data due to yield being severely damaged by salinity in one field, and harvesting incomplete in another field (data necessary for calculating N uptake). Therefore, out of six fields, four were considered representative and were used for developing the CropManage algorithms and recommendations.

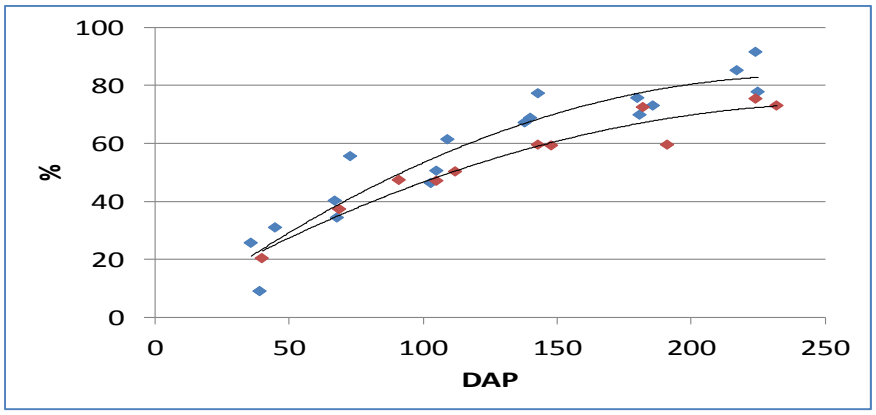


Figure 1. Canopy Cover of four fields monitored in Oxnard, California. Different colors represent different cultivars, where blue is a proprietary cultivar, and red is UC public cultivar (San Andreas).

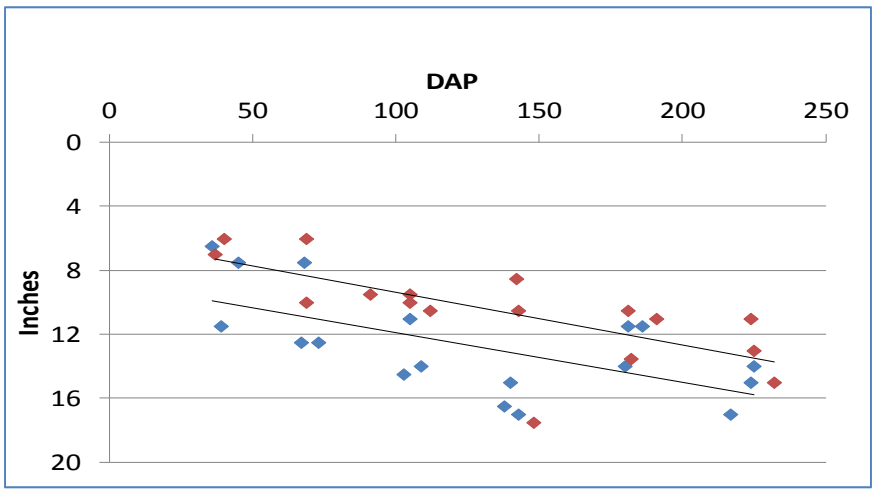


Figure 2. Root depth development of four fields monitored in Oxnard, California. Different colors represent different cultivars, where blue is a proprietary cultivar, and red is UC public cultivar (San Andreas).

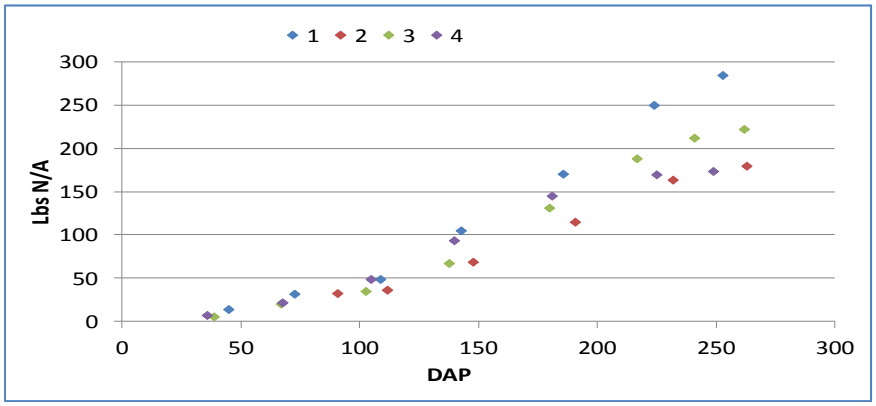


Figure 3. Nitrogen uptake curve of four fields monitored in Oxnard, California. Different colors represent different fields.

- **Years 2 and 3:** Water and N fertilizer recommendations from CropManage were assessed in six field studies (four fields in Ventura County, and two fields in Monterey County), in comparison with the standard irrigation and fertilization practices of the grower in each of those fields. In three of those studies the treatments (CropManage vs Grower Standard) were replicated in randomized plots; the other three studies comparison between blocks (CropManage vs Grower Standard, non-replicated). Overall, the results of this study are encouraging. CropManage's recommendations significantly increased yields in two of the fields by 22% and 29%, while it did not decrease yields in any field and substantially reduced fertilizer use in most fields. Opportunities for water savings also exist, depending on the efficiency of irrigation management of each field (most growers are actually under-irrigating their crops). The results of these studies were demonstrated in two field days and five workshops.

All planned tasks for this project were successfully executed. The data collected in the first year (modeling of crop growth) was representative of the fields and coherent to what is expected for strawberries. Although the results of the validation studies (CropManage's recommendations) varied in all six study sites, the finds were favorable to the outcome of this project: CropManage's recommendations either increased yield, or decreased fertilizer and water use with the same yield. Where water and fertilizer use were greater, yields were also increased. Increased yield with increased inputs from CropManage's recommendations generally indicates that the grower's standard practices under-irrigated and/or under-fertilized their fields. Those later cases are examples of the accuracy of CropManage's recommendations, which are based on the first year of research, while the grower standard practices weren't based on research-based information. Soil nitrate levels kept around 5-10 ppm NO3-N in the CropManage treatments indicates that its significantly greater fertilizer amounts did not cause conducive conditions to nitrate leaching; in addition to greater yield, those treatments had greater vegetative biomass (N applied was used by the plants). Several growers have shown interest in either continuing or to start using CropManage after observing the positive results presented at the field days and at the workshops, which is a strong indication of the success of this project. Considering how slow adoption of management practices are in agriculture, the results of this study are very encouraging.

In summary, the favorable results of this study are highlighted by the consistence of same or greater yields from the CropManage treatments, and the interest from growers and farm managers in using this program. The unusual developments were not significant enough to affect the outcome of this study, and they were mostly related to unpredictable issues such as the two fields that didn't have representative data on Year 1 (due to salinity and harvesting issues), and the disproportional lygus pressure on field # 5 of the field assessment of CropManage.

The overall scope of the project did not benefit commodities other than specialty crops.

Project Director: Determined methods, procedures, defined cooperating growers in Ventura County, coordinated treatment applications, data collection and performed data analysis.
Project Manager: Defined cooperating growers in Monterey County, coordinated treatment applications and data collection.
Project Collaborators: Helped with defining cooperating growers.
Staff Research Associate: Assisted with sensor's installation and data collection

Goals and Outcomes Achieved

The measurable outcome of this project is for strawberry producers to improve their efficiency of water and N fertilizer usage. The main goal of the project was to quantify that strawberry growers are improving water and N fertilizer management. As of June 2017, approximately 450 CropManage users were using it for managing water and N fertilizer of strawberries. While adoption rate is still small in Ventura County (approximately 20 users), project staff expect that it will considerably increase in the next couple years after the results of this study are extended further in this area. The significantly greater number of users in Monterey County exemplifies that adoption rates for management practices in agriculture are relatively slow, since the first studies with CropManage in strawberries for that area started around 2012. Although there is no absolute method for measuring if those growers are improving water and N management, the use of CropManage recommendations are most likely improving water and fertilizer use efficiency (lbs of water or N fertilizer per lbs of fresh fruit). Unfortunately CropManage does not keep track of yields, and for that reason an exact measure of efficiency cannot be estimated. However, based on the positive results obtained on the field studies, project staff can conclude that CropManage's recommendations of water and N fertilizer are most of the time more efficient than growers'.

The goal of this project is well aligned with the goal of the University of California, Agriculture and Natural Resources, which is: to improve water and N use efficiency. Therefore, the project manager and project director will continue to work on improving the accuracy and effectiveness of CropManage and on achieving this goal indefinitely, and with that the long-term outcome measures.

The fact that approximately 450 people are using CropManage specifically for water and N fertilizer management of strawberries is encouraging and it indicates that the goal of improving water and N fertilizer management is being accomplished. Considering the trend of increasing CropManage user numbers every year, it is expected that the number of users will considerably increase in the next couple years.

Since strawberries were not part of the CropManage system at the time this project started, the initial project baseline was that zero strawberry producers and growers were effectively managing their water and N fertilizer usage. The current baseline comprises of the updated number of CropManage users and the positive results obtained with the assessment of CropManage's recommendations, which resulted in either higher yields or lower water and N fertilizer use.

The results of the field assessment studies are encouraging and indicate that CropManage's recommendations are ergonomically sound and that they improve water and N fertilizer use efficiency (Table 1).
There are 450 people already using CropManage for improving water and N fertilizer management. This means that roughly 5-10% of strawberry acers in Watsonville and Oxnard are using CropManage for their management decisions. The project believes that this percentage will continue to grow and that they will meet their 20% target within the five year time period.

Table 1. Yield, water and fertilizer use of CropManage treatments relative to the grower standard for each study site.

Study #	Location	Marketable yield relative to grower standard	Water use relative to grower standard	Fertilizer use relative to grower standard
1	Oxnard, California	22% higher	14% higher	34% higher
2	Oxnard, California	2% higher	Same	35% lower
3	Oxnard, California	29% higher	32% higher	26% higher
4	Camarillo, California	Same	22% lower	Same
5	Salinas, California	Non-representative*	21% higher	11% higher
6	Aromas, California	2% higher	29% lower	10% lower

*Irrigation block with CropManage treatment had substantially greater lygus damage compared with the grower standard (44.6 vs 27.6%, respectively).

Beneficiaries

The beneficiaries of the project are growers, production operation companies, farm managers, Certified Crop Advisors, consultants, researchers, and anyone else involved in managing water and N fertilizer for strawberry production. In addition, residents of the strawberry production areas in California will benefit from the adoption of more efficient and sustainable production practices, which will lead to reduced off-site movement of nitrate (improving drinking/ground-water quality) and improved water availability.

Project staff expect that that CropManage will be used for management decisions on 20% of the strawberry acres in the Watsonville, Santa Maria and Oxnard areas within five years from now. At the end of the project, June 2017, it's estimated that approximately 5,000 of strawberries grown in California are managed with CropManage. In addition to the growers who are benefiting from more efficient water and N fertilizer management, it's estimated that approximately 30% of the population of the three major strawberry producing areas in California (approximately 350,000 people) will benefit from decreased off-site movement of NO3-N and from water conservation.

Lessons Learned

Positive experiences from the project: CropManage has shown to be an efficient tool for managing water and N fertilizer. Results obtained in this study are encouraging and they show that this software can be used as an important decision supporting tool by the strawberry industry. Although adoption rate of new management practices in agriculture is usually slow, the fact that 450 people are using CropManage for strawberries is an indication of the success of this project.

Lessons learned from the project: The execution of the first year of the project involved data collection from multiple fields, which were managed by multiple parties. Two of the fields monitored in Ventura County during that first year presented issues with data quality and they had to be excluded from the final results (data from four fields were used instead of six).

The outcome measure of the project was achieved, although in a slower speed than originally projected in the project proposal. It takes time for agricultural practices to be adopted, and while the project was successfully completed, it was unrealistic to expect that 10% of strawberry acres would adopt the technology only a year

after the results were completed. At this point the results of the project have only been extended to the industry a little less than a year. The adoption rates for new management practices in agriculture are much slower than most or any other industry and this is what caused the delay in progress for the project reaching their 10% target goal.

Additional Information

CropManage website: Cropmanage.ucanr.edu
Attachment 1: Field Days Handout
Attachment 2: Fertilizer Rresearch and Eeducation Program Conference - Poster Presentation
Attachment 3: CropManage Workshop



2016 Field Day. Oxnard, California.



2017 Field Day. Oxnard, California.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 30	**Project Title:** Testing Decision Support Tools for Evapotranspiration Based Irrigation Management	
Grant Recipient: University Corporation at Monterey Bay	**Grant Agreement No.:** SCB14030	**Date Submitted:** December 2017
Recipient Contact: Lee Johnson	**Telephone:** (650) 604-3331	**Email:** Lee.F.Johnson@nasa.gov

Project Summary

California's Central Coast relies on groundwater to produce cool-season vegetables that generate total economic output exceeding $3 billion annually. Yet, since the adoption of the Agricultural Discharge Order by the Central Coast Regional Water Quality Control Board in March 2012, growers are now under increased water quality regulations, and may face future restrictions on use of nitrogen fertilizer and possibly water availability. To meet water quality objectives, growers may need to improve both irrigation and nitrogen management of their crops.

The California Irrigation Management Information System (CIMIS) operates a network of weather stations to map grass reference evapotranspiration (ETo), a combined measure of plant transpiration and soil evaporation. Applying ETo for a particular crop requires a number of calculations that can be time consuming and somewhat complex, while most vegetable growers manage multiple fields and have limited time to develop customized watering schedules. Surveys show that only a minority of farmers integrate CIMIS data into irrigation decisions, opting instead for more subjective approaches such as look/feel of the soil/plants. As vegetable crops are highly sensitive to water stress, many growers over-irrigate to minimize the potential for yield losses. Excess applied water may potentially leach nitrate and salts into groundwater, while over-pumping can exacerbate intrusion of seawater to coastal aquifers. Additional problems in the region have recently been imposed by episodic drought, which has served to lower the water table in many areas.

Low-cost mitigation and adaptation strategies can help address the challenge. This project mainly involves expansion of stewardship practices & natural resource conservation. The project further developed and enabled beneficial management practices to enhance viability of the agriculture sector and environment. The main goal was to demonstrate use of a decision model, CropManage, to support crop evapotranspiration (ET)-based irrigation scheduling decisions in cool-season vegetables. CropManage is a free, internet-based software application developed by University of California Cooperative Extension (UCCE).

In this project, replicated irrigation trials were established to apply differing amounts of water as a percentage of modeled crop ETo. Supporting measures included crop fractional cover, applied water, soil water balance, and soil nitrate. Crop viability was evaluated in terms of marketable yield. The study provided further insight to crop water requirements and associated best management practices of romaine lettuce and green cabbage. All crops were grown to commercial standards & specifications at the United States Department of Agriculture (USDA), Agricultural Research Station in Salinas. Satellite observations of crop fractional cover for the region were acquired, processed, and archived by NASA's Satellite Irrigation Management Support (SIMS). An applications programming interface was developed to link CropManage with SIMS. The SIMS data can be used as an alternative method of parameterizing CropManage at the individual field or farm level.

This project built on two prior Specialty Crop Block Grant Program (SCBGP) projects. Under the 2011 SCBGP Project 16: *Improved Tracking of Water Use in Specialty Crops*, irrigation trials were performed in a simulated commercial production setting at the USDA Research Station in Salinas, with cooperation of major specialty-crop commercial producers. The project demonstrated the use of two irrigation scheduling tools (CropManage, SIMS) for production of industry-standard marketable head lettuce/broccoli yields with applied water totals 23-34% below standard practice. Briefings were provided to approximately 100 growers and crop consultants at UCCE continuing-education workshops in 2013 and 2014. Results were presented to an additional 200 irrigation experts at the American Society of Agriculture & Biological Engineers, and United States Committee on Irrigation & Drainage. A refereed journal article was published in HortScience.

Under the 2013 SCBGP Project 43: *Online Irrigation and Nitrogen Management Tool for Cool Season Vegetables*, UCCE modified CropManage for use in additional cool-season vegetable crops including leaf lettuce & cabbage, and demonstrations were performed in commercial fields. While useful in terms of grower acceptance, these demonstrations were constrained in design in that they involved single-strips and hence were unreplicated, which precludes statistical analysis for quantitative interpretation. In addition, the fields remained under grower management, and the research team had limited ability to control key aspects of the experiment such as water application. The experiments conducted in this study incorporated scientific concepts including plot replication, block randomization, repeatability (over two years). They also enabled examination of a greater variety of water applications, including those below full ET replacement, incorporated more monitoring devices, and generated results that can be disseminated in the scientific literature in addition to the broader specialty-crop stakeholder community.

Project Approach

A main portion of the project called for the establishment of a series of replicated irrigation trials in cool-season vegetables, to include planning, performance and data analysis. Scientific field trials were conducted on leaf lettuce and green cabbage using commercial production practices. A complete randomized block design was used for each experiment, to include four irrigation treatments and six replications per treatment. Following sprinkler irrigation for germination and establishment, drip irrigation was applied at 50%, 75%, 100% and 150% of crop ETo (water use) as estimated by CropManage in conjunction with CIMIS reference ETo. Flow meters provided real-time monitoring of applied water per treatment.

Nadir-view digital multispectral photos were taken periodically to monitor crop development (percent cover) during the crop expansion period. Harvest and crop quality evaluation was performed in cooperation with commercial vegetable shippers/handlers, for derivation of marketable yield. Results were shared with specialty crop stakeholders through industry meetings, continuing education events (*e.g.*, UCCE Irrigation & Nutrient Management Day), and professional society presentations. Target audiences were Central Coast vegetable growers, USDA Natural Resources Conservation Service, Resource Conservation District, crop consultants, farm advisers, and irrigation researchers/engineers. Romaine yields from the 100% and 150% ET treatments were not significantly different and were similar to industry averages, while yields were significantly lower for the 50% and 75% ET treatments. The 100% ET treatment resulted in the greatest water and nitrogen use efficiency. For cabbage, the 2015 bulk product yield from the 150% treatment exceeded the 100%, while the 2016 yields from those two treatments were not significantly different. In both years, cabbage yields from the reduced water treatments (50%, 75%) were significantly lower.

The project solely benefited specialty crops, specifically cool season vegetables.

UCCE provided overall guidance and oversight of cultivation practice, including fertility management and specification of irrigation amounts on the CropManage treatment. USDA-Agricultural Research Service provided daily monitoring of field condition, performed most upkeep tasks, and advised the project on third party crop management needs (such as herbicide/pesticide spray applications). UCCE and USDA assisted with harvest and equipment setup/removal, and advised on statistical analysis of yield and quality evaluation data. UCCE hosted Irrigation/Nutrient Management Workshops (continuing education events) that attracted over 100 specialty-crop growers and crop consultants in both 2016 and 2017, and conducted several CropManage hands-on training sessions throughout the region.

Commercial cooperators (Fresh Express, Dole Fresh Vegetables) provided harvest forecasts and guidance on crop quality evaluation. Fresh Express deployed harvest crews & equipment for romaine harvests at their own expense. Seed and fertilizer contributions were provided by Central Valley Seeds and Wilbur-Ellis. California State University Monterey Bay was active in management and performance of all project aspects.

Goals and Outcomes Achieved

The activities supported planning, procurement, maintenance, data collection and data analysis and reporting associated with four irrigation trials. Uniform amounts of sprinkler irrigation were used for crop establishment. A surface drip system was then used to water the field plots in a complete randomized block design (four treatments, six replications), managed through a four way irrigation manifold. The CropManage decision tool was used to prescribe irrigation amounts per treatment for each irrigation event. Supporting cultivation practices included soil preparation, bed shaping, planting, crop thinning, weeding, spray treatments (pesticide, herbicide, fungicide), fertilizer management, and harvest. Primary data collection included applied water, crop fractional cover, and marketable yield. Established statistical procedures were used to analyze the data for treatment effects.

The potential to improve specialty-crop irrigation efficiency by way of ET-based irrigation, as guided by irrigation scheduling software, were achieved and demonstrated during the project term. Broader adoption of decision-support tools by the grower community is a continuing, longer-term process. Continual improvements are being made regarding performance and accessibility of CropManage, along with extended support for additional commodities. Toward this end, the CropManage v2.0 web-application was released in late 2015. The CropManage v3.0, which is designed to improve operation on smart phones and tablets, is under development and is scheduled for release December 2017.

UCCE continues to hold industry hands-on workshops dedicated to CropManage operation, which has a growing userbase and has gained additional programmer support at the UC Division of Agriculture and Natural Resources institutional level. There were about 550 registered CropManage users in February 2015 (near the beginning of the project) and about 1,300 registered users, an increase of 136%, as of June 2017. Also, CropManage now provides about 1,000 recommendations per month, a 43% increase, versus 600-700 in 2014. An application programming interface has been implemented to allow CropManage users to extract crop development data directly from NASA's SIMS. Performance of additional demonstration trials would offer continued value in terms of grower acceptance of the concept of ET-based irrigation and use of CropManage and related software tools, particularly as CropManage continues to expand capability for monitoring additional crop types.

During the final months, the project results were presented in an Evapotranspiration session of the American Society of Civil Engineers, World Environmental & Water Resource Congress. An abstract was accepted for presentation at the American Society for Horticultural Science, Annual International Conference. A review paper, titled "New approaches to irrigation scheduling of vegetables," was published in a Horticulture special issue: Refining Irrigation Strategies in Horticultural Production. Among other things, the paper addressed ET-based irrigation scheduling, field instrumentation, software tools including CropManage, and evolving remote sensing capabilities. A technical article on the romaine experiments was drafted and is in preparation for submission to HortScience or other refereed journal as appropriate. CropManage v2.0 training sessions were held in the Central Coast (Salinas, California) and South Coast (Ventura, California).

Several types of baseline data were collected, analyzed, and archived on a per-treatment basis during each experiment. Irrigation amounts were monitored by flow meters during each irrigation event. Crop fractional cover was monitored every 3-4 days by a combination of direct dimensional measurements and multispectral camera. Daily reference ETo was monitored by the California Department of Water Resources (CDWR) and extracted from the CIMIS archive. Soil moisture was monitored by neutron probe and tensiometers. Nutrient demand was monitored by the soil nitrate "quick-test." End-of-season foliar nitrogen concentration was determined by the UC Davis Analytical Lab. Crop yield and crop quality data were gathered in cooperation with industry collaborators. Irrigation and fertilizer datasets are archived as part of the CropManage on-line database.

The CropManage decision-support tool was used in conjunction with CDWR/CIMIS grass-reference ETo data to guide irrigation scheduling of romaine lettuce and green cabbage at specified ET replacement levels ranging from 50-150% of crop water use. CropManage is designed for ease-of-use and offers a convenient and cost-effective way to gain information on crop water requirements for large numbers of fields. Romaine yields from the 100% and 150% ET treatments were not significantly different and were similar to industry averages (~20 tons/ac for carton product), while yields were significantly lower for the reduced water (50%, 75%) treatments and would not be considered commercially viable. The 100% ET treatment exhibited the greatest water-use efficiency and nitrogen use efficiency. Applied water totals for the 100% treatment were 7.3" in 2015 and 9.7" in 2016, compared with typical amounts of 12-18" for drip systems (Leaf Lettuce Production in California, UCANR Publication 7216). For cabbage, the 2015 bulk product yield from the 150% treatment exceeded the 100% (35 vs. 31 tons/ac), while the 2016 yields from those two treatments were not significantly different (~37 tons/ac). In both years, cabbage yields from the reduced water treatments (50%, 75%) were significantly lower and not commercially viable. Applied water totals for the 100% treatment were 13.3" in 2015 and 12.7" in 2016, compared with typical amounts of 12-18" for drip systems (Cabbage Production in California, UCANR Publication 7208).

Beneficiaries

The main project beneficiaries are growers and shippers of cool-season vegetables based in California, which is the nation's leading production region.

Main beneficiaries of this project were cool-season vegetable growers in California coastal valleys, who generate $3 billion/year economic output on some 330,000 acres in Monterey County alone (Economic Contributions of Monterey County Agriculture, Agricultural Commission). The region is a major source of domestic and export food supply, for instance producing some 30% of lettuce worldwide. The proposed experiments involved two important cool-season vegetable crops. Leaf lettuce is the leading Central Coast

revenue generator, at $800M annual value and occupying about 80,000 acres. Cabbage is also among the region's "Ten Million Dollar Crops," with value of $40M (2012 Monterey Crop Report). The project served to better define baseline water requirements for those crops, demonstrate potential for water conservation & mitigation of nitrate losses, and strengthen stakeholder confidence in available decision tools. Partially as a result of this project, the CropManage user base increased from 550 to 1300 registered users over the 2015-2017 time period.

Lessons Learned

The irrigation trials served to better define specialty-crop water requirements and support efficiencies of water application and/or energy use for pump operation. Interactions with the specialty-crop community have reinforced the need for decision-support tools designed with strong emphasis on human factors, accessible user interface, and implementation on a variety of mobile platforms to allow convenient on-site operation. Two software upgrades were performed with respect to these factors throughout the project, as based on user feedback, with additional revisions planned under funding from additional sources.

There were no unexpected outcomes or results related to this project. The goals and outcomes of this project were fully achieved.

Additional Information

Presentation summary as below--

Project Director 2017. ET scheduling study on romaine lettuce. UCCE Irrigation and Nutrient Management Annual Seminar, (continuing education event for growers and crop consultants), 23 February, Salinas, California. [Attendees 110]

Cahn, M., 2017. Cropmanage – online irrigation and nutrient management tool. UCCE Irrigation and Nutrient Management Annual Seminar, (continuing education event for growers and crop consultants), 23 February, Salinas, California. [Attendees 110]

Johnson, L., M. Cahn, S. Benzen, I. Zaragoza, L. Murphy, T. Lockhart, and F. Melton, 2016. ET-based Irrigation Management in Leaf Lettuce and Cabbage: Results from 2015 Trials. Proceedings USCID Water Management Conference, U.S. Committee on Irrigation & Drainage, (Eds. S. Macaulay, D. Bradshaw, S. Anderson), pp. 81-86, ISBN 978-1-887903-53-0, 17-20 May, San Diego, California. [Attendees 50]

Johnson, L., M. Cahn, S. Benzen, I. Zaragoza, L. Murphy, F. Melton, F. Martin, A. Quackenbush, T. Lockhart, 2015. Testing an irrigation decision support tool for California specialty crops. Hydrology session, Amer. Geophysical Union Fall Meeting, 14-18 December, San Francisco, California. (Presentation #H53G-1745). [Attendees 40]

Cahn, M., L. Johnson, S. Benzen, L. Murphy, T. Lockhart, and I. Zaragoza, 2017. Optimizing water use of romaine lettuce using an evapotranspiration based method. American Society Horticultural Science Annual Conference, 19-22 September, Waikoloa, Hawaii (accepted). [Attendees 75]

Cahn, M., L. Johnson, S. Benzen, L. Murphy, T. Lockhart, and I. Zaragoza, 2017. Optimizing water use of romaine lettuce using an evapotranspiration based method, Amer. Soc. Civil Engineers, World Environmental & Water Resource Congress, 21-25 May, Sacramento, California. [Attendees 35]

Cahn, M., T. Hartz, R. Smith, B. Noel, L. Johnson, and F. Melton, 2015. CropManage: An online decision support tool for irrigation and nutrient management. Proceedings, Western Nutrient Management Conference, Int'l Plant Nutrition Institute, 5-6 March, Reno, Nevada. [Attendees 40]

Cahn, M. and L. Johnson, 2017. New approaches to irrigation scheduling of vegetables. Special issue: Refining irrigation strategies in horticultural production. *Horticulturae* 3, 28; 10.3390/horticulturae3020028 [1,000 full-text views as of July 2017]

Johnson, L., M. Cahn, S. Benzen, L. Murphy, and T. Lockhart. Yield response of romaine lettuce to various ET-based irrigation regimes. In preparation for *HortScience.*

CropManage hands-on training sessions: Salinas (Mar. 2016, Apr. 2017), Santa Cruz (January 2016), Ventura (May 2017), Watsonville (March 2017), California. [Attendees 25-40 per session]

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 31	**Project Title:** Effectiveness Study of Multiple Off-Farm Treatment Practices for Specialty Crop Farmers	
Grant Recipient: San Jose State University Foundation on behalf of Moss Landing Marine Laboratories	**Grant Agreement No.:** SCB14031	**Date Submitted:** December 2017
Recipient Contact: Joaquin Ramirez	**Telephone:** (408) 924-1440	**Email:** Joaquin.ramirez@sjsu.edu

Project Summary

The Salinas Valley supports farming of specialty crops including multi-year perennials (strawberries and artichokes) and annuals (leafy greens and broccoli) in constant production, leaving little opportunity for field fallowing. These intensive agricultural operations have led to impaired water quality for which the Central Coast Regional Water Quality Control Board (RB3) has developed a regulatory Agricultural Order, known as the Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands (Ag Order). The Central Coast Wetlands Group (CCWG) and partners have demonstrated load reduction potential of off-farm treatment systems (bioreactors, treatment wetlands, etc.) based on the results of local pilot projects over the past decade. However, data from these pilot projects, along with studies in other parts of the United States, are difficult to compare between system types because field variables including pollutant load, flow and retention time and temperature are inconsistent among studies. The purpose of this Treatment Effectiveness Project was to study the nutrient load reduction potential of several off-farm treatment systems for the management of water quality within the Salinas Valley.

This project is an important step toward the use of treatment systems within defined drainage basins to reduce nutrient loading that cannot be dealt with by employing on-farm practices alone. As a resource, it allows farmers to make informed decisions on how to best improve water quality and meet state regulatory objectives for their specific specialty crops and drainage conditions. The water quality regulations that have been adopted to ensure environmental protection have added significant costs to Salinas Valley farmers in terms of both funding to implement practices and fines if not in compliance.

Specifically, this project supports unique efforts to investigate the effectiveness of several commonly used treatment options under similar environmental conditions. Unfortunately, many funding sources do not support these research activities. Without research opportunities such as this effort, industry and regulatory agencies are at an impasse to develop alternative compliance options. The project research will improve water quality and help farmers to comply with regulations through a better understanding of the most cost-effective practices for treating surface runoff under different farm constraints.

This project did not build upon a previously funded Specialty Crop Block Grant Program project. The project partners are building off the success of this project within a recently awarded Natural Resources Conservation Service (NRCS) grant to establish an industry-lead nutrient cooperative compliance program for the Ag Order's discharge requirements. California State University, Monterey Bay (CSUMB) and CCWG researchers have begun looking for additional funding to improve and expand nutrient decay rate curves and investigate additional treatment systems.

Project Approach

This project: 1.) Quantified nutrient load reduction of various treatment designs under the same field conditions; 2.) Improved load reduction models using local data; and 3.) Supported adoption of treatment systems for the Ag Order compliance, reducing farmer costs.

Task 1 - Project Construction: CCWG created an "outdoor laboratory" to test the decay rate constants for nitrates within 12 treatment chambers using standard flow rates, retention times, and nutrient inputs. Actions taken:
Permitting: In 2015, a Coastal Development Permit was submitted but approval, and contingent construction of the bioreactor chambers, was severely delayed. The grading permit was approved by the County, and construction of the project began in September 2016.

Creation of 12 total above-ground chambers for treatment systems: Construction of 12 above-ground chambers, each measuring 80'x2.5'x5', was completed in spring 2017. The 12 linear chambers were contained in a large earth basin and each chamber were separated by chain-link fencing and posts, and lined with impermeable pond liner. Perforated drainage was installed beneath the pond liner to prevent water from pooling under the chambers. Sump pumps were installed to regulate ground water interactions with the chambers. Winter flooding restricted access to the site (needed to install wood chips and plant materials) and caused considerable delays into late spring 2017. Initial flow studies were completed while site access was limited, and initial nutrient load reduction experiments began June 5, 2017.

Pipe and pump installation and retention system for water: Individual chamber inlet and outlet piping and pumps were installed and appropriately modified based on initial flow experiments (Attachment 1). Dedicated power lines and a PG&E transformer were installed to ensure that continuous power was available to regulate flows and maintain sampling equipment. A fore bay to the treatment chambers was constructed to retain water, reduce sediment, and maintain consistent flow to all the treatment chambers through a distribution trough. The fore bay contains an overflow mechanism that is connected to the adjacent agricultural ditch, and two bypass lines that are connected to the treatment wetland, located just beyond the bioreactor. The trough runs across the beginning of the chambers and allows for adjustable flowrates and hydraulic residence time (HRT) in each chamber using adjustable v-notch distribution points. A CSUMB student created a model to calculate v-notch height adjustments in order to achieve specific flow rates into the chambers. A different model was used to calculate flowrates for specific HRT within each treatment. The standpipe at the end of each chamber is perforated to collect treated water from the entire water column. Removable screens were needed to cover each standpipe and prevent larger debris (e.g. woodchips, algae) from clogging the perforations. The outlet of each chamber discharges into the adjacent treatment wetland. The height of the pipe outlet acts as the hydraulic control for the height of the water within the chamber, allowing easy access for water sampling.

Filling the chambers with materials to create three replicates of 4 treatment systems: Initial treatment systems to be tested include 1) wood chip bioreactor; 2) heated wood chip bioreactor; and 3) wetland emergent plant growth chambers and an agriculture ditch/control treatment. The treatments were successfully filled on May 31, 2017. To fill the vegetated wetland channels, *Hydrocotyle* (known as pennywort) was transplanted from the adjacent agricultural ditch and was suspended in the channels by using several sections of wide mesh for support.

Tracer tests to determine to standardize rate of water flow: The Watson Lab at CSUMB completed a set of three flow model runs to estimate retention time, water flow rate, and depth for each treatment. These models aided the design and construction of the various treatment chambers and development of load reduction models for each treatment type.

Task 2 - Project Monitoring, Model Development and Partner Outreach Description: CCWG and partners used resulting data from each of the treatments to develop load reduction models and evaluate the functional constraints of each technology. The captured data will enable growers to reduce nitrate levels in farm runoff through application of treatment techniques best suited for the specific specialty crops and drainage conditions. Actions taken:
During construction permitting delays, the scientific team worked to improve the data collection capacity of the system and further integrate the resulting data into industry-led discussions with RB3. CCWG and CSUMB researchers continued collaborations to identify additional projects that could be implemented collaboratively to further nutrient reduction research and program development goals. A pilot bioreactor was constructed in March 2016 and provided the project team with a single- chamber working laboratory while construction delays at the multi-chamber were addressed. This allowed for research into retention times, nutrient reduction rates, and pesticide removal potential. Lessons learned from construction of and research at the pilot bioreactor provided invaluable insight and improvements to the design and construction of the 12-chamber bioreactor.

Sample and monitor input and output parameters (temp, DO, salinity, conductivity): Matching funds provided by Anthropocene Foundation enabled the CCWG team to purchase a multi-parameter water quality monitoring probe that includes a nitrate sensor. The probe is incorporated into the Hydra-Nutrient Analyzer, an automated sampling system, which collects and analyzes source drainage water and water from each of the nutrient reduction chambers every four hours. This consistent, continuous sampling significantly increases the resolution of the nutrient reduction models and can account for daily fluctuations in nutrient loading. The Hydra-Nutrient Analyzer has been tested in a lab setting and was deployed May 19, 2017 to collect load reduction data necessary to build nutrient reduction curves. After deployment in the field, a number of hardware issues were discovered and resolved, including: installation of valve filters to prevent snails from clogging the collection/analysis system, replacement of the nitrate probe, and reworking inadequate pumping of source water samples from the fore bay. During June 2017, 16 sets of grab samples were collected from the distribution trough (source water), each of the 12 chambers, and the end of the treatment wetland, to inform nutrient reduction curves and capture initial reduction processes after the bioreactor was turned on. A YSI sonde was used to collect temperature, dissolved oxygen (DO), salinity and specific conductivity data, and a turbidimeter was used to test turbidity. Nutrient sampling was conducted by collecting 30ml of water, using a 50ml syringe with filter, at each sample location.

Collect field records of ambient temperature and recent rainfall events. The Moss Landing Marine Labs Weather Station is online and collecting continuous data.

Lab analysis of water samples for nitrates: At the pilot bioreactor, nutrient concentration grab samples were collected at the input and output locations. Nutrient concentrations in source water for the multi-chamber system were collected daily in September 2016. Fluctuations in daily nutrient concentrations in these samples documented the benefits of sampling nutrients within all treatments multiple times a day.

After completion of contraction of the multi-chamber bioreactor, the Hydra-Nutrient Analyzer was deployed and recalibrated using grab samples taken from the same locations from which the system draws its samples. All grab samples were processed in the Null Lab at Moss Landing Marine Labs.

Tracer tests to determine mechanisms and rate of water quality improvement: After construction was completed, the Watson Lab at CSUMB completed a set of flow model runs to estimate retention time, water flow rate, and depth for each treatment. Additional tracer tests were performed to confirm the HRT, especially in the wood chip treatment channels.

Data synthesis and analysis: See Attachment 2 for a complete description. Reductions were calculated from grab samples collected in June 2017, assuming a one-day HRT. Nutrient reduction rates were averaged by treatment and for all dates. Initial results document a significant reduction in nutrient concentrations in the heated and unheated woodchip treatments, but not in the vegetated and control treatments. Initial results indicate that the unheated woodchip treatment is outperforming the heated woodchip treatment. This may change as the bioreactor is better established, and during the colder months of the year which usually arrest performance of nitrate-consuming bacteria.

Develop and refine models: See Attachment 5 for a complete description. The model results indicated that all three channels with a given treatment behaved similarly to each other, and differently to channels with a different treatment. All channels experience nutrient reduction to varying degrees. The woodchip channels experienced much greater reduction than the control and surface-vegetated channels. The cool woodchip channels experienced slightly more reduction than the warmed channels, probably due to the shorter residence times apparent in the warmed woodchip channels. There was no apparent difference in the instantaneous rate of reduction between the cool and warmed woodchip channels. These results were obtained in mid-summer; the project team would expect a different result in winter, when the temperature difference between the cool and warmed channels is expected to be much greater. Warmer temperatures were indicated to have a positive effect on reduction in all channels.

While the nature of the results is consistent with a denitrification process (the intended outcome), it cannot yet rule out that the reduction is due to other processes, such as adsorption or conversion to other nitrogen species. All that was observed is reduction in the concentration of certain aqueous inorganic nitrogen species. This is typical of many bioreactor studies.

Initial model-based estimates of reduction rates for each treatment are shown in Table 1 (below), notwithstanding the shortness of the data set, and the lack of winter data. Based on the data collected to date, and assuming a near-optimal (i.e. summer) temperature of 20°C, the nutrient reductions in woodchip reactors of the kind the project team installed could be expected to be around 6-7% per hour, or 75-80% per day.

Treatment	Channel number	First-order reduction coefficient (at 20C) by channel	First-order reduction coefficient (at 20C) mean	Reduction per hour (at 20 C) by channel	Reduction per hour (at 20 C) mean	Reduction per day (at 20 C) by channel	Reduction per day (at 20 C) mean
Control	2	0.154	0.15	0.6%	0.6%	14%	14%
Control	7	0.113		0.5%		11%	
Control	11	0.183		0.8%		17%	
Cool woodchips	1	1.763	1.45	7.1%	5.9%	83%	75%
Cool woodchips	5	1.687		6.8%		82%	
Cool woodchips	9	0.914		3.7%		60%	
Warm woodchips	3	1.953	1.70	7.8%	6.8%	86%	80%
Warm woodchips	8	1.166		4.7%		69%	
Warm woodchips	12	1.973		7.9%		86%	
Floating vegetation	4	0.185	0.18	0.8%	0.7%	17%	16%
Floating vegetation	6	0.201		0.8%		18%	
Floating vegetation	10	0.139		0.6%		13%	

Table 1. Reduction rates estimated from fitted model for each treatment.

Outreach to growers based on results: Tours of the multi-chamber bioreactor have been orchestrated with CSUMB researchers and new questions and experiments are in development. Several CSUMB graduate students are now working on the project, documenting flow characteristics and nutrient load reductions. Partnerships have been established with California Department of Pesticide Regulation and new pesticide reduction studies and toxicity experiments are being developed and are scheduled for funding at this and the adjacent pilot bioreactor. CCWG is working with the Monterey County Resource Conservation District (MCRCD) and the Monterey Grower-Shipper Association to help cooperative groups of specialty crop growers adopt these treatment systems within defined drainages and gain credit for their construction with state regulatory agencies. The MCRCD recently received a grant from the United States Department of Agriculture (USDA), NRCS to help farmers construct treatment systems, and will use the data from this project to complete a site evaluation and cost-benefit analysis needed for industry to select the most effective treatment system. See Attachment 3 for a full list of outreach activities.

The overall scope of the project solely benefitted specialty crops and specialty crop producers. Data results focused on nutrient reduction potential of various treatments within the highly productive Salinas Valley specialty crop farming areas. This research specifically focused on aiding farmers to meet regional environmental laws and centers on agriculture practices unique to this region and these crops (drip tape, tile drains, etc.). All grant funds were expended on grant related activities.

Each team member excelled in completion of their tasks and meeting their responsibilities. The project team was able to work around permit delays and construction challenges. The Watson Lab at CSUMB used their hydraulic modeling capabilities to guide chamber design and flow regulation infrastructure to obtain equal flow and residence times for each chamber as needed to establish accurate load reduction estimates. They also aided in design and construction of thermal insulation needed to raise temperatures within the heated chambers. The Null Lab at the Moss Landing Marine Laboratories (MLML) provided field support and rapid return of nutrient analyses to generate reduction data enabling the team to produce fine scale changes in chamber design and sample collection strategies necessary to optimize nutrient reduction estimations. MLML staff invested significant time in building the Hydra-Nutrient Analyzer auto sampler. CCWG staff and interns effectively coordinated chamber construction, hydraulic design, and data collection. Staff continually

integrated project design refinements into the system to achieve optimal performance. CCWG managed reporting, budget oversight, and project completion. Each member performed above expectations and was driven by the importance and innovative nature of the project goals. The entire technical team aims to identify additional funding to continue the study of nutrient reduction techniques now that the multi-chamber bioreactor research facility is operational.

Goals and Outcomes Achieved

Due to permit and weather related construction delays, nutrient load reduction sampling of the various treatments was completed in the spring and summer of 2017. Additional student field assistants were hired to assist with sample collection to complete the extensive data collection, analysis and modeling required to achieve the key goals and outcomes of this project. This includes documenting load reductions and developing load reduction curves for several different treatment options. The CCWG team coordinated data collection and analysis efforts among the partners to ensure that the goals and outcomes of this project were achieved. The Null lab prioritized the analysis of more than 210 nutrient samples during this period and completed all Quality Assurance measures needed to verify results. MLML staff invested significant time to ensure that the Hydra-Nutrient Analyzer auto sampler functioned properly and data generated by the Hydra and Null lab were consistent. CCWG partnered with CSUMB to obtain a summer intern to focus additional field and office time to collect, analyze and process nutrient load reduction data for load reduction estimations. The Watson lab at CSUMB focused their efforts during the spring and summer on improving hydraulic residence time for each treatment chamber and logging fluctuations in temperature to establish precise measurements needed to establish the nutrient reduction curves. The combined focus of the technical team allowed us to meet project outcomes and goals and develop scientifically defensible nutrient reduction estimates for the tested treatment options.

Key outcomes of this project were to create the nutrient reduction curves for the tested treatment systems. A long-term outcome is for the specialty crop industry to use this information to identify appropriate nutrient treatment systems for construction on their farms. The project team are working with the MCRCD and the Grower-Shipper Association of Central California to help cooperative groups of specialty crop growers adopt these treatment systems within defined drainages and gain credit for their construction with state regulatory agencies. The MCRCD recently received a Conservation Innovation Grant from the USDA, NRCS to help farmers construct treatment systems and will use the data from this project to complete a site evaluation and cost benefit analysis needed for industry to select the most effective treatment system.

The following activities were completed in the final months of the project:

1) The chambers were filled in April 2017: Completed in May 2017- a total of 320 yards of wood chips were placed into the six test chambers.
2) In May 2017, water samples were taken to determine water quality: 210 nutrient and basic water chemistry samples were collected in June - equating to 15 individual load reduction calculations for each treatment chamber, or 45 load reductions for each treatment type.
3) Data synthesis and analysis is ongoing as data are collected: Synthesis is complete and load reduction data are attached to this final report.
4) Models will be further refined as data are generated. Staff at CSUMB continued to input data to refine nutrient reduction curves weekly through June: All data have been submitted to CSUMB researchers who have used those data to generate load reduction curves for each treatment type.

5) Initial outreach has begun and continued through the end of the project: CCWG has successfully integrated the use of this project's load reduction information into the MCRCD's USDA, NRCS grant effort in coordination with the Grower-Shipper Association. The results of this project will help farmers select appropriate treatment systems.

The project set target was to establish decay rate/load reduction estimates for each of the four discrete treatment systems. Daily concentration estimates were collected from 16 sampling events (Figure 1, below), and were used to calculate reduction rates in two ways. The first method uses a modelling approach to account for variability in flow rate/retention time, initial source water concentration, and average water temperature (Table 1, within Project Approach section). The second method calculated reduction assuming a one-day residence time for average concentration by treatment over the sampling period (Table 2, below).

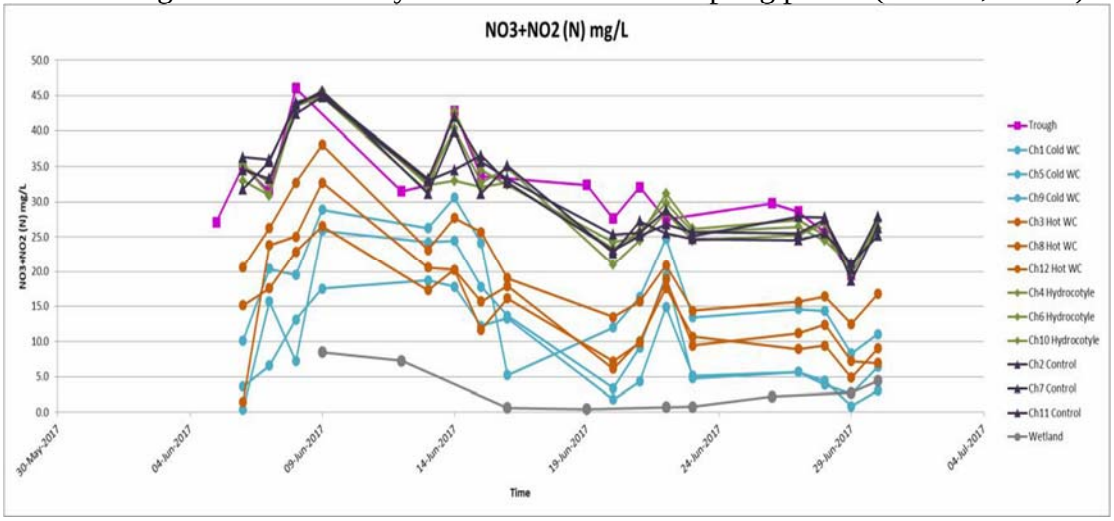


Figure 1. Daily concentration of water discharged from each of the 12 treatment chambers and source water (trough), as well as the adjacent treatment wetland.

Treatment	Average dischage concentration	Flow Rate (g/m)	HRT	area (sq ft)	Volume (cubic feet)
Ag Ditch	32.47	4.64	21.96	400	1000
Hydrocotyle	32.85	4.39	21.16	400	1000
Cool woodchips	13.51	2.78	20.65	400	500
Heated woodchips	18.23	2.64	22.12	400	500
Treatment wetland	3.27	43.35	84.00	465,000	558000

Treatment	Percent Reduction	mg/L Reduction	Load Reduction g/day	Load Reduction (grams/day) per 1000 sq ft of treatment	Concentration (mg/l) Reduction per 1000 sq ft
Ag Ditch	3%	0.90	22.68	56.70	2.24
Hydrocotyle	2%	0.46	11.08	27.69	1.16
Cool woodchips	45%	14.87	225.44	563.61	37.19
Heated woodchips	28%	9.21	132.72	331.79	23.03
Treatment wetland	89%	20.99	6,176.63	13.28	0.05

Table 2. Average nutrient reduction estimates for each treatment.

Quantified results of key project outcomes:

1.) Construction of a working laboratory of four treatment measures replicated three times each for statistical validation: The project team constructed an 8,000 square foot research facility that includes dedicated

power, an automated nutrient sampling system, and flow regulation infrastructure that can be modified for a range of flow rates. The infrastructure supports water quality research within 12 treatment chambers within a working agricultural landscape.

2.) Establish decay rate/load reduction estimates for each of the four discrete treatment systems: Load reductions were established for each of the treatments (Tables 1 and 2) and decay rates were calculated by integrating information on initial concentration, flow rates and water temperature. See Attachment 5.

3.) Dissemination of results to various users: Initial results have been presented at three regional workshops and industry meetings, discussed with RCD and Grower-Shipper staff on three occasions, and presented at the California Headwaters to Oceans Conference in May. Results of decay rates will be presented at an upcoming Agriculture Water Quality Alliance meeting and used by partners to aid project selection and design for the USDA, NRCS grant project. Please see Attachment 3 for a full list of outreach events.

4.) Integration of load reduction estimates into a watershed-based alternative compliance strategy: Load reduction estimates have been provided to the agriculture cooperative development team (results presented at the most recent meeting). The USDA, NRCS grant directly references the use of this project's results by specialty crop farmers to design and prioritize treatment projects and aid negotiations with the state regulators (by providing defensible and quantifiable load reduction estimates of proposed actions).

The Nature Conservancy, MCRCD, Grower-Shipper Association of Central California, Monterey Bay National Marine Sanctuary and CCWG are working with leaders in the agriculture industry to develop a farmer cooperative in which landowners/growers in a defined drainage work together to address water quality as a group. The results of the multi-chamber bioreactor project have been compiled and are informing the team of future options for construction within adjacent watersheds where such measures have not yet been installed.

The partners above have reported these findings to 100% of interested state and regional regulatory agencies (State and Regional Board, Department of Pesticide Regulation, Monterey County) and are representing the findings of the multi-chamber project as a member of the Central Coast bioreactor work group. The partners are scheduled to meet with Regional Board staff and the executive officer in late February 2018 to present findings of this and other projects and investigate mechanisms to recognize farmers helping implement these water quality improvement projects. See Attachment 7 for the project introduction sent to Regional Board 3.

Beneficiaries

The beneficiaries of this project will be any specialty crop g
rowers in the region that are looking for effective ways to improve water quality before it leaves the farm. Growers are actively seeking innovative ways to improve water quality and are open to novel beneficial management practices, such as edge-of-farm or off-farm woodchip denitrifying bioreactors and constructed treatment wetlands. The data generated by this project will help farmers meet agriculture waiver requirements.

The load reduction estimates will be used in development of the Agriculture cooperative for two watersheds in the lower Salinas Valley (Attachment 4). Between 20 and 30 different specialty crop farmers are anticipated to participate in these Phase I cooperatives when established, representing more than 3,700 acres of specialty crop agriculture lands. If successful, the Cooperative approach to the Ag Order compliance is expected to be reproduced throughout specialty crop areas of the Salinas Valley and Central Coast.

Lessons Learned

General Design Considerations when building a bioreactor:

1.) Choose dimensions:
The width and length of a bioreactor will depend on the desired amount of water to be treated. There is little consensus regarding optimal dimensions, but it is the project goal to use denitrification rate data to build a model that will estimate required bioreactor size based on the desired number of acres to be treated and the peak flow from that land.

2.) To line or not to line:
Using a polyethelene pond liner ensures all water entering the chamber is treated and leaves via the outlet, as opposed to some unknown amount of water contributing to groundwater recharge. While this makes quantifying the total amount of water treated easier, there are drawbacks to using a liner when it comes to maintenance and construction. From past experience, making the lining leak free at the outlet is difficult, and any liner above the water-line makes great habitat for rats to nest in. Though there are ways to mitigate these problems, an alternative option in predominantly clay soil, as is present in the Lower Salinas Valley region, is to have an unlined chamber.

3.) Choose source material for woodchips:
While there is little evidence to suggest a significant difference between source material for woodchips, pressure treated wood and eucalyptus should be completely avoided because of their undesirable chemical composition.

4.) Filling the bioreactor:
The bioreactor can be filled by using a tractor to dump woodchips in or near the site, and using pitchforks to manually spread the woodchips. However, if the chamber is inaccessible by tractor, contracting with a blown woodchip delivery service, is a great alternative.
Note: If using pond liner, do a leak test by filling the chamber with only water before filling it with a treatment. All repairs become more difficult when navigating around woodchips or plants.

5.) Maintenance:
Leaving a treatment-free space around both the inlet and outlet of the chamber allows for easy access for maintenance and repairs. The woodchip chambers contain barriers that allow water to pass through but hold the woodchips in place. Nevertheless, routine maintenance will still be required to prevent clogging and biofouling.

The unexpected growth of algae (*Ulva intestinalis*) in the control chambers provided the opportunity to partner with local organizations who are interested in using the biomass of this algae to develop agricultural fertilizers and biofuels for use on farms. Such a partnership can help increase nutrient cycling and efficiency in agricultural production and treatment of runoff.

Heated wood chips begin to produce similar reductions in nutrient concentration after a fortnight delay in denitrification. The delay and resulting denitrification processes are different between heated and cool wood chip chambers. It is uncertain if modifications to the chambers can be made to increase the efficiency of the heated chambers to offset added materials costs.

The aquatic plant *Hydrocotyle* showed limited nutrient reduction value, even as biomass increased significantly. Further studies are needed to determine if shallower water (i.e. more root contact) would increase nitrogen uptake rates. *Hydrocotyle* may also be a valuable secondary product of treatment chambers if nitrogen reductions can be improved.

The treatment wetland showed the most consistent nitrogen removal capacity (as expected) but was found to be less efficient in load reductions because of the significant acreage needed to construct the wetland. The project team anticipate that because nitrogen removal rates within wetlands are dependent on initial concentration (zero order reaction) a significantly smaller wetland may produce a disproportionately large removal capacity. Further sampling at 500 foot increments within the wetland will aid the understanding of load reduction within small wetlands relative to initial nutrient concentrations.

All goals and outcomes were achieved. However, data collection was compressed within one sample season (spring/summer) due to permit and construction delays. Future sampling during fall and winter seasons (funding dependent) will help document denitrification during sup-optimal seasonal conditions.

Permit delays were not expected because the constructed infrastructure was placed on agriculture lands and was comprised of agricultural management measures. However, because of this project's link to the treatment wetland project directly downstream, this project was found to need to be covered within the larger site permit, leading to delays.

Additional Information

Please see Attachments 1-7 for more information on this project. A publication is anticipated to be written in 2018 that reflects the success of this set of experiments. The project team, along with CSUMB, will continue to seek additional research funds for this project site and expand the number of treatment types and field conditions tested to increase the amount of available information for growers.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 32	**Project Title:** Development of a Statewide Spatial/Mapping Database for Almonds, Walnuts, and Pistachios	
Grant Recipient: Almond Board of California	**Grant Agreement No.:** SCB14032	**Date Submitted:** December 2016
Recipient Contact: Debye Hunter Gabriele Ludwig	**Telephone:** (209) 343-3230 (209) 343-3230	**Email:** dhunter@almondboard.com gludwig@almondboard.com

Project Summary

The purpose of this project was to produce a field by field spatial crop (almond, walnut, pistachio, dried plums) and orchard age spatial database using remote sensing analysis, representing about 1.5 million acres in California's Central Valley. This database will address the need for accurate, timely and cost-effective nut crop acreage data, which currently did not exist as a comprehensive spatial data product.

This project is important and timely because nut commodity organizations currently purchase annual, non-spatial crop acreage data that is available no earlier than April or May of the following year. These data historically underestimate acreage, are mostly non-spatial, and can be less than 75 percent accurate. The method used for this project is highly accurate, completed sooner, and samples 100 percent of the population (without subjective surveys). Never in California's history has spatial crop data been as important as it is now; it informs agricultural decisions for managing fragile water supply, environmental stressors such as climate change, increasing regulatory requirements at the state and federal levels, and expanding global markets. These decisions require comprehensive information about crop acreage and location.

The project did not build on a previously funded Specialty Crop Block Grant Program (SCBGP) project but was developed based on a need identified in the 2010 SCBGP Project 47: *Carbon Dynamics of Orchard Floor Applied, Chipped Almond Prunings as Influenced by Irrigation Methods, Soil Type, Cover Crop Management, and Farm Practices*.

Project Approach

The activities and tasks performed during the grant period are as follows:

- Finalize Imagery Selection – It was initially thought that these imagery data would need to be purchased at an estimated cost of $74,240, however the National Agricultural Imaging Program (NAIP) provided imagery sooner than expected for the 2014 growing season and was of sufficient quality to serve the project's purpose. The savings were used to add an additional crop (statewide distribution of dried plums) to the classification effort. Imagery used for this effort included not only NAIP image resources, but also Landsat and in some cases other imagery already obtained by Land IQ for other projects conducted in California.
- Finalize Geographic Information System (GIS) Acquisition – It amounted to acquisition of county pesticide use reporting data, recent Department of Water Resources (DWR) spatial data for a few select areas, county crop reports, and the National Agricultural Statistics Service (NASS) Crop Data Layer (CDL). All of these resources act as supporting lines of evidence for the final remote sensing approach. Other resources used as fact checking information included County Ag Commissioners'

reported acreage (although not spatial), irrigation district reported acreage (when available), historic reported acreage, etc.

- Quality Assurance/Quality Control (QA/QC) Ground Truthing – The work amounted to traversing the areas of tree crop production for approximately 4,000 miles and acquiring the ground truth data set required for training data. Approximately 10-12% of all almond orchards in California's Central Valley were logged by location. The ground truth dataset is acquired for two purposes. The first purpose is to acquire the necessary "training dataset" data for the remotely sensed efforts. The second purpose is to provide for an "independent validation dataset" that can be set aside for accuracy assessments once classification has been finalized.
- Imagery Processing – The task consisted of geo-referencing and processing of the NAIP imagery resources. Again, other image resources were used to some extent (e.g. Landsat) to provide foundational temporal signatures.
- Field Boundary Generation – This task consisted of completing the initial coverage of field boundaries. Initially, all permanent crop field boundaries had to be delineated. This included any tree or vine crop found within California's Central Valley or exterior fringe counties growing almonds. This allowed for analysis of all permanent crops and segregation of almonds in particular (Figures 1 and 2). Figure 1 is a zoomed in representation of the delineation of fields with the irrigated area only. Figure 2 is an image of the Central Valley wide extent of these field boundaries.

Figure 1. Example of field boundaries.

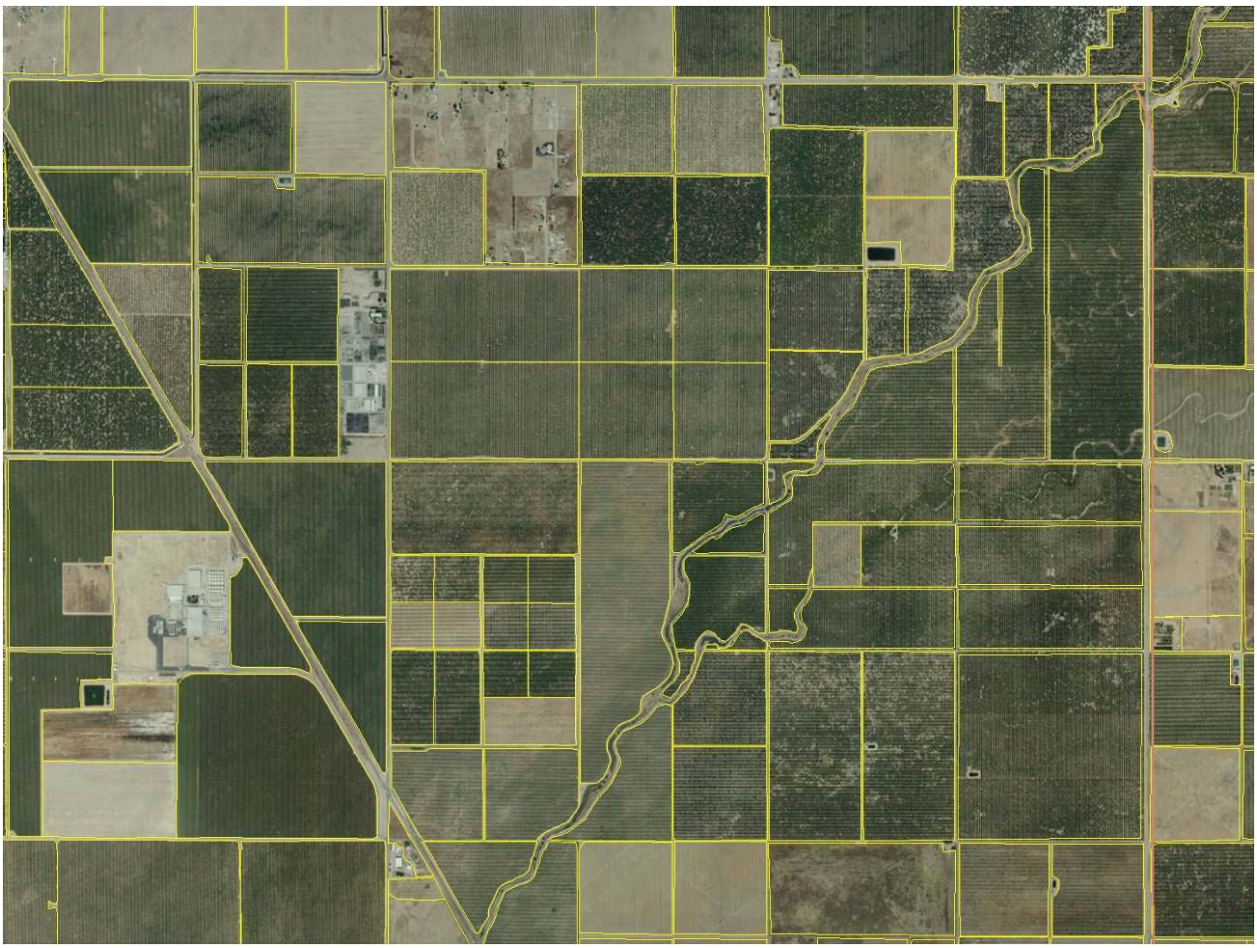
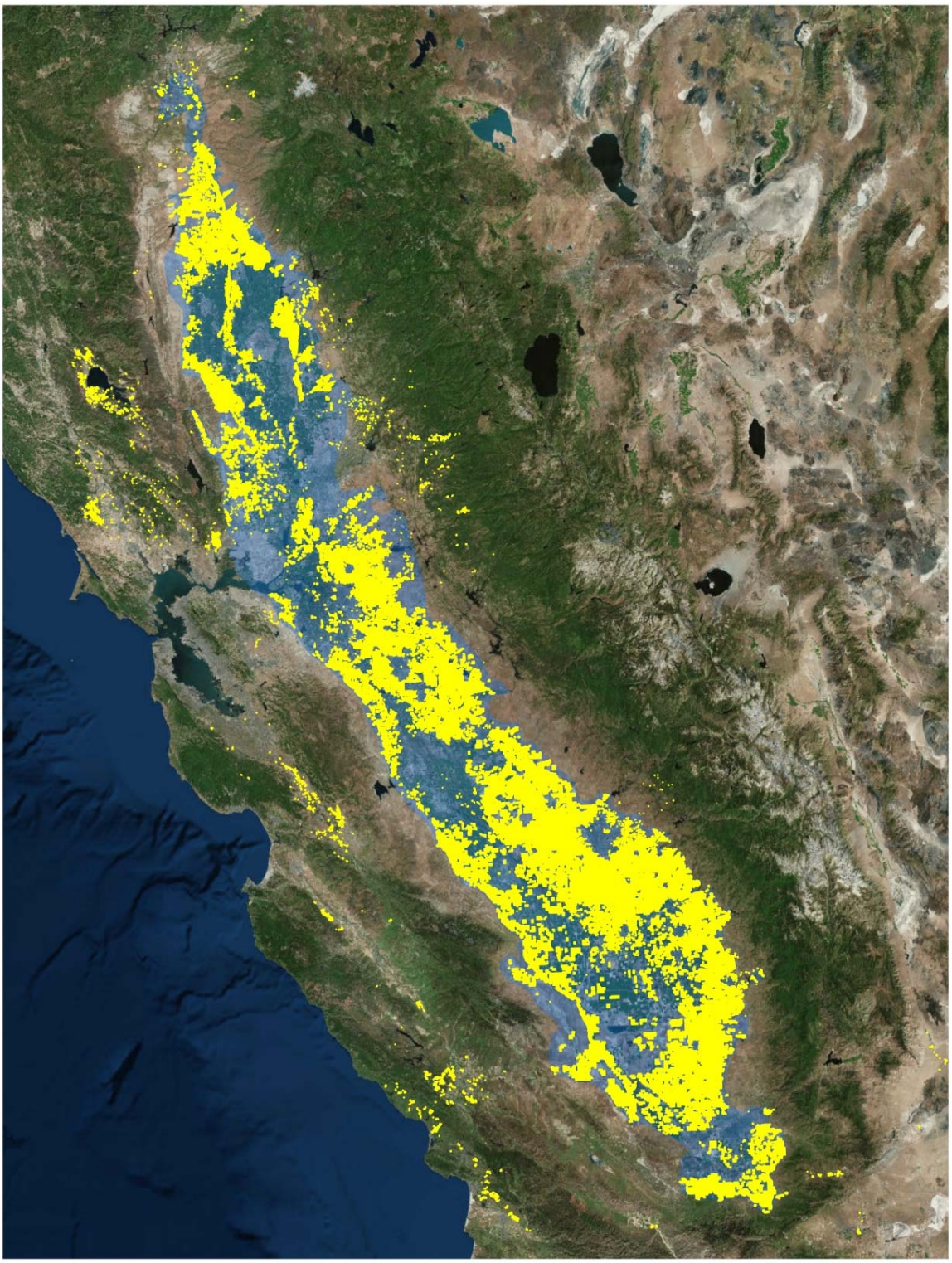


Figure 2. Example of permanent crop field boundaries for the entire state.



- Analysis – This activity consisted of generation of the analytical parameters including spectral, temporal, and textural information from the imagery. Crop classification and accuracy assessments are finalized. Performance of the final QA/QC review was conducted concurrently with benchmark comparisons and orchard age analysis that were completed through September of 2015. Final accuracies were between 97 and 98 percent.
- Interim Results Delivery – All interim results were ready for delivery; however internal data management protocols are still being determined between Land IQ and the involved commodity organizations. These protocols are not part of the grant funded activities, however are being developed for the purposes of internal data management integrity and use.
- Perform Benchmark Comparisons – The purpose of this task was to compare and carefully utilize other spatial resources for verification or for informing project staff work efforts. This task was finalized with the use of some CDL mapping information as well as some county mapping efforts conducted at the county level. By far, most counties do not have spatial data information.
- Orchard Age Analysis - Land IQ developed an automated methodology for orchard age determination and acquired the series of Landsat imagery required to complete this task. QA/QC of final orchard delineations has been completed and has been delivered.
- Package Data – All data have been made available to each organization either through a web map application or through original file format. Centralized data management is critical for data integrity and management actions. Land IQ is currently providing this data management under a separate contracting mechanism.
- Reporting and Documentation – The main component of this task involved documentation of meta data and completion documentation of this work.
- Interim Results Delivery – This activity is 100% completed for all commodity groups. The individual cooperating commodity groups have been given access to a web map application for the purpose of viewing the information.

The funds provided to complete this work were only used for almond, walnut, pistachio, and dried plum orchard mapping. No other commodity benefited from the use of these funds.

The following organizations provided significant contributions including tree crop development information, general distribution, production trends, proximity information, acreage estimates, matching funds, and/or in-kind contributions:

- California Pistachio Research Board
- California Walnut Commission
- Almond Board of California
- California Dried Plum Board
- Land IQ

Land IQ in consultation with each of the four commodity groups performed the technical work (remote sensing analysis) to develop the tree crop mapping results.

Various information resources were obtained and/or technical communications took place with University of California, Davis Department of Plant Sciences, Paramount Farming, Blue Diamond Almonds, DWR, and

California Department of Conservation, further providing multiple lines of evidence for the ultimate and final classifications.

Goals and Outcomes Achieved

The specific measureable outcomes/goals and progress toward achieving these outcomes/goals are as follows:

1. Location and extent of about 1.5 million acres of almonds, walnuts, pistachios and dried plums in the Central Valley – This is the sum of the estimated analyzed acreage for the state of California for the four tree crops for 2014 and can be spatially represented as a result of the foundational mapping effort. Relative to the approximate 8 million acres of irrigated crops within California's Central Valley, this is a significant portion.
2. Determination of total acreage of each crop – As a result of the spatial mapping, the total acreage for each of the four tree crops was determined and also on an orchard by orchard basis. Not only was the acreage determined, but more importantly the actual geographic location of each individual tree crop is now known. The total acreage of each crop (almonds, walnuts, and pistachios) was determined within at least 95% accuracy. The individual orchard locations can be grouped according to a number or regional, county, or other spatial boundaries with GIS software capabilities.
3. Determination of orchard age – Once the individual orchards were mapped, a backwards looking time series analysis was performed on available imagery as far back as 1984 for each orchard until the spectral and textural signature changed from an orchard to bare ground. At that point, this was considered as the planting year to determine the age of that orchard. The orchard age accuracies achieved 85-90% as compared to grower information and planting records throughout time.
4. Select data for biomass estimation in ongoing collaboration with UC Davis – for the past two years, the ABC has been investigating with researchers from UC Davis an estimation of biomass or carbon accumulation within the woody material of the tree crops. ABC provides all orchard data to UC Davis (tens of thousands of orchards, rather than a minimum of 80) for continued research use.
5. Creation of GIS ready datasets – Because the created data are spatial in nature, this automatically facilitates the GIS ready datasets. These datasets are constantly being updated as new orchards are planted or old orchards are removed. Thus, data management protocol and version control are critical.
6. Outreach through development of spatial databases, GIS products, maps, publications, etc. Data will facilitate other outreach products including: layering with other spatial data, regulatory boundaries, water district supply boundaries, groundwater recharge opportunities, previous crop determinations, etc. - Since completion of the mapping efforts, Land IQ has been working with the ABC, in particular, to interpret the results relative to other spatial data resources (e.g. soil type, previous crops, irrigation districts, etc.). These additional analyses were funded separately and not as a part of this scope of work.

Communications with all four tree crop commodity organizations have already taken place to determine a consistent Data Management Protocol and how the anticipated GIS datasets and products will be made available, who will use them for industry wide analysis, and how these data can be integrated with other publically available spatial information (not a part of this grant funding effort, however).

Long term outcome measures include 1) application of base map for annual updates; 2) applications of the spatial tree crop data beyond the scope of this project. The spatial database that was completed during this project can be used in subsequent years because it provides a base layer on which annual updates can be conducted with much less effort than the original mapping effort. Applications of the spatial data beyond the

scope of this project have already begun. For example, spatial orchard data has been used in conjunction with other spatial data resources to evaluate suitability of groundwater recharge sites in California's Central Valley, an analysis of previous cropping systems, and an analysis of past and current consumptive use. Moving forward, the commodity organizations are now investigating the relationship to solar installations, and proximity to schools and daycares in response to regulatory concerns.

Actual accomplishments mirrored the goals established for this project. No goals were unattainable.

The specific, field location of approximately 1.5 million acres of walnuts, almonds, pistachios and dried plums were mapped throughout California. The spatial data is on an orchard basis, meaning that the true acreage of each nut/fruit crop is mapped. No roads, farmsteads, irrigation ponds, etc. are included in the acreage data. The age of each of these orchards was also determined on a field by field basis. GIS datasets have been completed, and all of the spatial information has been developed into an interactive web-based mapping portal that allows users to see the location of orchards by crop and by age.

The major successful outcomes of this project include 1) the completion of a state wide; field-level nut/fruit tree crop map; 2) the determination of orchard age of every walnut, almond, pistachio and prune orchard in California's Central Valley.

Beneficiaries

The groups that benefit from this project's accomplishments include:

- California Pistachio Research Board - The California Pistachio Research Program is a California State Marketing Order, authorized by a grower referendum in December 2007 and operating under the oversight of the California Department of Food and Agriculture. Mandatory assessments paid by pistachio producers are used to fund research on pistachio propagation, production, harvesting, handling and preparation for market as well as provide educational opportunities and materials for pistachio growers. Hundreds of pistachio growers have benefited from this information as a result of use of the information by the California Pistachio Research Board.
- California Walnut Board - The California Walnut Board was established in 1948 to represent the walnut growers and handlers of California. The Board is funded by mandatory assessments of the handlers. The California Walnut Board is currently implementing an industry-wide focus on use of these data and it too is expected to benefit hundreds if not thousands of walnut growers. The data are actively being used.
- Almond Board of California - The Almond Board of California promotes almonds through its research-based approach to all aspects of marketing, farming and production on behalf of the more than 6,000 California Almond growers and processors. Established in 1950 and based in Modesto, California, the Almond Board of California is a non-profit organization that administers a grower-enacted Federal Marketing Order under the supervision of the United States Department of Agriculture.
- California Dried Plum Board - Since 1952, the Marketing Order for California Dried Plums has been directing marketing and research activities related to dried plums. The California Dried Plum Board represents 900 dried plum growers and 21 dried plum packers under the authority of the Secretary of Food and Agriculture.

The potential economic impact of this project is far-reaching and difficult to quantify at this time. The database developed by this work is already being used to inform decisions for research and marketing purposes. Examples include: water management such as groundwater recharge sites; transportation as affected by size of harvested crop (determined partially by tree age); composted animal waste management (proximity for use on orchards); evaluation of proximity of orchards to schools and daycare facilities potentially impacting spray restrictions, analyses relevant to responding to queries from the media.

Lessons Learned

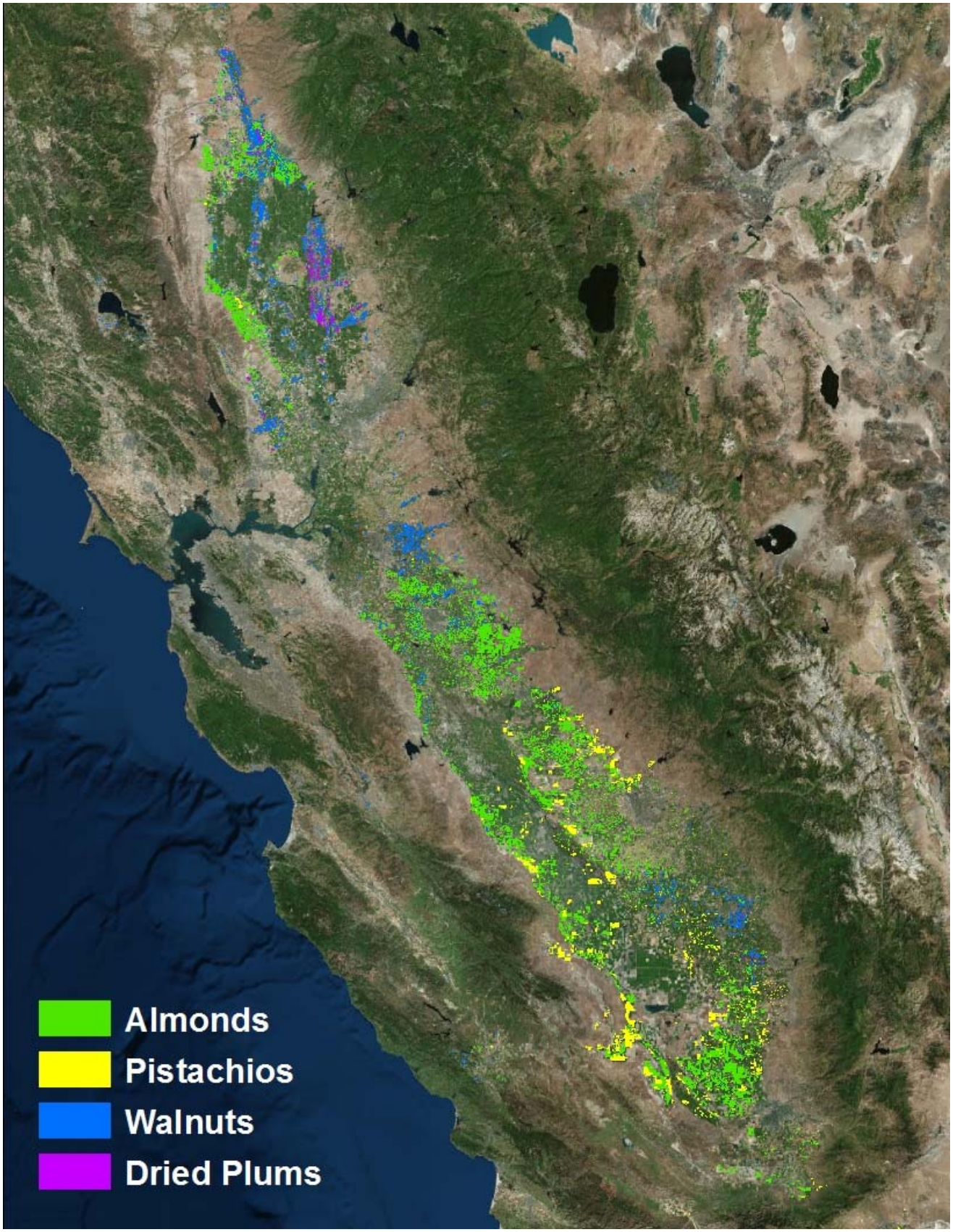
The vast majority of information learned as a result of this work has been positive. Perhaps the most influential positive outcome is the fact that the four commodities now have a baseline mapping product that can be updated in future years without nearly the effort required to establish an original mapping product. Also, the true irrigated acreage of the four crops and their exact locations are now known. This information can be used in relation to regulatory requirements, surface and groundwater management, haul distances, various proximity analyses, etc. No real negative results were experienced. The commodity organizations now have to understand the management of data and protection of grower confidentiality.

There were no unexpected outcomes or results. All goals and expectations were met or exceeded.

All outcome measures of the project were achieved.

Additional Information

Please see image on next page for example of final statewide spatial distribution results. The image shows all four tree crops as follows: almonds = green, pistachios = yellow, walnuts = blue, dried plums = purple. The spatial distribution of almonds occurs throughout the Central Valley from north to south. Walnuts are more prevalent in the northern portions of the Sacramento Valley, areas north of Modesto in Stanislaus and San Joaquin counties, and areas in proximity to Visalia in Tulare County. The vast majority of pistachios are found in the southern Central Valley. Dried plums are mostly found in the northern Central Valley.


Almonds
Pistachios
Walnuts
Dried Plums

USDA Project No.:	Project Title:	
33	Development of a Solar Thermal Drum Dryer for Specialty Crop Purees and Pomaces	
Grant Recipient: USDA, Agricultural Research Service	**Grant Agreement No.:** SCB14033	**Date Submitted:** December 2017
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Project Summary

When specialty crops are processed into fresh-cut, canned, or frozen form, a low-value but nutritionally-dense co-product called "pomace" is often produced. Pomace includes the skins, seeds, and other fibrous parts of the fruit or vegetable. Pomaces are also high in moisture, so specialty crop processors need an environmentally-friendly way to rapidly dry these materials. In addition, purees of several California specialty crops are already directly processed into high-value products; plum powder (a fat-replacing, moisture-binding ingredient for baked goods) is an example of one of these products. Drum drying can dry purees and pomaces in a matter of seconds. The moist material is poured onto a hot metal drum, adheres to the drum surface in a thin layer, loses water as the drum rotates, and is scraped off the drum by a blade when drying is complete. This drying technology is straightforward and efficient; however, to heat the interior of the drum, drum dryers (DDs) currently require steam obtained from non-renewable energy sources, such as natural gas-fired boilers. Solar thermal systems direct and concentrate the sun's rays in order to heat up a heat transfer fluid – this can be water, a water/glycerol mixture, or an oil. The hot heat transfer fluid can then be used for any of a number of tasks: providing domestic hot water, circulating in the heating or cooling loop of a building, etc. In the past few years, researchers at University of California Advanced Solar Technologies Institute (UC Solar) have demonstrated that temperatures in the range required by DDs can easily be achieved by their solar thermal systems. Research on the two technologies separately suggested that solar thermal technology could provide a renewable source of heat for drum drying of California specialty crop purees and pomaces, but the actual direct combination of the two technologies had not yet been investigated. Thus, the objective of this project was to develop a solar thermal drum dryer (STDD) that would rapidly dry specialty crop purees and pomaces.

This project addressed three broad areas of concern to specialty crop processors: increasing revenues, reducing food waste, and reducing environmental impact of processing. Pomace stabilized by a STDD could be sold year-round, so fruit and vegetable processors who currently sell or give away raw, wet pomace to livestock operations will be able to command a premium price for their now shelf-stable pomaces. STDD systems will enable the development of new dried products from purees and pomaces, turning low-value or waste streams into revenue streams. In addition, recent regulations such as AB 32 (California Global Warming Solutions Act of 2006) have created an incentive for food processors to implement technologies that emit no or low amounts of greenhouse gases. Drum drying requires a nominal amount of electricity to run the circulation pumps and turn the drums; the vast majority of the energy in the process is thermal (not electric), and when the thermal energy is provided by sunlight, there is no associated generation of greenhouse gases.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Executive Summary:

This project was a joint effort between the Primary Investigator's (PI's) research team at the United States Department of Agriculture – Agricultural Research Service (USDA-ARS) and the co-PI's research team at the University of California, Merced (UC Merced). USDA-ARS team members dealt with the acquisition and measurement of the specialty crop materials, and also advised on issues associated with drum drying. UC Merced team members brought their expertise in solar thermal collection systems to bear on the challenge of providing the heat for the STDD for specialty crop purees and pomaces. Baseline operating and energy use data was collected on a conventional DD. The STDD was developed in two generations. The 1st generation prototype had a flat-plate (griddle) geometry; the 2nd generation was a benchtop double DD. The project purchased a used double DD to serve as the basis for the 2nd generation prototype. Dissemination of project results occurred throughout the project period via presentations at scientific meetings and tradeshows, a peer-reviewed scientific manuscript, and an article published by the UC Merced news service.

Establishing Baseline Data & Obtaining Specialty Crop Purees/Pomaces:

In the first year of the project, the team characterized the energy usage of a conventional single DD located at the USDA-ARS laboratory in Albany, California. This DD had been decommissioned and in storage at the laboratory for a number of years and required a new Johnson joint (rotary joint) to bring it back into working condition. Once this part was procured and installed, measurement of the condensate generation and time-to-dry of prune pomace and carrot pomace on the conventional DD established the baseline energy consumption for this system. Specifically, the conventional DD consumed 1500 kJ to 7000 kJ of energy to dry a 750 g to 1750 g sample, with the exact value depending on the specific specialty crop material being dried.

Small quantities (1-2 buckets) of prune pomace and carrot pomace were shipped to USDA-ARS by cooperating processors for the baseline-establishing activities; since the team required larger quantities for future testing, site visits were set up. In March 2015, the project team visited a processor of prune concentrate in Madera, California. Prune pomace is a thick, sludgy co-product of the prune concentrate process. The project team toured the production facility, noted relevant processing conditions (flow rates of materials, temperatures, etc.), and collected several buckets of fresh prune pomace. USDA-ARS scientists measured the color of the pomace and found it had a moisture content of 66% and water activity of 0.96. Water activity is a measure of microbiological and chemical stability of a food product due to the availability of water in the product. Dried materials must have a water activity less than 0.6 to be shelf-stable. Thus, reducing water activity below 0.6 was an important processing goal throughout the project. In May 2015, the project team visited a carrot processing facility in Arvin, California, where they again toured the production facility, noted relevant processing conditions, and collected pomace. Carrot pomace is less viscous (i.e. thinner) than prune pomace, so the two materials together presented a good range of textures to be tested on the STDD. The project team analyzed the fresh carrot pomace for color, moisture content (82%), water activity (0.99). In July 2016, the PI visited a tomato processor in Los Banos, California, for a discussion of the project, a facility tour, and pomace collection. Since this visit occurred later in the project, only the first two pomaces were available to test on the 1st generation prototype. The project team was unable to identify an industrial cooperator that already produced drum-dried material from California specialty crops, so California-grown strawberry puree was purchased from a commercial vendor.

Constructing the 1st Generation Prototype STDD & Testing Initial Materials:
To start with a simple design, a griddle-style flat-plate heater was commissioned and constructed in 2015. This unit was considered the 1st generation prototype of the STDD. The surface of the flat-plate heater approximated the surface of a DD; the primary difference was only geometry. This 1st generation prototype was tested with carrot pomace, prune pomace, and strawberry puree. The photos below show the specialty crop materials as they were dried on this unit and an assortment of dried carrot pomace samples.





Constructing the 2st Generation Prototype STDD & Conducting Designed Experiments:
In 2016, the 2nd generation prototype dryer (small-scale double DD) was purchased and refurbished at the USDA-ARS Albany, California laboratory. The 2nd generation prototype dryer was then transported to the UC Merced testing facility in Atwater, California, where it was interfaced with an electrically-heated test oil loop for troubleshooting, and then finally interfaced with the UC Solar eXternal Compound Parabolic Concentrator (XCPC) solar thermal array. The 2nd generation prototype was initially tested with the strawberry puree, which it was able to dry from 91% moisture to less than 1% moisture in less than 2 minutes. The corresponding reduction in water activity was 0.99 to less than 0.25, so the shelf-stability criterion of water activity below 0.6 was definitely reached. A full designed experiment was used to optimize the drying of prune pomace and tomato pomace on this prototype STDD. The detailed results are given in the peer-reviewed paper "Solar Thermal Drum Drying Performance of Prune and Tomato Pomaces" published by the journal *Food and Bioproducts Processing* (See Attachment 5). Briefly – the two pomaces were tested with different amounts of added water (to improve coating of the materials on the drums) and maltodextrin (drying aid) and at different residence times and drum surface temperatures. All tested conditions resulted in shelf-stable, dried pomaces. The optimum levels of the tested variables were determined, based on the dual goal of minimizing water activity and color change. Minimal color change would indicate minimal nutritional losses in the product. For the carrot pomace, a full designed experiment had already been carried out on the 1st generation dryer, so some confirmation runs were done on the 2nd generation dryer to translate the results from one piece of equipment to the other.

The first photo below shows some of the project team members with the 2nd generation prototype STDD at the UC Merced facility in Atwater, California. The other photos show the tomato pomace being applied to the STDD, solar collectors being covered to adjust the drum temperature, dried prune pomace puree as it is scraped from the rotating drum, and dried carrot pomace reaching the doctor knife (take-off blade).








Dissemination of Project Progress Updates and Results:

- February 2015 and July 2015: Distribution of 1-page flyers at the California League of Food Processors (CLFP) Expo (industry tradeshow) in Sacramento, California and the Institute of Food Technologists Annual Meeting in New Orleans, Louisiana.
- February 2016: Project booth at the CLFP Expo
- July 2016 and October 2016: Scientific presentations about project results at meetings of the American Society of Agricultural and Biological Engineers (July), Institute of Food Technologists (July), and UC Solar Research Symposium (October).
- March 2017: Peer-reviewed manuscript "Solar Thermal Drum Drying Performance of Prune and Tomato Pomaces" submitted to the journal *Food and Bioproducts Processing*
- March 2017: News story "Renewable Power Project Could Help Cut Food Processing Costs, Feed People and Animals" released by UC Merced University Communications
  URL: http://www.ucmerced.edu/news/2017/renewable-power-project-could-help-cut-food-processing-costs-feed-people-and-animals
  The News Story has been picked up by the Sierra Sun Times and a Canadian food processing equipment manufacturer.

In theory, the STDD technology developed in the course of this project could be used to dry non-specialty food crops and other materials (e.g. wood pulp for paper production). Since multiple public-facing presentations and publications about the project have been generated, this remains a possibility, and it is beyond the control of the project staff how the published information is used. However, during the project

period, the only materials tested on both generations of drum dryer were sourced from California specialty crops. This was ensured by direct collection at California processing facilities (for the carrot, prune, and tomato pomaces) or purchase from a California processor (for the strawberry puree - Del Mar Food Products Corp. in Watsonville, California). Lab notebook records and purchase receipts document the material collection.

The project team consisted of the following individuals at USDA-ARS and UC Merced:

- PI: Research Agricultural Engineer from USDA-ARS
  - The PI was responsible for collecting pomaces from cooperating companies. The PI designed the drying experiments for the 1st and 2nd generation prototype dryers as well as assisted with moisture content, water activity, and color measurement of raw and dried materials. The PI also coordinated the booth presentation at the February 2016 CLFP Expo, created visual aids and handouts for the booth, and staffed the booth during the expo. The PI procured small supplies directly and worked with USDA-ARS procurement staff for acquisition of special purpose equipment. The project results were reported by the PI at the July 2016 Institute of Food Technologists meeting. The PI was the lead and corresponding author on the peer-reviewed journal manuscript about 2nd generation prototype dryer.
- Co-PI: Professor from UC Merced
  - The Co-PI supervised and trained the project Graduate Student Researcher (GSR). The Co-PI advised on technical issues associated with interfacing the 2nd generation prototype dryer to the XCPC solar thermal array. The Co-PI assisted with the response surface experiments for the 1st and 2nd generation prototype dryers.
- GSR from UC Merced
  - The GSR designed the plumbing interface and monitoring system for the 2nd generation prototype dryer. The GSR executed the drying portion of the response surface experiments on the 1st and 2nd generation prototype dryers. The GSR was responsible for supervising the volunteer undergraduate students who assisted with these experiments. The GSR shipped dried samples to USDA-ARS Albany lab for analyses. The GSR staffed the project booth during the February 2016 CLFP Expo. Project results were reported by the GSR at the July 2016 American Society of Agricultural and Biological Engineers meeting and October 2016 UC Solar Research Symposium.
- UC Solar Executive Director (UC Solar ED) from UC Merced
  - The UC Solar ED attended the February 2015 CLFP Expo and distributed project flyers. The UC Solar ED staffed the project booth during the February 2016 CLFP Expo. The UC Solar ED advised on dryer design issues during project team meetings as well as assisted with collection of pomaces and process measurements. The UC Solar ED also assisted with the transport of the existing single DD to Merced for potential future use in project.
- Food Technologist (FT) from USDA-ARS
  - The FT rehabilitated the existing single DD in Albany. The FT assisted with testing of condensate generation from purees and pomaces on this dryer (baseline establishment activity). The FT helped design the 1st generation prototype dryer and commissioned fabricator to construct this equipment. The FT also assisted with collection of pomaces and process measurements. The FT assisted with testing of materials on the 1st generation prototype flat-plate heater. The FT staffed the project booth during the February 2016 CLFP Expo. The FT helped coordinate the transport of the 2nd generation prototype dryer to Atwater.

- Research Engineer (RE) from USDA-ARS
    - The RE attended the July 2015 Institute of Food Technologists and distributed project flyers to stakeholders. The RE prepared pomace sample blends for use in the response surface experiments as well as assisted with the collection of pomaces and processed measurements. The RE assisted with moisture content, water activity, and color measurement of dried materials from the response surface experiment. The RE staffed the project booth during the February 2016 CLFP Expo. The RE also assisted with the testing of materials on the 1st generation prototype flat-plate heater. Project results were reported by the RE at the July 2016 American Society of Agricultural and Biological Engineers meeting.

The project staff are grateful for the assistance of the partnering companies which provided pomace for the STDD trials. In addition to allowing the project team to tour their processing facilities and collect pomace, these partners provided helpful feedback and suggestions regarding process feasibility, harvest timing, and material handling challenges.

Goals and Outcomes Achieved

The expected measurable outcome from the project was the displacement of 95% of a pilot-scale conventional DD's heating-related energy with solar thermally-derived energy. When it was first delivered to the UC Merced facility in Atwater, the 2nd generation prototype dryer was tested using by oil circulated through an electric heater. The oil was run at temperatures and flow rates that would be achievable through solar heating with the XCPC solar thermal system. Once the 2nd generation prototype dryer was successfully run on this test loop (after some plumbing fixes), it was disconnected from the electrically-heated test loop and connected to the XCPC solar thermal system. In September 2016, project staff had their first full demonstration of the fully solar-thermally heated 2nd generation prototype dryer. The XCPC solar thermal system heated the heat transfer oil to 145°C-148°C; this led to drum temperatures that were more than adequate to dry single-strength California strawberry puree from 91% moisture to less than 1% moisture in less than 2 minutes. Thus, the project team achieved and exceeded the displacement of 95% of the dryer's heating-related energy with solar thermally-derived energy: the 2nd generation prototype dryer, in fact, derives 100% of its heating-related energy from the solar thermal array. This outcome was demonstrated with four California specialty crop materials: strawberry puree, carrot pomace, tomato pomace, and prune pomace.

The 95%-displacement outcome was short term and was achieved within the project duration.

At the end of the project in February 2017, only two accomplishments set forth in the work plan had not yet been accomplished. The first was the writing and submission of a peer-reviewed journal article about experiments with the 1st generation prototype dryer. Since the 2nd generation prototype dryer was a full STDD (vs. a simplified version), the project team focused their writing efforts on a manuscript about this system. The manuscript about the earlier prototype was eventually submitted in March 2017. The peer-reviewed journal article about the 1st generation prototype dryer was accepted and published by the journal *Food and Bioproducts Processing* in September 2017. It should be noted, that results from the 1st generation prototype had also been publicized via poster presentations at the July 2016 meetings of the American Society of Agricultural and Biological Engineers and Institute of Food Technologists. The second was identification of a California processor that currently drum-dries fruit/vegetable purees. This shortfall was addressed by purchasing commercially-produced puree instead of collecting it directly from a cooperating company.

During the first year of the project, measurement of the condensate generation and time-to-dry of the specialty crop purees and pomaces on the conventional drum dryer established the baseline energy consumption for this system. As previously described, it was found that the conventional DD consumed 1500 kJ to 7000 kJ of energy to dry a 750 g to 1750 g sample, with the exact value depending on the specific specialty crop material being dried.

In the experiments involving the 2nd generation prototype dryer, 100% of the thermal energy was provided by sunlight. This project has demonstrated that solar thermal technology is well-suited for the task of drying industrially-generated fruit and vegetable purees and pomaces while requiring no thermal energy from fossil fuel sources.

Beneficiaries

The beneficiaries of this research are three main groups: Specialty crop processors (including growers who do their own processing) who generate puree and/or pomace as a co-product, processors who already directly dry specialty crop purees into powdered form, as well as academic, government, and industry researchers who study ways to improve food processing equipment.

Positive economic impacts for the specialty crop industry stem from three sources: co-product valorization, reduced co-product storage energy requirements, and reduced drying energy requirements. Processors who currently allocate their pomaces to low- or no-value uses will realize a new income stream from co-product valorization and cost savings from the elimination of a need for chilled- or frozen-storage for their products. Current puree-to-powder processors will realize cost savings from a reduced reliance on grid-supplied energy for their drying needs. Since the thermal energy required for crop drying far outweighs the mechanical energy needed for operations such as conveying and drum rotation, these energy savings will be substantial. If these processors currently use steam generated by burning natural gas, they will eliminate 100% of their drying-related natural gas usage (and the associated greenhouse gas production) by adopting the solar thermal drum drying technology.

Numerous academic, government, and industry researchers were informed of the project results and will be able to design more environmentally-friendly specialty crop processing equipment as a result. The number of attendees at the events where formal presentations about the project results took place are estimated to be:

- CLFP Expo: 2,000 attendees (majority from California)
- American Society of Agricultural and Biological Engineers: 9,000 attendees (international)
- Institute of Food Technologists: 23,500 attendees (international)
- UC Solar Research Symposium: 100 attendees (majority from California)

Lessons Learned

Lessons Learned from Positive Experiences

- The original project budget included $22,000 for purchase of a new small DD that would be the basis for the prototype STDD. The project team identified a used DD that was an equivalent substitution from a California food equipment reseller. The purchase cost of the used DD was $7,500; some small parts and plumbing fixtures were needed to refurbish the unit (~$5,000); and there were associated freight costs (~$1,000). Thus, in the end, the used version of the equipment resulted in a net savings of ~$8,500, which was applied to other aspects of the project.

Lessons Learned from Negative Experiences

- When this project was proposed, it was assumed that there were a substantial number of processors in California who already used drum drying of fruit/vegetable purees to produce flaked or powdered products. These would have been obvious beneficiaries of the work of this project, since they would learn how to swap out fossil fuel-generated steam for solar thermal energy but keep their existing drum drying equipment. However, despite the best efforts of the project team, no such California companies could be identified, although companies in Illinois, Oregon, and Washington state were identified. Perhaps the results of this project will spur a new drum drying industry in California.
- Initial experiments on the 1st generation prototype dryer were performed using a fully-randomized response surface experiment design – a common statistical approach to scientific experiments in which multiple variables need to be tested at the same time. The variables for this project were formulation-type [added water, added drying carrier] and process-type [drying time, drying temperature]. Normally, this type of experiment design works quite well. However, it is poorly-suited to situations in which one or more of the variables is difficult to change. In this project, the formulation variables and the drying time were easy to change, but the drying temperature (i.e. the surface temperature of both generations of dryer) was difficult to change. This was because the heat transfer fluid (the oil that circulated through the electric heater or XCPC solar thermal array) could not be cooled down quickly. So, moving from a high temperature setpoint to a lower setpoint could take several minutes or hours. This made the experiments take several weeks to complete, even for a relatively small set of variables to be tested. In the midst of these first experiments, the PI happened to attend an "Exploring Best Practices in Design of Experiments" seminar put on by a statistics software vendor. The workshop highlighted the split-plot design - a newer and under-used alternative to the fully-randomized response surface design. Compared to the latter approach, the split-plot design sacrifices a small amount of statistical power to gain the ability to group experimental runs by the variable(s) that are hard to adjust. In the present project's case, this meant that multiple runs could be done at the same setpoint temperature (no need to jump from high to low back to high, etc.). Implementing a split-plot design for all of the experiments from May 2016 onward enabled the project team to accomplish the same amount of data collection in about a quarter of the time that would have been needed if work had continued using the fully-randomized response surface design. Although some time in early 2016 was essentially wasted with the less-efficient experimental approach, the project team was glad to have identified the better alternative for the remaining experiments. The major lesson learned was to thoroughly explore all possible statistical designs and carefully consider practical constraints before starting an experiment.

The project team was pleasantly surprised to find that materials with relatively large seeds and/or skin particles (tomato pomace and strawberry puree) could be drum-dried without blending them beforehand. The gap between the two drums is very small – 125 μm or about 1/200th of an inch – so it was conceivable that seeds and some larger skin flakes simply would not feed through. This is an encouraging finding, since it means that no pre-processing would be necessary in the industrial implementation of a STDD; pomace or puree with seeds could be directly fed to the STDD.

Another unexpected but encouraging result – detailed in the *Food and Bioproducts Processing* paper – is that the minimum drum surface temperatures that are predicted to be necessary to dry prune pomace and tomato pomace are 46°C and 18°C, respectively. These mild drying temperature requirements indicate that much moisture removal occurs simply from mechanical pressing of the pomace in the nip between the two drums.

These temperatures are also very easily achieved on the STDD, which bodes well for industrial implementation of this process.

Regarding the inability of the project team to identify California companies that currently drum-dry specialty crop purees, the lesson learned was to identify stakeholders as early in the project as possible (preferably before the project even starts, during the proposal development process). If the team had done this, the need to procure commercial purees would have been identified earlier, and a wider variety of these purees could have been incorporated into the project.

Additional Information

Attachment 1: Poster Presentation – "Optimization of Flat Plate Drying of Carrot Pomace"

Attachment 2: Poster Presentation – "Process and Formulation Effects on the Quality of Flat Plate Dried Pomace"

Attachment 3: Poster Presentation – "Solar Thermal Powered Drum Drying of California Specialty Crops"

Attachment 4: Copy of proceedings paper titled "Efficiency and Design Analysis of a Solar Thermal Powered Flat Plate Dryer" from July 2016 American Society of Agricultural and Biological Engineers meeting.

Attachment 5: Peer-reviewed journal article titled "Solar Thermal Drum Drying Performance of Prune and Tomato Pomaces" which was accepted and published by the journal *Food and Bioproducts Processing.*

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
34	Developing and Implementing a Self-Assessment Program for Stewardship Practices in California Cherry Production	
Grant Recipient: California Cherry Board	**Grant Agreement No.:** SCB14034	**Date Submitted:** December 2017
Recipient Contact: Nick Matteis	**Telephone:** (916) 441-1063	**Email:** nick@agamsi.com

Project Summary

There had been an increasing demand in the agri-food supply chain to know what practices United States farmers were using to grow crops and in order to document their level of sustainability. California cherry growers were using many sustainable farming practices, including practices that optimized inputs to produce a commercially viable crop and not compromise the ability to do so in the future. However, California cherry growers had no way to document the level of implementation of these sustainable practices or to identify where improvements could be made. California cherry growers needed a program that would enable them to: do confidential self-assessments of practices; aggregate assessments to report on industry-wide levels of implementation of important practices; identify where improvements could be made; and bring about an increase in key practices through targeted education that would improve the farm's economic and environmental performance.

Major retail food sellers and food service companies were incorporating sustainability into their business strategies. Retailers and consumers, both nationally and internationally, were demanding more accountability by growers in the farming practices used to grow their crops. This project allowed California cherry growers to develop a sustainable program foundation and online self-assessment tools that enabled the industry to document sustainable practices, and established a cycle of continuous improvement to meet current and future supply chain demands.

A previous 2010 Specialty Crop Block Grant Program (SCBGP) Project 4: *Multi-Commodity Sustainability Programs: Assessment and Implementation* was used to develop a practice-based self-assessment template for the sustainable production of specialty crops and then to fine-tune this template for nine specialty crops, including cherries. Working with a stakeholder group from the cherry industry, a draft self-assessment workbook for cherry production was produced and underwent preliminary review and editing during the 2010 project.

This project finalized the workbook draft with cherry growers and incorporated it into a web-based self-assessment workbook, similar to ones used by the wine and almond industries. Cherry growers would then use this to assess their practices. Using a value mapping process, each practice question was rated on the economic, environmental, and social value it provided for the farm. The online tool was used to aggregate the self-assessment data and a report was produced that benchmarked the level of implementation of each practice. From this report, practices that provided the most value and were implemented by the most growers would be identified as strengths. Practices that provided the most value but were not implemented by many growers were identified as opportunities for growers to enhance their farms' sustainability and would be the focus of targeted education with cherry growers at field days and workshops.

Project Approach

The following activities from the work plan were achieved during the first reporting period: (1) Assembling of a Steering Committee at the start of the reporting period to work with the project lead to finalize the cherry self-assessment workbook and to help with implementation of other tasks in the work plan. The committee members consisted of: four University of California Farm Advisors and five Grower/Packer shippers. (2) The project team worked with the Steering Committee to revise and finalize the draft of the self-assessment workbook for cherry production that was created under 2010 SCBGP Project 4: *Multi-Commodity Sustainability Programs: Assessment and Implementation*. This was done through three Steering Committee webinars held on November 20, 2014; January 21, 2015; and February 5, 2015 as well as through numerous email communications. The self-assessment workbook draft was finalized in early March 2015. (3) The self-assessment workbook was loaded onto the online software system platform. The online workbook was then proof-read and checked for bugs. This process was ongoing and was completed during the second reporting period. (4) A value mapping methodology was used to assign economic and environmental value to each self-assessment practices.

The California Cherry Self-Assessment Program was presented to California cherry growers at seven different meetings and workshops. All of the meetings were located in the Stockton region of California. The project Steering Committee felt that although there was significant cherry acreage in the central and southern San Joaquin valley, most growers were already accustomed to attending meetings held in the Stockton region. This was considered the home base for the major cherry packing sheds. Four meetings were organized by packing sheds for their grower clients, two by Chinochiolo/Stemilt of California (January 18th and 29th, 2016), and one each by Primavera (February 23, 2016) and Rivermaid (February 24, 2016). One meeting was organized by the project Steering Committee (February 16, 2016), one meeting was the annual California Cherry Board Research Review (January 26, 2016), and one was the California Cherry Board Cherry Day (March 2, 2016). The combined attendance to these meetings was in excess of 600 growers. At each meeting, attendees were introduced to the Cherry Self-Assessment Workbook, informed of its importance to the California cherry industry. The growers were then showed how to fill it out, and how to create an account to use the online self-assessment system. The outcome of these meetings and workshops was that 25 cherry growers created accounts for the online self-assessment. These growers assessed 105 orchards totaling 5,250 acres, which represented 16% of the total cherry acreage in California. The assessments were aggregated and the results were incorporated into the *Sustainability Report for the California Cherry Industry* (see Attachment 1).

The project team worked closely with SureHarvest in order to reach the project objectives. SureHarvest completed a summary of the self-assessment data analyses, identified the three Best Management Practices (BMPs) in each of the five core management areas. SureHarvest also established the baseline level of percentage of growers using each BMP with the assessment data collected, and drafted the *Sustainability Report for the California Cherry Industry* summarizing project outcomes. An outreach and education grower workshop was convened on August 16, 2016 which focused on increasing the level of implementation of BMPs. A final sustainability report was produced highlighting all BMP's in 10 key growing areas which incorporated 200 growing practices.

The overall scope of the project did not benefit commodities other than specialty crops. All project expenditures were tracked to ensure that all grant funds were used to solely enhance the competitiveness of specialty crops.

The project Steering Committee was made up of members representing the grower community, cherry packing sheds, the California Cherry Board, and the University of California. The committee played a significant role in strategic planning for the locations of the meetings, provided venues for the meetings and agendas, invited growers to attend and encouraged growers to participate in the self-assessment.

Goals and Outcomes Achieved

The online system collected self-assessment data for 16% of the cherry orchard acreage in the state. The participation rate exceeded the target participation goal of 10% of the California cherry industry. Analyses and reporting of the self-assessments data was initiated to establish three key BPMs in the five core management areas (nutrients, energy, pests, soil, and water) that would be the focus of increasing adoption by cherry growers.

The industry-wide report indicated far more strengths in sustainability practices than opportunities. Therefore, in each of the five core management areas there were sometimes less than three BMPs that could be promoted to have greater adoption by the industry. The following areas were noted as key BMP areas whereby the California cherry industry could increase adoption (Note: Some of the key areas identified below may need further consideration i.e. in the energy management category use of solar systems and deployment of an energy audit may not have as significant relevance as in a cherry orchard, energy consumption and/or space for solar energy systems is less likely to be adopted due to low energy demand for orchard management):

1. Soil Management Opportunity/Key BMP
    - A nutrient management plan was implemented that used a "budgeting approach" to determine crop nutrient needs and it included factors like crop tissue analyses, soil type, time of year, soil moisture, crop demand, predicted yield, and nitrates in irrigation water. The percentage of growers using the practice based on the acreage and grower data collected was 53%.
2. Water Management Opportunity/Key BMPs
    - A flow meter was installed on wells and/or pumps and monitored and the amount of water used per irrigation was tracked to optimize water use. The percentage of growers using the practice based on the acreage and growers data collected was 12%.
    - A berm or other barrier existed around the wellhead that prevented surface water from running from the perimeter to the wellhead. The percentage of growers using the practice based on the acreage and growers data collected was 47%.
3. Pest Management Opportunity/Key BMPs
    - The University of California Integrated Pest Management Year Round Plan for cherries was followed by those responsible for pest management on the farm. The percentage of growers using the practice based on the acreage and growers data collected was 26%.
    - Smart™ sprayers (sprayers that would automatically switch off when trees are missing and at row ends) were used when applying pesticides. The percentage of growers using the practice based on the acreage and growers data collected was 36%.
4. Energy Management Opportunity/Key BMPs
    - One or more solar energy systems were located on the property and generated electricity. The percentage of growers using the practice based on the acreage and growers data collected is 12%.

- An energy audit for the farm was done to identify the areas of farm management that require the most energy and which can therefore become the targets for optimizing energy use. The percentage of growers using the practice based on the acreage and growers data collected was 2%.

5. Nutrient Management Opportunity/Key BMP
    - A nutrient management plan was implemented that used a "budgeting approach" to determine crop nutrient needs and included factors such as crop tissue analyses, soil type, time of year, soil moisture, crop demand, predicted yield, and nitrates in irrigation water. The percentage of growers using the practice based on the acreage and grower data collected was 53%. (Note this was the same practice as noted in the soil management section, as this practice was closely linked to both nutrient and soil management.)

These benchmarks were to be used to measure improvement in use of each practice at the end of one, three, and five years; with a target increase of at least 25% of growers over the five year period. The workbook was taken offline once the initial BMP data had been received from 16% of the total acreage from the California cherry industry. When the Sustainability Report was presented to the California Cherry Board it was noted that the industry would need to supply $25,000 per year to maintain the site. The board of directors decided that there was not enough overall support to approve this expenditure. The workbook was therefore taken offline, making the use of the system to inform and recommend practices to the industry inaccessible.

Twenty five cherry growers completed self-assessments of 200 practices, using the online self-assessment system developed for the project, for 105 orchards, totaling 5,250 acres. There were an estimated 33,000 acres of cherries in California. The data in the self-assessment database represented 16% of the total acreage, exceeding the goal of 10%. Prior to this project, there had been no formal assessment of the California cherry industry's BMPs relating to sustainability.

The final *Sustainability Report for the California Cherry Industry* indicated that of the acreage assessed, there were far more grower strengths and BMPs being practiced by more than 70% of the cherry orchards. The report also highlighted grower opportunities to consider adoption of high value practices adopted by 50% or less of the assessed growers. Some of the practices were subjective in nature considering the realities associated with energy needs in an orchard and energy assessments; the need for a sustainability practice economic analysis; water quality and cleaning of equipment as water quality was not a significant issue in the major growing regions and equipment needs varied; employee benefits and 401k plans as they were not extremely common due to high utilization of contracted workers rather than hiring employees and or some farm/orchards were small enough in acreage and need to be managed by the owner and few part time workers at most. See below for a series of charts indicating the grower strengths and weaknesses as identified by the report:

Widely Used Important Soil Management Practices – Strengths

Soil Managememt	% Orchards Using Practice	Confidence Interval (95%)
Knowledge of orchard soil type	94%	4.9%
Enhancing water infiltration rates	94%	2.0%
Monitoring soil chemistry	93%	5.3%
Enhancing soil quality with cover crops	99%	2.1%
Use of fertigation	75%	8.8%

Widely Used Important Water Management Practices – Strengths

Water Management	% Orchards Using Practice	Confidence Interval (95%)
Enhancing orchard soil drainage	100%	0.0%
Monitoring water infiltration rates during irrigation	84%	8.8%
Irrigation system distribution uniformity	77%	12.6%

Widely Used Important Pest Management Practices – Strengths

Pest Management	% Orchards Using Practice	Confidence Interval (95%)
Pest monitoring	98%	3.0%
Use of economic thresholds	91%	5.9%
Use of comprehensive action thresholds	96%	4.3%
Pest monitoring record keeping	100%	0.0%
Pesticide resistance management	89%	6.5%
Sprayer calibration	97%	3.7%

Widely Used Important Management Practices – Strengths

Food Safety	% Orchards Using Practice	Confidence Interval (95%)
Food safety program	100%	0.0%
Air Quality Management		
No burning of orchard prunings	100%	0.0%
Regulation of vehicle speed on dirt roads	91%	5.9%
Waste Management		
Hazardous material training	100%	0.0%
Pesticide container recycling program participation	100%	0.0%
Ecosystem Management		
Vegetation buffers along water courses	88%	-
Financial Management		
Cost and revenue tracking by orchard	96%	4.3%
Cost benefit analyses of practices	91%	5.1%

Widely Used Important Workplace Practices – Strengths

Work Place Management	% Orchards Using Practice	Confidence Interval (95%)
Employee education	91%	5.8%
Company personnel industry awareness	97%	3.7%
Company personnel industry leadership	80%	8.2%
Job performance	74%	9.1%
Land use planning	72%	9.3%
Charitable contributions	92%	5.5%
Regional water use and quality planning	98%	3.0%

Important Management Practices Not Widely Used – Opportunities

Soil Management	% Orchards Not Using Practice
Nitrogen management planning using budget approach	47%
Water Management	
Use of flow meters	88%
Well head protection	53%
Pest Management	
Use of UC IPM Year Round Pest Management Plan for Cherries	74%
Use of 'Smart' sprayers	64%

Important Management Practices Not Widely Used – Opportunities

Energy Management	% Orchards Not Using Practice
Installation of solar energy panels	88%
Energy audit	98%
Waste Management	
Water quality and cleaning farm equipment	49%
Financial Management	
Cost benefit analysis of new sustainabl practices	58%
Workplace Management	
Employee health benefits	50%
Employee 401k plans	58%

Beneficiaries

Groups and operations that benefited from the completion of the project's accomplishments were the California cherry farmers that completed the sustainability self-assessment and the California cherry farmers that were able to review the final report generated through the aggregation of the practices measured to understand where their practices measured compared to current defined sustainability and BMPs in the

industry. A better understanding by the farmers on where current practices and additional practices might enhance an overall sustainability score then has a positive benefit for the 22 cherry shippers in California.

The number of beneficiaries affected by the projects accomplishments was 600 California cherry farmers and 22 cherry packing sheds. The potential economic impact of the project related to the marketing value generated by the communication to the distribution chain/retailers and consumers the positive action taken by California cherry farmers to effectively manage all resources that were dedicated to bringing a high quality fruit to the market and that that resource management ensures continued production year over year.

Lessons Learned

Lessons learned:

1. Advisement from the steering committee to refine the online self-assessment workbook provided an ideal diversity of expertise to advise a cherry farming specific set of practices to incorporate into the workbook.
2. The committee also provided additional guidance on grower outreach and refined the project's approach to conduct fewer stand-alone workshops and rather integrate the education of grower about the workbook into already planned grower meetings coordinated by the major packing facilities in the state. This provided much more efficiency in educating as many growers in one instance as possible.
3. As mentioned above, the final report generated by the project measured adoption rates of BMPs displayed a high adoption rate of many key practices classified as industry strengths when it came to soil management, water management, food safety, pest management and work place management. However, some of the opportunities noted by the report were subjective, and would need to be assessed based on the realities and needs on an orchard by orchard basis. The report captured as effectively as possible the measure of industry practices as a whole. Careful attention should be paid by any grower using the data to determine the practical applicability of potential opportunities to adopt new practices.
4. Though the online workbook was carefully designed and provided a user-friendly interface, a key learning was that the maintenance fee (approx. $25,000) to keep the workbook live on its website and lack of overall stakeholder support proved to be unsustainable for the Cherry Board. Thus, the tool was no longer accessible online. However, if the Cherry Board should decide to reactivate the online workbook, it was designed to do so.
5. The results from the project's work provided a tool that could be used in the future should the California cherry industry decide to adopt an industry wide sustainability program. There were no unexpected outcomes or results that were an effect of implementing this project.

Additional Information

Attachment 1: *Sustainability Report for the California Cherry Industry*

USDA Project No.:	Project Title:	
35	A Continuous Leaf Monitoring System to Detect Plant Water Status to Assist in Irrigation Management of Specialty Crops	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB14035	**Date Submitted:** December 2017
Recipient Contact: Shrini K. Upadhyaya	**Telephone:** (530) 752-8770	**Email:** skupadhyaya@ucdavis.edu

Project Summary

This project addressed the issue of efficient use of water resources in orchard and vineyard crop production. Increasing urban demand for water coupled with increasing scarcity of water resources has become a challenge to nut and grape producers in California. Fresh water consumption in crop production in the Central Valley region of California exceeds the annual precipitation, making it an unsustainable practice with serious implications for the future of crop production in this fertile valley. California growers are facing substantial cuts in water delivery to produce crops. There is an urgent need to develop technologies and practices to assist production agriculture in conserving precious water resources while maintaining the desired yield and quality of the crop. In addition, conventional technology for determining plant water status (PWS), including the pressure chamber to measure stem water potential and leaf water potential (LWP), is labor-intensive and time consuming, requiring travel to the field around solar noon under the sweltering conditions of the Central Valley growing season.

To address the challenge of quantifying PWS in a convenient manner, a recently patented real-time, continuous sensor suite (leaf monitor) was developed to measure leaf temperature and other microclimatic variables (i.e. photosynthetically active radiation (PAR), relative humidity, air temperature, and wind speed). This device obtains leaf temperature using a thermal infrared (IR) sensor and collects information to calculate the crop water stress index (CWSI) when used with dry leaf and saturated leaf reference values. This project sought to use the leaf monitor technology to schedule irrigations and maximize water productivity through deficit irrigation in both almond and grape crops. The objectives of this study were: (i) to implement a variable rate PWS based irrigation management scheme in almonds and grapes which accounts for spatio-temporal differences in an orchard or vineyard throughout an entire growing season, (ii) to evaluate the effect of PWS based deficit irrigation on yield and quality compared to grower practice, (iii) to quantify the effect of this practice on water use, and (iv) to evaluate this strategy's feasibility of implementation.

The statewide drought which ended in the winter of 2016-2017 was one of the most severe droughts in California history. California's arid climate in conjunction with climate change projections indicate that this drought will not be the last. Projects that assist farmers to enhance water use efficiency are not only timely but also critical for the future agricultural economic productivity of California. With the advent of information technology, a vast amount of data regarding crops and their growing conditions can now be collected using various sensors and can rapidly be made available to growers via the internet. However, this massive amount of sensor-derived data can be very confusing. The relevant elements of this "Big Data" must be distilled from the information available and should become useable knowledge which in turn should be the basis for decision-making. The overall objective of this project was to use the vast amount of plant, soil, and environmental data obtained using a wireless network of sensors to develop a decision support system to

implement a precision irrigation management scheme (how much, when, and where) which conserves water and improves water use efficiency in orchard and vineyard crop production in California.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The leaf monitors were installed in nonpareil almonds at Nickels Soil Lab in Arbuckle, California and in Cabernet Sauvignon wine grapes at Colony Ranch Vineyard in Galt, California in both stress based and grower treatments. At Nickels, leaf monitors reported data through a wireless mesh network, whereas at Colony each leaf monitor communicated data to the internet through individual cellular modems. The communication system at Colony was developed by a microelectronic company in Milpitas, California. The leaf monitor and communication system in grapes are shown in Figure 1. Management zones based on soil and plant characteristics were developed in each field in order to tailor irrigation needs to the specific conditions of relatively homogeneous regions within a field.



Figure 1: Top left: photograph of the leaf monitor in grapes. Bottom left: photograph of the leaf monitor without the dome to show the thermal IR sensor looking at a grape leaf. Right: the communication system developed by Cermetek Microelectronics that was used in grapes.

Each field had one simulated dry leaf monitor installed on a leaf whose stem had been cut and one saturated leaf monitor installed on a tree or vine which received extra water compared to the other trees or vines in the field. During the first season, anti-transpirant was sprayed on the leaves to simulate the dry leaf, as per suggestions from plant physiologists. In almonds, the anti-transpirant had to be reapplied every few weeks to remain effective. In grapes, the anti-transpirant was ineffective in closing the stomata. The project staff found that the behavior of a leaf with a broken stem was the same as a leaf with anti-transpirant in almonds. Therefore, the stem of the leaf was broken in almonds and grapes in an attempt to simulate the dry condition in those crops, which worked well. This strategy was continued in the following seasons in both crops.

Latching solenoid valves were installed in both fields to enable wireless irrigation control of each zone separately (variable rate irrigation). Pressure sensors allowed project staff to verify the length of irrigations. The irrigation setup (drip lines, valves, etc.) was modified at Colony and at Nickels so that each approximately 5-acre plot was ready to implement precision irrigation.

During the growing seasons of the project, midday stem water potential (SWP) measurements were taken two or three times per week in both fields using a pressure chamber to verify leaf monitor plant water status predictions. Since SWP is a well-established parameter for determining physiological plant water stress, SWP measurements were compared to a CWSI or a modified CWSI (MCWSI) calculated from the leaf monitor data. One goal of the project was to find a correlation between CWSI or MCWSI and SWP to develop a method for farmers to use the leaf monitors to make reliable irrigation decisions based on Public Water System (PWS) without going to the field to take measurements. Irrigation management targeted particular SWP values based on the type of crop and its stage in the growing season. The crop water stress index was calculated using the following equation:

$$CWSI = \frac{\left(T_{leaf} - T_{air}\right)_{observed} - \left(T_{leaf} - T_{air}\right)_{sat}}{\left(T_{leaf} - T_{air}\right)_{dry} - \left(T_{leaf} - T_{air}\right)_{sat}}$$

where T_{leaf} is the leaf temperature, T_{air} is the air temperature, ‘sat’ refers to the leaf from saturated tree/vine, ‘dry’ refers to the dry leaf, and ‘observed’ refers to the leaf being monitored for plant water stress.

The project approach in developing irrigation management strategies in almond and grape crops involved collecting large amounts of leaf monitor data, which were analyzed both qualitatively and quantitatively. From the leaf monitor data, the difference between the air temperature (T_{air}) and the leaf temperature (T_{leaf}) (i.e. T_{diff}) was computed on a continuous basis as a qualitative indicator of plant water stress. The project staff compared T_{diff} of the saturated tree/vine and T_{diff} of the dry leaf to T_{diff} of the observed tree/vine to qualitatively determine how well the observed tree/vine was transpiring, as shown in Figure 2. When a plant is well irrigated and transpiring fully, the stomata will open and the leaf temperature will decrease, making it lower than the air temperature. As a result, T_{diff} will increase when the plant is not under stress. T_{diff} of the observed tree/vine should be higher than T_{diff} of the dry leaf and lower than T_{diff} of the saturated tree/vine unless the leaf has died or recently received a large amount of water. The project staff looked at the T_{diff} data and the CWSI data on a daily basis in both crops to decide how much and when to irrigate. An example of the T_{diff} and CWSI results plotted on a daily basis can be seen in Figure 2, which includes almond crop data spanning from July 5 to July 19, 2016. Evapotranspiration (ET) requirements were also computed on a daily basis using the data from the California Irrigation Management Information System (CIMIS).

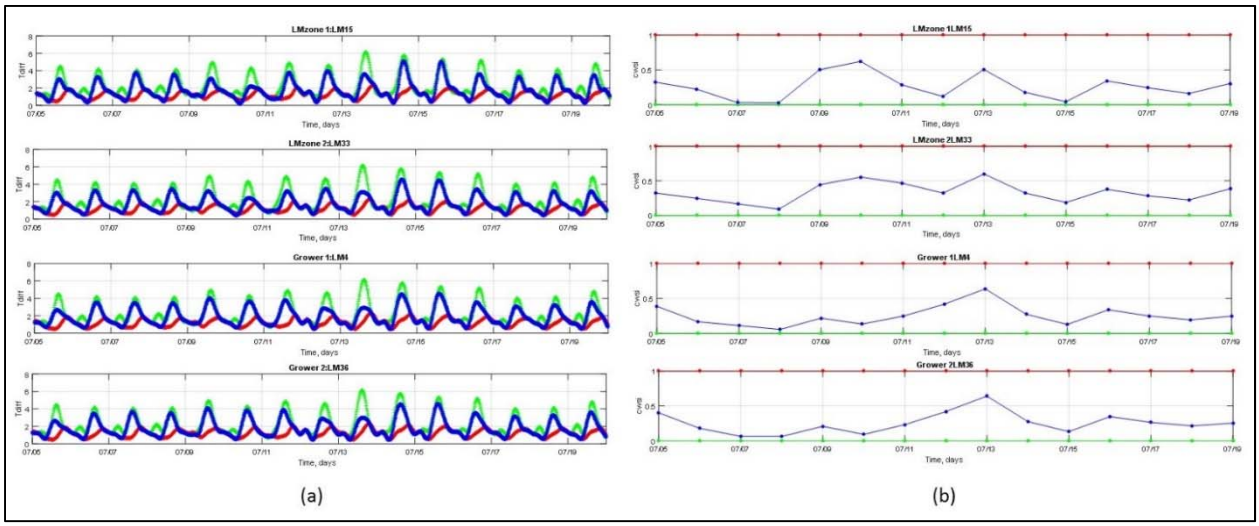


Figure 2. Results for almonds. From top to bottom in both (a) & (b): Treatment Zone 1, Treatment Zone 2, Grower 1, Grower 2. (a) T_{diff} plots over time for all zones. (b) CWSI stress patterns over time for all zones from July 5-19th. Red curves are representative of dry tree behavior and green curves are representative of a fully saturated tree. Blue lines are daily data for a monitored tree in that zone. Each point represents a day. Irrigation management was planned such that for the most part, every 3rd day showed stress.

The feasibility of leaf monitor use in grapes was verified in the 2015 growing season, and irrigation management was implemented during the 2016 growing season. In almonds, irrigation management began near the end of the 2015 growing season, and was continued through the 2016 and 2017 growing seasons.

In both crops, water use, quality, and yield data were obtained and analyzed after harvest. In almonds, the quality (kernel characteristics) and yield analyses showed no statistically significant differences in the kernel characteristics or yield between stress-based and grower-based managements. However, differences in water applied per tree and in water productivity were both significant between the treatment and grower zones. Both stress-based management zones required less water compared to grower practice. Zone 1 required 75% and Zone 2 required 86% of the water applied by the grower practice, equivalent to 69% and 80% of ET_c, respectively. In other words, Zone 1 had a 25% water savings and Zone 2 had a 14% water savings. The water productivity in almonds was 1,905 lb/ac-ft in Zone 1, 1,610 lb/ac-ft in Zone 2, and 1,534 lb/ac-ft in the grower zone. In grapes, a statistical analysis of yield quality found a significant difference only in malic acid content due to zones and treatment. Analysis of water usage data indicated Zone 1 and Zone 2 each received 69% of the amount of water that the grower managed rows received. The water productivity in grapes was 24,385 lb/ac-ft in Zone 1, 28,061 lb/ac-ft in Zone 2, and 17,595 lb/ac-ft in the grower zone. A promising conclusion from this project is that water savings in irrigation management of almond and grape crops are possible without significantly affecting yield and quality, except for malic acid in grapes.

In 2016, the leaf monitor housing was upgraded using 3-D printer technology, making it easier to install and to inspect in the field in both almond and grape crop. The improvements in the new design allowed project staff to – (i) easily place the leaf in a mesh holder, (ii) open the diffuser dome quickly and easily to inspect the leaf, (iii) easily move the IR sensor to point at the leaf, (iv) ensure a good airtight seal between the upper and lower parts of the housing, and (v) eliminate metal parts of the device that can burn the leaf during the hot summer months. In the 2017 growing season in almonds, two additional equipment improvements were made. A 3-D printed leaf holder was designed and implemented to ensure that the IR sensor points directly at the

leaf. Moreover, a second IR temperature sensor was installed to monitor a dry leaf in the same dome as the monitored leaf, as shown in Figure 3. This latter modification ensured comparable microclimatic conditions between the monitored and dry leaves, computationally critical for energy balance theory and for crop stress index calculation.

Project results were disseminated in publications as well as at multiple public events, including field demonstrations. The leaf monitor system was demonstrated in the almond orchard to over 200 farmers at Nickels Field Day in 2016 and 2017. A pamphlet with water savings, water productivity, crop yield, and quality analysis was distributed to the attendees at this event each year. The results of the project were published in both technical and trade journals, as described in a later section of this report.

The project did not benefit commodities other than specialty crops.

Over the two growing seasons, partners included the Almond Board of California, E&J Gallo Winery, and Nickels Soil Lab.



Figure 3. Pictures of the 2017 version of the leaf monitor with two thermal IR sensors, one for the dry leaf and one for the live leaf, in almonds. Note: light diffuser dome is not shown.

Goals and Outcomes Achieved

Management zones were created at Nickels and Colony in the spring of 2015. In almonds, management zones were created based on spatial variability in soil (texture, electrical conductivity (EC) at two different depths, and digital elevation) and plant characteristics (light interception and canopy temperature). The digital elevation sample points were obtained using Real-Time Kinematic (RTK) GPS units and a laser rangefinder; canopy cover was measured by an Unmanned Aerial Vehicle (UAV). Leaf temperatures at points throughout the orchard were sampled with a handheld sensor suite with an IR sensor. In grapes, management zones were

created based on the same soil characteristics as in almonds as well as plant characteristics, including NDVI (Landsat image) and yield maps from the 2014 growing season. In both crops, discrete georeferenced data points of soil and plant characteristics using GPS were interpolated using a kriging technique. Maps of data for each tree/vine were then classified into management zones using the United States Department of Agriculture's Management Zone Analyzer software and unsupervised fuzzy classification, as shown in Figure 4 for almonds and Figure 5 for grapes. Although plant and soil characteristics were weighted equally in the zone creation, there was a clear similarity between the management zones created and the soil characteristics. Thus, these management zones are considered relatively stable over the years because they are based on static characteristics of soil.

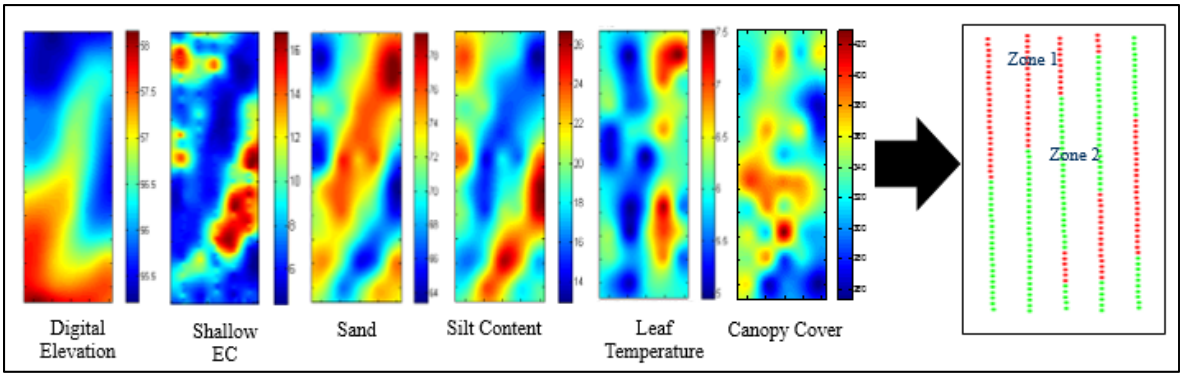


Figure 4. Two management zones in almonds at Nickels Soil Lab were created based on soil and plant characteristics using unsupervised fuzzy classification.

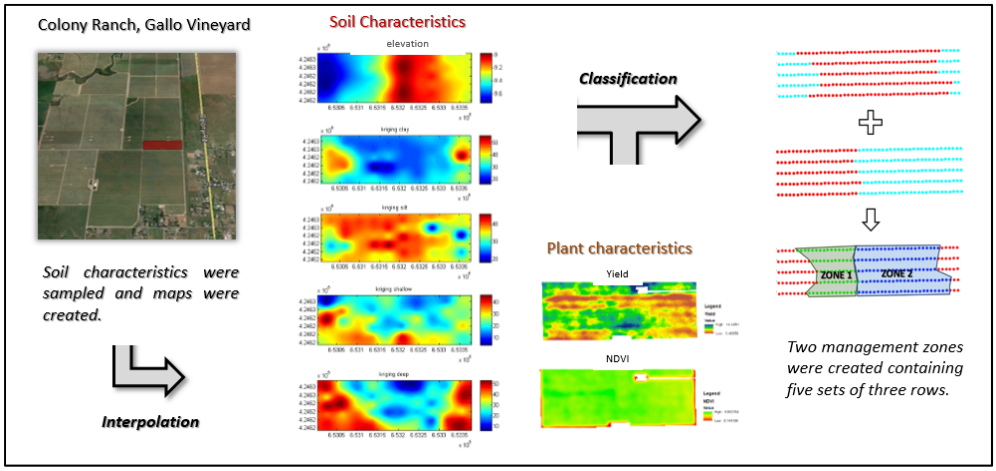


Figure 5. Two management zones in grapes at Colony Ranch Vineyard were created based on soil and plant characteristics using unsupervised fuzzy classification.

In each field, driplines and valves of the irrigation setup were modified so that an approximately five acre plot was ready for variable rate precision irrigation. In the almond plot, a wireless mesh network was installed with several solar powered nodes that communicated with a gateway computer. Each node was connected to a leaf monitor and a soil moisture sensor to continuously monitor soil, plant, and ambient conditions. Separate nodes capable of actuating latching solenoid valves for a programmed duration of time to implement site-specific irrigation were also included. In grapes, a wireless data acquisition and communication system consisting of several solar powered hubs was created. Leaf monitors and soil moisture sensors were connected to these hubs. A separate hub was capable of actuating latching solenoid valves to control irrigation. Maps of the node

or hub setup in each crop is shown in Figure 6. In both crops, irrigation management was implemented remotely through the internet. Pressure sensors were also installed in both fields to verify the length of time that irrigation actually occurred. The data from the leaf monitors, the soil moisture sensors, and the pressure sensors could be viewed and downloaded from the internet.

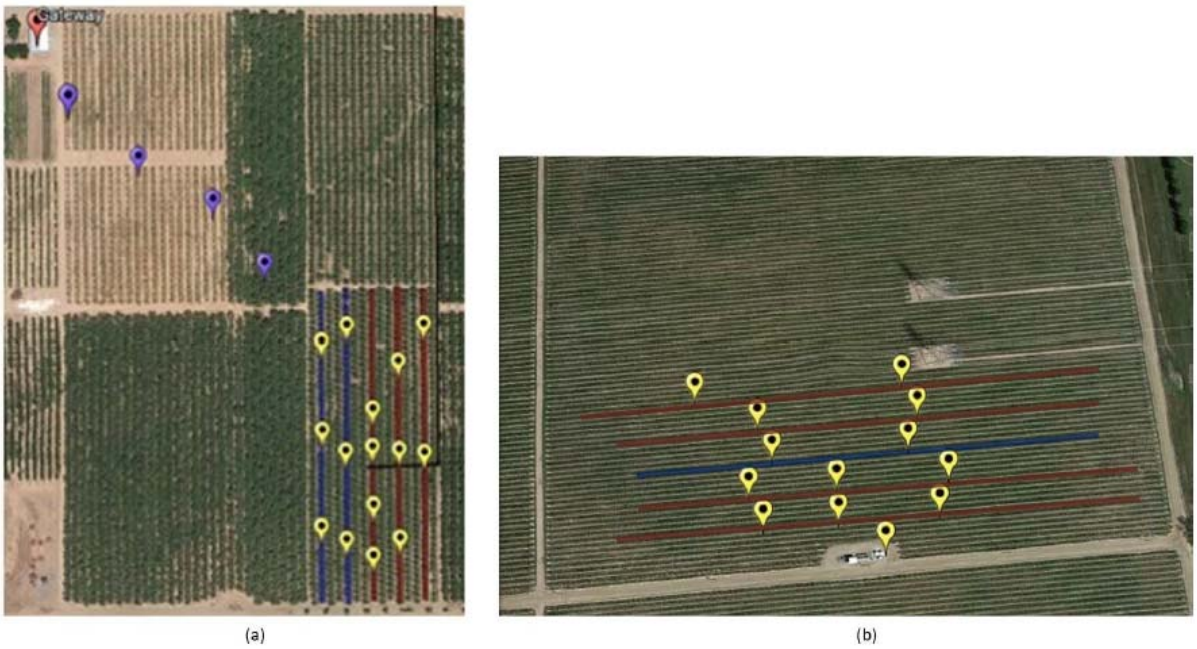


Figure 6. Google Earth images of (a) node locations (yellow), repeater locations (blue), and gateway location (red) in almonds and (b) hub locations in grapes. In each, blue rows indicate grower treatment and red lines indicate stress-based treatment.

In almonds, the leaf monitors were installed during the 2015-2017 growing seasons. The project team installed 14 leaf monitors at Nickels Soil Lab to monitor almond trees. In 2015, the leaf monitor system was installed to ensure that the system was working satisfactorily, but was only used for irrigation management for a few weeks prior to harvest due to the time involved in management zone creation and resulting modifications in irrigation setup. In 2016, leaf monitors were used to implement deficit irrigation management for the entire growing season. Irrigation management was based on PWS in three rows and current grower practice in two rows. The project team implemented irrigation management in almonds from May 17 to August 5 before the August 11 harvest in 2016. As listed in Table 1, a mild stress level of -14 to -12 bar (preferably -13 bar) was targeted until hull split began on June 24th. Once hull-split began, moderate stress in the range of -18 to -14 bar (preferably -16 bar) was targeted until July 18th; and following hull-split, efforts aimed to maintain stress above -13 bar. Irrigation management stopped when harvest preparations began on August 5th; the nonpareil variety of almonds was harvested on August 11th. For the duration of the season, the orchard was controlled by management zone and efforts were made to irrigate 2-3 times per week, to be consistent with the grower irrigation frequency. The goal was to wait a sufficient number of days before irrigating so that the stress value did not exceed the maximum SWP stress. With each irrigation in almonds, SWP should drop to unstressed levels then rise to the desired stress level after a period of time. A stress pattern developed with these irrigations and was reflected in calculated CWSI values. The day after irrigation, average zone stress decreased. The second day after irrigation, average zone stress decreased further, or stayed about the same as the previous day. On the third day, stress would increase significantly. Monitoring CWSI values for these trends in plant water stress accumulation, the team traveled to the field on days when CWSI

values were expected to be high to take SWP measurements and then make irrigation decisions. In this way, CWSI values were used as a guide for when to take SWP measurements and how much irrigation to apply. If the stress level was greater than the target SWP value, the water applied was increased in increments of 5% of ET per irrigation.

	SWP Range (bar)	SWP Target (bar)	CWSI Target (2016 Relationship)	CWSI Target (2015 Relationship)
June 6th –June 23rd	-14 to -12	-13	0.27	0.27
June 24th – July 18th	-18 to -14	-16	0.37	0.43
July 19th – August 5th	-14 to -12	-13	0.27	0.27

Table 1: PWS Targets in Almonds during the 2016 Growing Season

A similar procedure as in 2016 for irrigation management at Nickels Soil Lab is being implemented during the 2017 growing season. In addition to looking at CWSI values for making irrigation decisions and SWP for validation, the project team is also testing an instantaneous stomatal conductance based index for irrigation decision making. This new index is the ratio of the temperature difference between the dry leaf and the monitored leaf ($T_{dry} - T_L$) and a quantity related to vapor pressure deficit (VPD) known as $e_s(T_{leaf})$-$e(T_{air})$ (i.e., difference between saturated vapor pressure corresponding to the leaf temperature and vapor pressure of the ambient air in the vicinity of the leaf). In theory, when this ratio is higher, the plant is under less stress and when this ratio is lower, the plant is under greater stress. Looking at increases and decreases of this ratio from one day to the next was the primary basis of irrigation decisions during the 2017 growing season. An advantage of this new method compared to CWSI is that the ratio can be computed as often as the sampling rate of the leaf monitor (i.e. once every 15 minutes) whereas in the traditional method only one value of CWSI is computed per day using just the solar noon data. Additionally, this ratio eliminates the need for a saturated tree - a condition which may not be easy for growers to implement in order to use the leaf monitor. A challenge with this new method is determining precisely what value of the ratio indicates a need for irrigation for the purpose of automating irrigation decisions. This aspect is being investigated during the 2017 growing season.

Leaf monitors were installed in grapes during the 2015 and 2016 growing seasons. In 2015, the objective was to evaluate the feasibility of using leaf monitors in grapes. Thus, irrigation was not managed fully but an experiment was performed to evaluate the leaf monitor's ability to detect changes in PWS in grapes. SWP was measured in eight vines for a 10-day period; four vines were deprived of water to experience increasing amounts of stress and other four vines were watered daily after a long period of no irrigation to recover from stress. CWSI was also computed based on the leaf monitor data during this 10-day period and was compared to the SWP measurements. The multiple linear relationship for vines experiencing increasing stress between MCWSI and SWP, and CWSI and SWP had coefficients of multiple determination of 0.90 and 0.97, respectively. However, this strong correlation was not found in vines subjected to the wetting cycle from high stress. Coefficient of determination values of 0.51 and 0.45 were found for MCWSI versus Deficit Stem Water Potential (DSWP) and CWSI versus DSWP, respectively, for vines recovering from stress (data shown in subsequent section). It was observed that vines recovered relatively quickly from stress, while stress slowly built up for vines subjected to a period of water scarcity, indicating a possible hysteresis between increasing and decreasing stress. Initially, the DSWP vs. CWSI relationship from the 2015 season was used to make irrigation decisions to a specific maximum CWSI for that day. However, the DSWP measure of stress varied

greatly day to day, depending on the VPD. Further consultation with a plant physiologist and with the grower led to the suggestion to target a given stress level, reported as SWP instead of DSWP.

During the 2016 grape growing season, the leaf monitors were used to manage irrigation in grapes. Irrigation management was based on plant water stress for 12 rows and current grower practice for three rows. Twelve leaf monitors were installed at Colony to monitor grape vines. Two leaf monitors were installed in the grower treatment and four leaf monitors were installed in each stress based management zone. Stress based management took place from June 20 to September 19. SWP measurements were collected twice a week and CWSI was computed daily to make irrigation decisions. For grapes, a target sunny LWP, as opposed to SWP, was provided by a team of viticulturists. However, the leaf monitors were designed to be installed in the shade, so SWP is more directly correlated to shaded leaf temperature than LWP. Therefore, in the beginning of the season several concurrent midday LWP and SWP measurements were taken to determine the relationship between LWP and SWP. This dataset was used to calculate an approximate equation for LWP as a function of the measured SWP. A polynomial relationship was found between LWP and SWP with a correlation coefficient of 0.60, as shown in Figure 7. This relationship was used to approximate how close the SWP measurements were to the targeted LWP. A LWP of -13 bar, or an SWP of approximately -11.9 bar based on the calculated polynomial relationship, was targeted during 'veraison' (the onset of berry ripening). When the veraison phase was over around July 19, the target LWP was a slightly lower stress level of -12 bar (an SWP of approximately -10.5 bar), as directed by the viticulturists. Irrigation decisions were primarily based on the relative difference between CWSI values from one day to the next. Typically, the amount of irrigation was incrementally increased or decreased by 5% of the grower's irrigation to aim for the target CWSI and SWP (LWP) values. When significant changes in CWSI were observed or expected - as was the case on Mondays as the grower did not irrigate on Sundays - SWP measurements were obtained. Generally, SWP measurements were collected twice a week- when the stress level was high after the weekend on Monday or Tuesday and when the stress level was low on Thursday or Friday. In general, Zone 2 tended to be more stressed than Zone 1 when the same amount of water was applied to both zones.

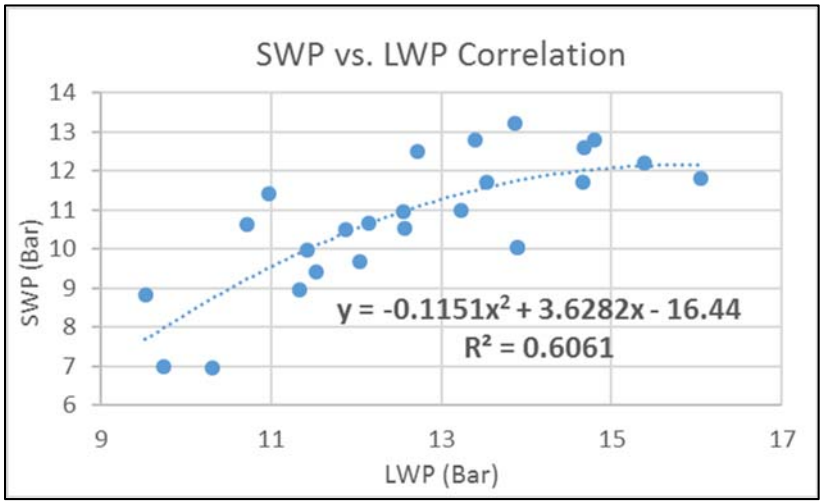


Figure 7. Midday Leaf Water Potential versus Midday Stem Water Potential measurements taken concurrently on several occasions. This graph shows positive values of SWP and LWP, though actual values are negative.

The research findings from both crops have been disseminated at a variety of settings. In almonds, the results obtained during the growing season were presented at the Almond Board of California Annual Meeting in

Sacramento, California as an oral presentation, as well as poster presentations in 2015 and 2016 to over 200 conference attendees each year. Results were also presented at the 2016 California Soil and Plant Conference in Visalia, California that was attended by over 100 participants. The attendees included growers, extension specialists, farm advisers, researchers and agricultural industry representatives. The project team presented the project's work at the Precision Agriculture Work group meeting in Davis, California (about 25 people, who were mostly farm advisers, extension specialists, industry representatives and researchers, attended this meeting). In addition, the project's results were presented at a project meeting on April 25, 2016, which was attended by University of California (UC) Davis researchers, the Almond Board Research Director, the World Food Center Director, and two E & J Gallo Winery representatives (approximately 20 participants). A demonstration of the wireless mesh network and leaf monitor system, and a poster were presented on UC Davis Picnic Day (April 16th) as a part of the Department of Biological and Agricultural Engineering open house (more than 100 people attended this event – mostly alumni, students and public). In October 2016, the project director presented the project and results in Chile (about 75 people – mostly researchers and students - attended this presentation). One of the graduate students presented a poster on the project and won a second place prize at a poster competition at the American Society of Agricultural and Biological Engineers (ASABE) California/Nevada Annual Section Meeting on February 15, 2017 in Tulare, California (about 100 people attend this event – mostly students and researchers).

In May 2016 and 2017, the almond results were presented to a group of over 200 farmers at Nickels Field Day in Arbuckle, California. In June 2016 results of this study was presented to over 100 attendees of the American Society of Enology and Viticulture (ASEV) in Monterey, California. In July 2016, a paper was presented at the 13th International Conference on Precision Agriculture in St. Louis, MO. This presentation was attended by about 40 scientists, engineers, and students. The student who made this presentation received Outstanding Graduate Student Researcher Award at this meeting. A poster presentation was made at the American Society of Enology and Viticulture Meeting in Bellevue, WA in June 2017. This poster presentation was attended by more than 200 people consisting mostly of researchers, students and grape growers. In 2017, two papers on this project were published in the ASABE Technical Library, one on the grape work and one on the almond work. Oral presentations on these papers were also made at the 2017 ASABE International Conference in Spokane, WA in July. These presentations were attended by about 40 researchers from all over the world. Project results on almonds were published in the ASABE Resource magazine in June/July 2017. Several grower oriented articles were published to bring the results of this project to end-users:

(1) Curtis, B. 2015. Precision irrigation management near in almonds. Western Farm press article dated July 7, 2015,
http://westernfarmpress.com/orchard-crops/precision-irrigation-management-near-almonds

(2) Huge Strides in Precision Irrigation, with More to Come. Almond Board of California article dated 8/12/2015,
http://www.almonds.com/newsletters/outlook/huge-strides-precision-irrigation-more-come

(3) Jefferies, A. 2025. High Tech Sensor System Allows for Precision Irrigation. Western Fruit Grower article dated 10/14/2015,
http://www.growingproduce.com/fruits/grapes/high-tech-sensor-system-allows-for-precision-irrigation/

(4) A radio interview by KCBS radio station on September 26, 2015, transcripts of which are available can be obtained from Mr. Michael Bower, Producer, CBS Radio News, KCBS Radio, San Francisco (E-mail: bowermr@gmail.com)

(5) Parsons, C. 2017. UC research explores continuous leaf monitor system to maximize irrigation in almonds. Western Farm Press, 6/23/2017. 2pp; http://www.westernfarmpress.com/tree-nuts/uc-research-explores-continuous-leaf-monitor-system-maximize-irrigation-almonds

Outcome measures of this project are long-term. Ideally, data from the leaf monitors would be collected in a variety of specialty crops to confirm that deficit irrigation can be implemented using this system without affecting crop yield, and perhaps improving or at least maintaining quality over multiple growing seasons. During this project, three seasons of data were collected for almonds and two seasons for grapes. Significant progress has been made in collecting multiple years of data in almonds and grapes, but the work should be continued to understand long-term effects of deficit irrigation over several (five to seven) years for specialty crops.

All goals were met by the end of the project. In addition, the project has been continued in almonds during the 2017 growing season to gather even more data for analysis. Moreover, additional systems are installed in grower and research plots throughout the state (one in Button and Turkovich walnut orchard in Winters, California; one in a Crain walnut orchard near Red Bluff, California; one in an UC managed experimental vineyard in Oakville, California; and one in a Nichol's Farm, Hanford, California). These systems are being monitored to determine capabilities of the system to implement PWS based irrigation management.

Completion of achieving outcomes are as follows:
Quantifying Plant Water Status in Almonds:
The analysis of the data obtained during the 2015 almond season shows that the CWSI and the DSWP are strongly correlated in almond crops. A second order polynomial was used to represent this relationship which agrees with what was found in previous years. Figure 8 shows the relationship between CWSI and DSWP for almond crops which had a coefficient of multiple determination of 0.79.

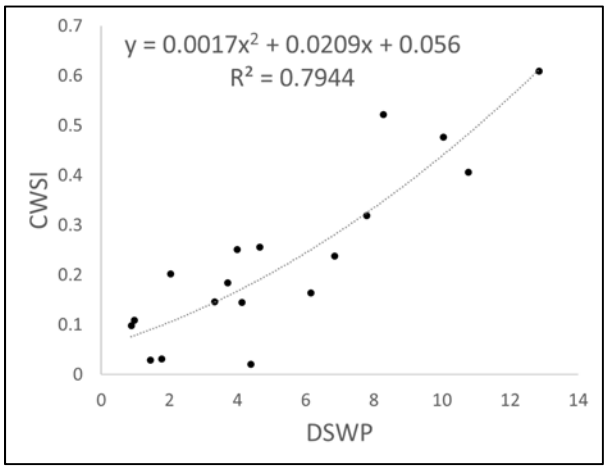


Figure 8. Crop Water Stress index versus Deficit Stem Water Potential for almond crops in 2015.

Figure 9 shows the relationship between SWP and CWSI in almonds during the 2015 and 2016 growing seasons. The figure on the left shows the relationship before and during hull-split for the 2016 season, while the image on the right shows the combined relationship for 2015 and 2016 growing seasons throughout all growth periods. A much tighter model fits the data before and during hull-split, with a correlation coefficient value of 0.78 during this time. During this period, a good amount of confidence can be placed in irrigation decisions in terms of achieving the targeted stress level. However, at lower SWP values there is greater variability in the data, particularly for the combined data, and the correlation coefficient decreases to 0.61 (Figure 9, right). This includes all data from 2015 which was collected after hull-split, as well as the post-hull split data of 2016. Thus, uncertainty in irrigation decisions will be higher in the post hull-split period.

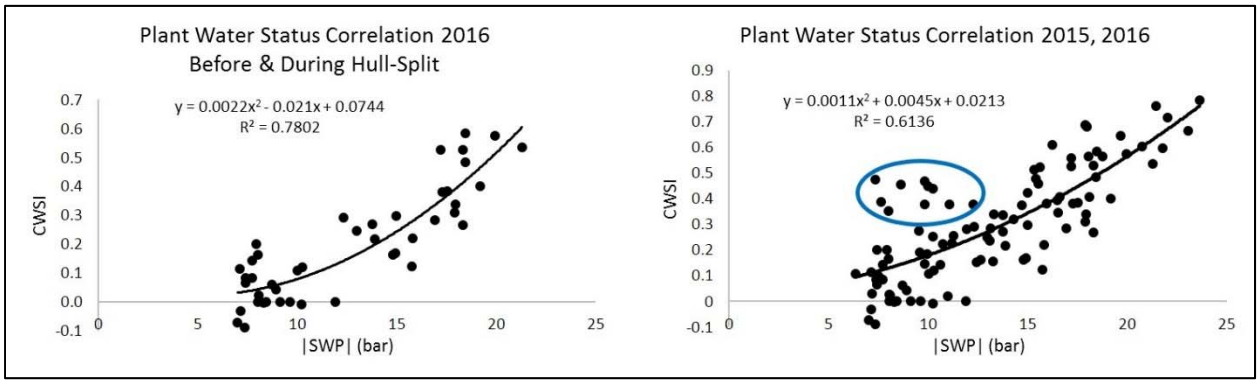


Figure 9. Relationship between SWP and CWSI stress indices over the course of the 2015 and 2016 growing seasons. From left to right, the data without three outliers corresponding to low VPD days (R^2=0.78) and plot with all data (R^2 = 0.61).

Inconsistencies between the two graphs in Figure 9 are most evident in the points encircled in blue on the right plot, which come from three days – August 3, 5, and 7, 2016. These values were collected after hull-split when it becomes more difficult to control plant water stress. It is possible that the trees acclimatized to increased stress levels during hull split period and could withstand higher stress levels after hull-split. In other words, a plant may be able to keep its stomata open to maintain productivity once it has gone through a period of increased stress. It is also worth noting that the VPD was relatively low on August 5, so it may be harder to understand the relationship between CWSI and SWP when the VPD is low. These observations are conjectures that need to be further investigated.

Figure 10 shows plant water stress by growth stage, and reflects changes in the desired stress level throughout the season. The actual stress of the treatment zones closely followed these goals in terms of SWP and confirms the approach to irrigation management did maintain PWS within the desired levels throughout the course of the season. While in most cases, SWP measurements were taken the day before irrigation (i.e. the day of highest plant water stress), the points on July 1 and July 8 are due to measurements taken the day after irrigation. Thus, even though they show low stress for that period, the stress was maintained in the desired range. Note that these SWP values are inverted to the positive for ease of interpretation.

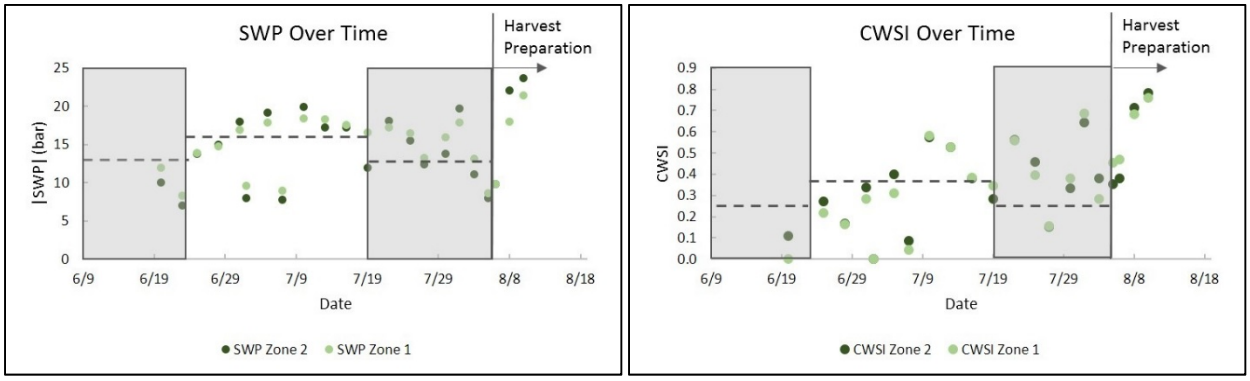


Figure 10. Stress plots before, during, and after hull-split. The image on the left shows how SWP was controlled over time to the desired levels (dashed lines) in both treatment zone 1 (light green) and treatment zone 2 (dark green). The image on the right shows how CWSI on the day of irrigation reflected the desired stress level.

Quantifying Plant Water Status in Grapes:

During the 2015 growing season in grapes, the initial 10-day experiment showed promising results. The multiple linear relationship for vines experiencing increasing stress between MCWSI and SWP, and CWSI and SWP had coefficients of multiple determination of 0.90 and 0.97, respectively, as shown in Figure 11. However, this strong correlation was not found in vines subjected to the wetting cycle from high stress. Coefficient of determination values of 0.51 and 0.45 were found for MCWSI versus DSWP and CWSI versus DSWP, respectively, as shown in Figure 12. It was observed that vines recovered relatively quickly from stress, while stress slowly built up for vines subjected to a period of water scarcity, indicating a possible hysteresis between increasing and decreasing stress. The rapid recovery of vines from stress indicates that the severity of stress imposed on the vines may have resulted in acclimatization of the plants making them to withstand stress and quickly recover in terms of their stomatal conductance and therefore, photosynthesis.

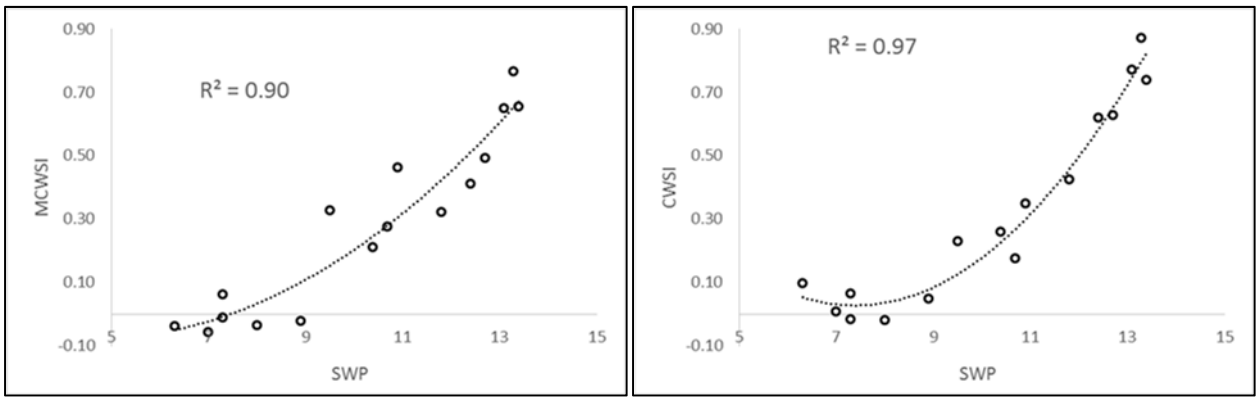


Figure 11. Comparison between MCWSI versus SWP & CWSI versus SWP in vines subject to a 10-day drying cycle at E & J Gallo Vineyard, Galt, California. This graph shows positive values of SWP, though actual values are negative.

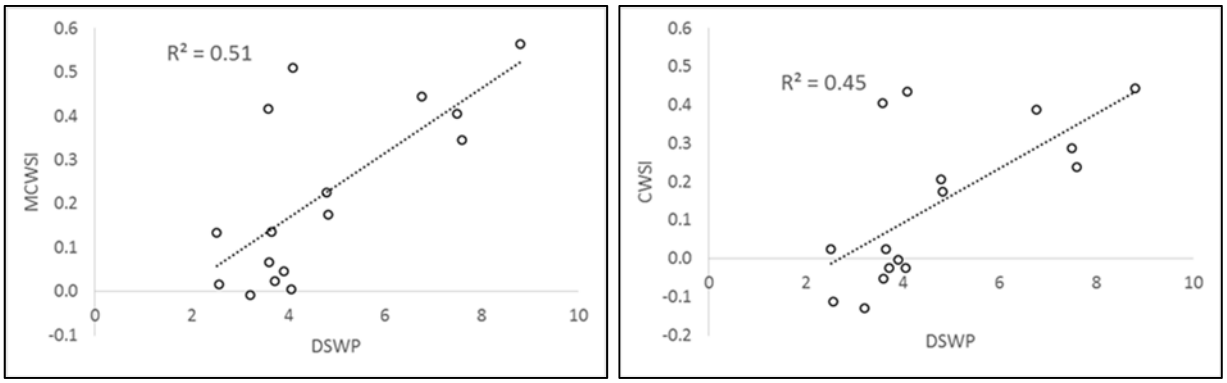


Figure 12. Comparison between MCWSI versus DSWP and CWSI versus DSWP in vines subject to a 10-day wetting cycle at E & J Gallo Vineyard, Galt, California. This graph shows positive values of DSWP, though actual values are negative.

Attempts were made to develop a relationship between SWP and CWSI in grape crop based on the data collected during the 2016 growing season. Although the initial trend was reasonable, the relationship between SWP and CWSI was unclear, particularly toward the latter part of the season. The analysis of CWSI versus SWP data indicated the relationship between the two from July 4th to July 26th, which approximately coincided with the veraison period, did not follow the same trend as the relationship during the rest of the season, as shown in Figure 13. A linear relationship with a coefficient of multiple determination value of 0.78 was found to fit the data obtained during this period. The data from the rest of the periods showed a second order polynomial relationship with a coefficient of multiple determination value of 0.96. Unfortunately, this lack of unique relationship during the entire season complicates irrigation management considerably and led to an investigation of the potential cause of this unexpected behavior. By the end of August, several leaves in the leaf monitors showed signs of senescence. During veraison period, the amount of water applied was reduced to as low as 45% of ET to maintain desired stress level suggested by viticulturists. However, this decrease in irrigation and resultant increase in stress level appeared to cause the older basal leaves to senesce. Consequently, several leaves in the leaf monitors had to be replaced, resulting in frequent re-calibration of CWSI computations. Moreover, the saturated leaf did not show saturated behavior from August 26th to August 31st, according to temperature difference data; this resulted in uncertain CWSI results during that period. At this point, the viticulturists recommended selecting the youngest fully mature leaf for observation. As per their advice, leaf monitors should be installed in the shade on a distal, fully mature leaf in grapes. On August 31st, all leaves were changed based on these new criteria. Starting September 1, the CWSI versus SWP relationship showed promising results with a second order polynomial relationship and a coefficient of multiple determination value of 0.83 (Figure 14). Since this was the first year of stress based management in grapes, it was a learning process in properly installing the leaf monitors and interpreting the data throughout the season.

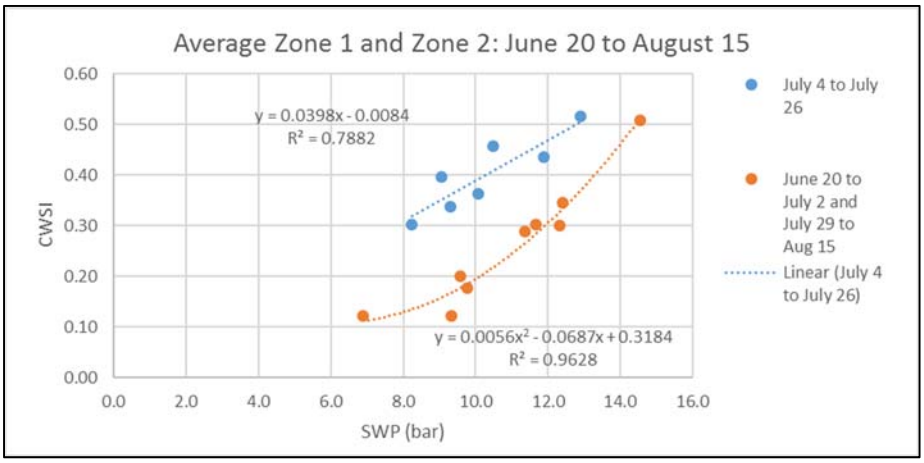


Figure 13. The Crop Water Stress Index versus the Stem Water Potential from June 20 to August 15 when basal leaves were selected when installing the leaf monitors. This graph shows the positive of SWP values for ease of interpretation.

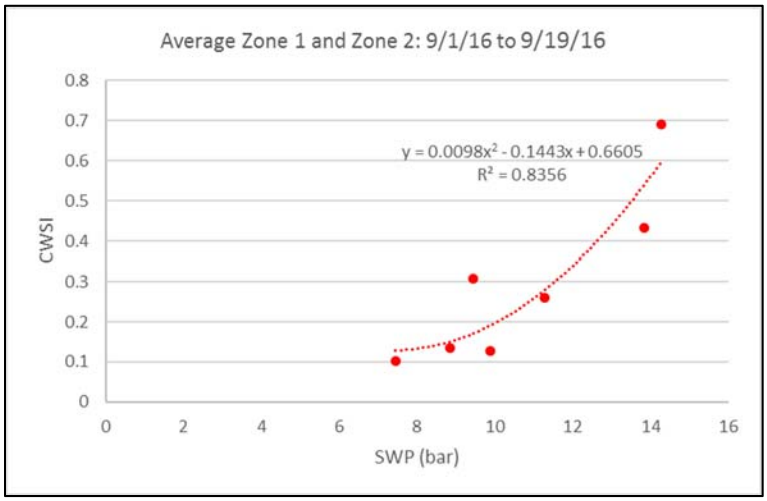


Figure 14. The Crop Water Stress Index versus the Stem Water Potential from September 1 to September 19 when distal leaves were selected when installing the leaf monitors. This graph shows the positive of SWP values for ease of interpretation.

Figure 15 demonstrates how irrigation was managed based on CWSI to try to satisfy the targeted stress levels based on SWP. A LWP of -13 bar, or an approximate SWP of -11.9 bar was targeted during veraison. After veraison concluded around July 19, the target LWP increased to -12 bar, or an SWP of approximately -10.5 bar, as directed by the viticulturists. Unexpectedly high stress levels following veraison led to two attempts to decrease the stress level to -10.5 bar. Although CWSI was primarily used to make irrigation decisions, SWP data was used for verification to protect the vines from receiving an inadequate amount of water during this phase.

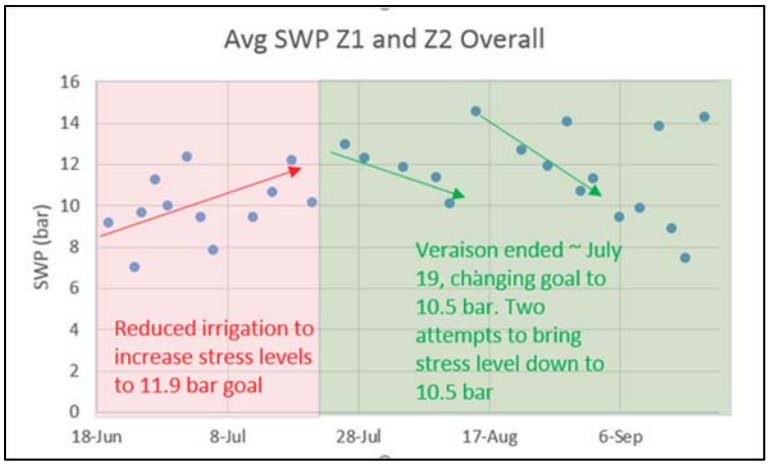


Figure 15. Average SWP values per zone during the growing season. This graph shows positive values of SWP, though actual values are negative.

Water Savings, Yield, and Quality:

Almonds

In almonds, the quality analysis showed no statistically significant differences in the kernel characteristics between the leaf monitor-based management and the grower-based management. The cumulative amount of water applied to Zone 1 was 75% of the grower application and in Zone 2 was 86% of the grower application. The cumulative water applied in the stress based management zones compared to the grower zone is shown in Figure 16. Water was used more efficiently by trees in the leaf monitor-based management zones, as reflected in increased water productivities in those zones: 1,905 lb/ac-ft for Zone 1, 1,610 lb/ac-ft for Zone 2, and 1,534 lb/ac-ft in the grower managed rows. The leaf monitor-based management also resulted in less water applied as a percentage of ET than the grower management. In Zone 1, 69% of ET_c was applied and in Zone 2, 80% of ET_c was applied, whereas in the grower rows, 94% of ET_c was applied. Detailed yield and quality results are shown in Table 2. It should be remembered that the primary purpose for managing stress in almond during the hull-split period is to promote hull-split and control hull rot.

Grapes

Grape quality and yield data from the 2016 growing season were analyzed. Since the E&J Gallo yield monitor did not record yield data due to a system malfunction, manually recorded yield data were used to estimate yield. Yield was measured for three vine-spaces near each leaf monitor. The yield was 18,660 lb/acre in Zone 1; 20,040 lb/acre in Zone 2; and 18,840 lb/acre in the grower zone. The water productivity was 24,385 lb/ac-ft in Zone 1; 28,061 lb/ac-ft in Zone 2; and 17,595 lb/ac-ft in the grower zone. The analysis found that 69% of the amount of water that the grower applied was applied to the stress-based managed zones. Statistical analysis showed no significant differences in yield between the grower treatment and the stress based treatment. Grape quality factors analyzed included grape quality index (GQI), anthocyanins, aroma, C6 compounds, skin damage, tannins, glycosides, malic acid, yeast-assimilable nitrogen (YAN), pH, brix, and moisture content. An additional factor of berry weight per 100 berries was also included. Statistical analysis found significant difference only in malic acid content due to zones and treatment. Detailed yield and quality data are shown in Table 3.

	Stress-Based		Grower
	Zone 1	Zone 2	Average
Yield (lb/acre)[a]	2550	2496	2756
Kernel mass (g)[a]	1.30	1.32	1.30
Kernel length (mm)[b]	24.0	23.9	24.1
Kernel width (mm)[b]	13.5	13.6	13.7
Kernel thickness (mm)[b]	8.5	8.5	8.4
Total Water Applied per Tree (gal)	2805	3246	3762
Water Productivity (lb/ac-ft)	1905	1610	1534
Water applied (% of Grower)	75%	86%	100%
Water Applied of Net ET (%)	69%	80%	94%

[a] Yield and mass results are zone averages for samples of 50.
[b] Volume measurements were based on a sample of 10.

*Table 2. Quality parameters and yield for the 2016 growing season. Note that quality results are zone averages for samples of 50. *Volume measurements were based on a sample of 10 kernels.*

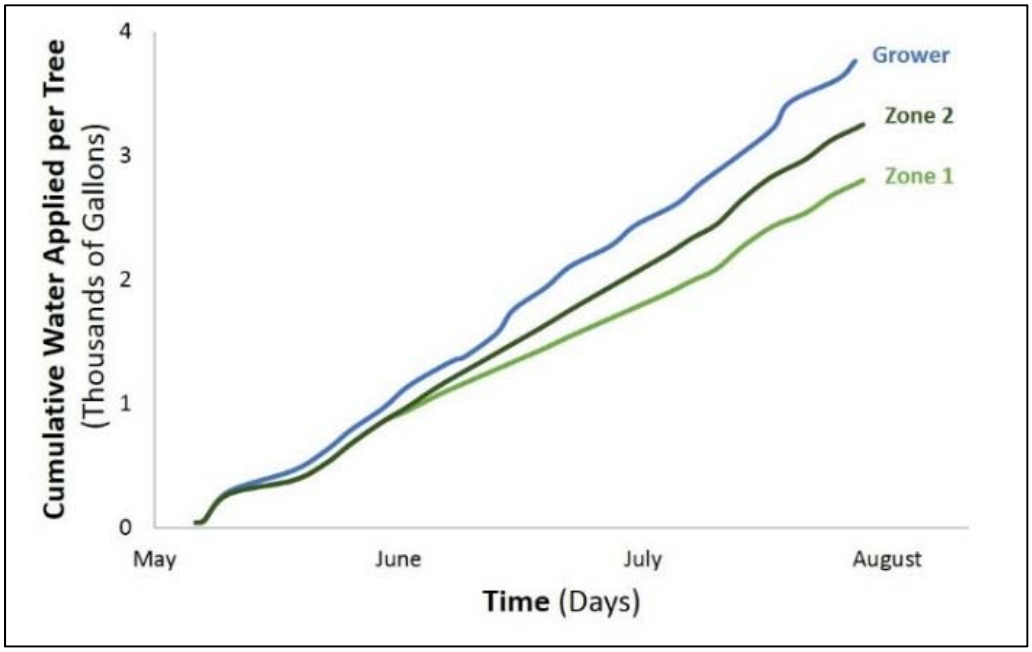


Figure 16. Cumulative water applied per tree (in thousands of gallons) in each treatment over the course of the 2016 growing season.

	Stress-Based		Grower
	Zone 1	Zone 2	Average
Yield (lb/acre)	18,660	20,040	18,840
Malic Acid	1359	1172	1546
Brix	22.93	23.10	22.95
GQI	56.75	62.00	49.50
Anthocyanins	1.26	1.35	1.11
Water Applied (% of grower)	69%	69%	100%
Water Productivity (lb/ac-ft)	24,385	28,061	17,595

Table 3: Grape yield and quality data

Water use was greater in grower treatment than in PWS based treatment. The cumulative amount of water used over the course of the irrigation season is shown in Figure 17.

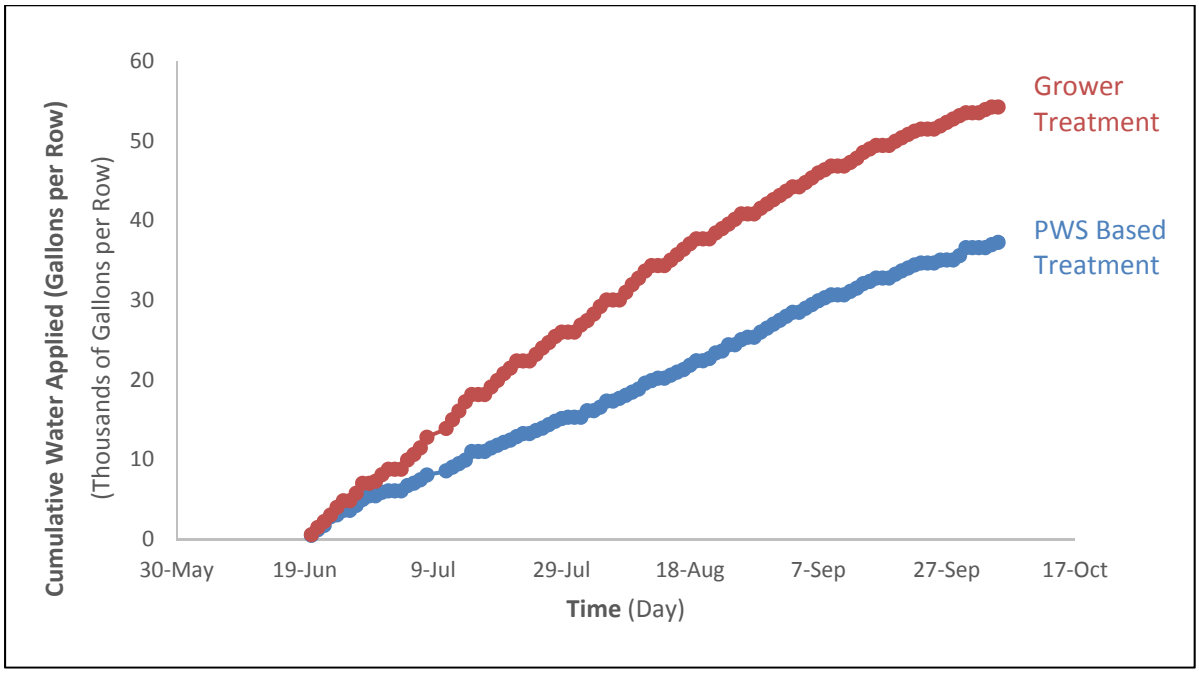


Figure 17. Cumulative amount of water applied in gallons to grower and stress-based management rows from June 20 to October 4

Further Analysis to Quantify PWS

The leaf monitor data was analyzed in quantitative and qualitative ways beyond the set targets of the project, particularly to integrate the environmental data in determining the plant water status of almonds and grapes. As mentioned previously, the CWSI versus SWP relationships in grapes were different during various parts of the growing season. Although the relationships were reasonably good individually, lack of a unique relationship was problematic since the determination of plant water status using the leaf monitor needs to be robust to make confident irrigation decisions. Even unique CWSI versus SWP relationship throughout the season, as in almonds, could be improved because too much scatter in the data from the trend curve could make the prediction unreliable as a method for determining PWS. Environmental factors such as incident radiation and vapor pressure related parameter [$e_s(T_{leaf})$ - $e(T_{air})$] can also affect a plant's ability to transpire and should be included in the analysis of PWS. In theory, increased [$e_s(T_{leaf})$ - $e(T_{air})$] must result in increased transpiration and greater leaf surface cooling, if the plant is not stressed. However, the presence of stress can induce stomatal closure and reduce transpiration and cooling. Factoring in environmental parameters in a more comprehensive stress index than CWSI may be the next step in developing a more accurate measure of plant water status using the leaf monitor. Three new methods for determining the plant water status have been investigated up to this point. They are still being tested and are described in the following paragraphs:

One new method of analysis is called the 'loops. As shown in Figure 18, the result of this qualitative analysis is a pair of loops for each day: (1) the PAR versus VPD loop, describing the environmental condition, and (2) the PAR versus T_{diff} loop, describing both the environmental condition and the plant stress level. Essentially, the lower plot in these loops shows how a shaded leaf behaves when it is subjected to stress and is exposed to

the ambient conditions seen in the top plot. The goal was to determine the changes in plant water stress from one irrigation event to the next to develop a method for making irrigation decisions during future growing seasons. The term 'irrigation period' was established to mean the period from one irrigation event up until but not including the next irrigation event. During one irrigation period of two to six days, the PAR should not change very much but the T_{diff} and the VPD usually change.

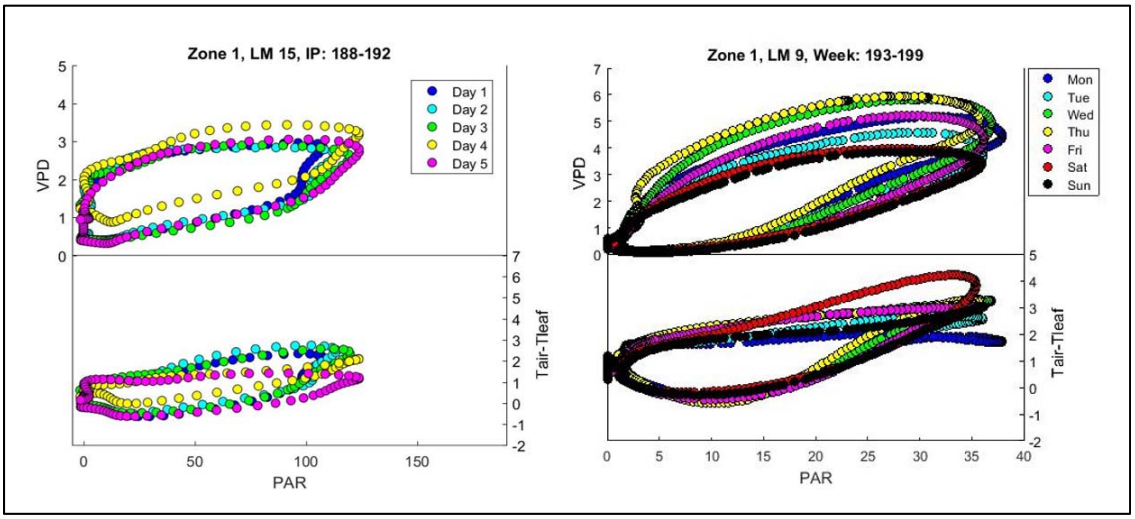


Figure 18. Left: An example 'loops' plot in almonds of PAR (µmol/m²/sec) vs. VPD (kPa) (top) and PAR vs. T_{diff} (Celsius) (bottom) for one irrigation period using the data from one of the leaf monitors in almond crop. Right: An example of the 'loops' plot in grapes from Julian dates 193 to 199.

Figure 18 shows an example of 'loops' plots in almonds (left) and in grapes (right). In almonds (Figure 18, left), the relationships between PAR and T_{diff}, and between PAR and VPD for the duration of one irrigation period in seen (Julian dates 188-192). Each day in the irrigation period is represented by a different color with the day of the irrigation event shown in dark blue. The challenge was to distinguish between increases or decreases in T_{diff} throughout the irrigation period due to changes in plant water stress level versus T_{diff} due to environmental changes. For example, in Figure 18 (left), the yellow loop (Day 4) in the PAR vs. T_{diff} plot shows lower T_{diff} in the afternoon than Days 1-3, suggesting a decrease in transpiration (lower T_{diff}). However, there was also high VPD on the 4th day (yellow colored) compared to the other days. In theory, the increased VPD must result in increased transpiration and higher cooling, if the plant is not at all stressed. However, the presence of stress can induce stomatal closure and reduced transpiration and cooling. Figure 18 (right) shows an example of the 'loops' plot in grapes from Julian dates 193 to 199. In grapes, vines were usually irrigated on Monday through Saturday but not on Sunday. On Monday and Tuesday, high stress (i.e. low temperature difference from decreased transpiration) is expected due to the lack of irrigation on Sunday, as shown in the blue and cyan loops. Later in the week, the stress usually decreases due to several consecutive days of irrigation, so the temperature difference tends to increase from increased transpiration. Looking at the 'loops' plots in both crops was very informative and provided insight into how light levels and VPD affect the plant water status.

The second new method of analysis is called the 'slopes.' This method compares the monitored leaves to the dry and saturated references from one irrigation event to the next. From the leaf monitor data of the monitored trees or vines, VPD was plotted versus $T_{leaf} - T_{air}$ each day. In addition, the responses of the saturated leaf and the dry leaf were also included on the same graph. Theoretically, all the VPD versus $T_{leaf} - T_{air}$ curves

corresponding to the monitored leaf should be somewhere in between the saturated and the dry curves. An example of this analysis is seen in Figure 19 in almonds (left) and grapes (right).

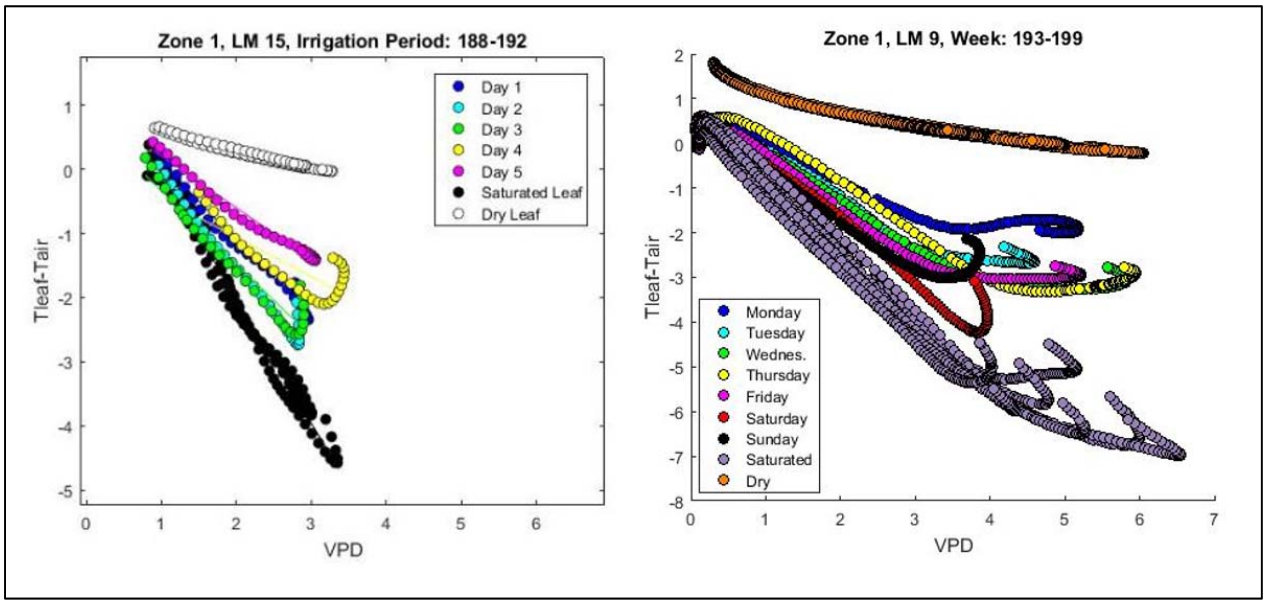


Figure 19. In almonds, Vapor Pressure Deficit versus T_{leaf} - T_{air} in the saturated leaf, the dry leaf, and the stressed leaf starting from the day of irrigation up until the day before the next irrigation (left). In grapes, Vapor Pressure Deficit versus T_{leaf} - T_{air} in the saturated leaf, the dry leaf, and the stressed leaf for one week (right).

Figure 19 (left) shows the VPD versus $T_{leaf} - T_{air}$ relationship of a monitored almond leaf for the duration of one irrigation period using data taken when the PAR was 50 µmol/m^2/sec or higher but before 5 P.M., the time of approximate maximum VPD. Figure 19 (left), shows the VPD vs. $T_{leaf} - T_{air}$ relationship for the saturated leaf (black), the dry leaf (white), the monitored leaf on the day of an irrigation (dark blue), and the days following the irrigation day (light blue, green, yellow, and magenta). On the irrigation day, the monitored leaf's 'slopes' curve is higher than the saturated line, so it may not have yet fully benefitted from the applied water. During the next two days (light blue and green), the lines become closer to the saturated line, indicating the applied water has reached the plant. However, on Day 4 (yellow), the line moves toward the dry leaf line again, indicating increased stress. On the last day of this irrigation period, Day 5 (magenta), the line moves even closer to the dry leaf line, indicating even higher stress. This same analysis was also performed in grapes. Figure 19 (right) shows the relationship between VPD and $T_{leaf} - T_{air}$ in grapes from Julian dates 193 to 199 for the saturated leaf (purple) and for the dry leaf (orange). Between the saturated and the dry 'slopes' curves are the VPD versus temperature difference behavior of a monitored leaf for each day in the week in a different color. Since the vines were usually not irrigated on the weekend, the curve on Monday (blue) lies closer to the dry leaf curve (orange). By Friday (pink), several irrigations have caused the curve to move closer to the saturated leaf curve (purple). Observing the direction of the lines from day to day with respect to the positions of the dry leaf and saturated leaf lines may be another means of qualitatively determining the plant water stress and making irrigation decisions. However, this approach along with the 'loops' method need to be made analytically robust to become irrigation decision making tools.

The third method of analysis is called the 'ratio' plots. An instantaneous stress index related to the stomatal conductance of the leaf is currently being used as the basis of irrigation decisions during the 2017 almond

growing season. This instantaneous stress index is the ratio of the difference between the dry leaf temperature and the live leaf temperature (T_{dry} - T_{leaf}) and the vapor pressure related parameter [$e_s(T_{leaf})$-$e(T_{air})$]. Theoretically, as leaf transpiration increases, the ratio will increase, but as transpiration decreases (increased stress), the ratio will decrease. Examples of the 'ratio' plots are shown in Figure 20.

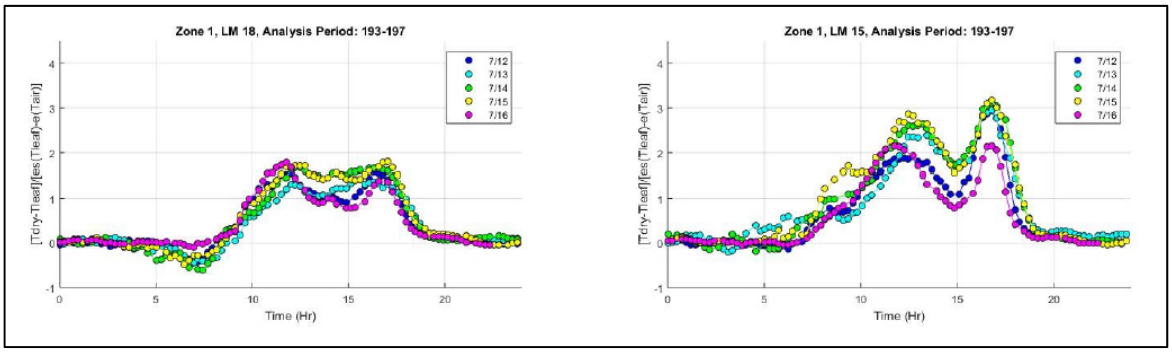


Figure 20. The ratio of T_{dry} - T_{leaf} over VPD proxy ($e_s(T_l)$-$e(T_a)$) throughout the day from July 12 to July 16 for leaf monitor 18 (left) and leaf monitor 15 (right).

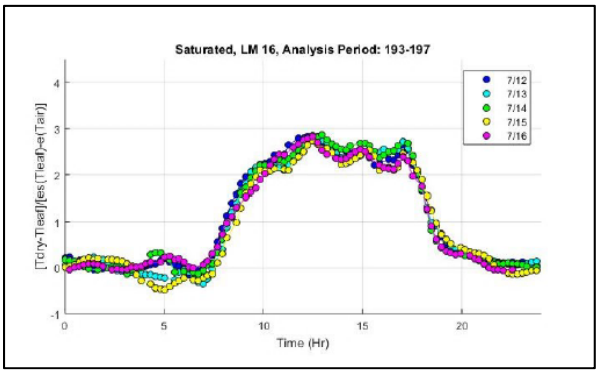


Figure 21. The ratio of T_{dry} - T_{leaf} over VPD proxy ($e_s(T_l)$-$e(T_a)$) throughout the day from July 12 to July 16 for the saturated leaf.

Zone 1 was irrigated on July 12 (blue) because the ratio was low, indicating stress. The next day, the ratio increased and remained high until July 16; on July 16, the lower 'ratio' plot curve (magenta) indicated that plant water stress increased. Therefore, Zone 1 was irrigated again on July 16. Figure 21 shows the 'ratio' of the saturated leaf from July 12 to July 16. Since the saturated leaf is always well-watered, the 'ratio' does not noticeably change from day to day, indicating that the 'ratio' of a plant under no stress would be a specific, relatively constant value. Although it is only a conjecture now, each leaf may have a certain 'ratio' that indicates a saturated condition depending on the particular leaf's characteristics and its environment.

The major successful outcomes of the project are as follows: The results from the CWSI versus SWP relationships were promising in both almonds and grapes. In almonds, a polynomial relationship was found between CWSI and SWP before and during hull-split in 2016, with a coefficient of determination of 0.78. The combined data from the 2015 and 2016 growing seasons in almonds resulted in a coefficient of determination of 0.61. More SWP and CWSI results are being collected in almonds during the 2017 season. In grapes, an initial 10-day experiment during the 2015 growing season showed promising results. The multiple linear relationship for vines experiencing increasing stress between MCWSI and SWP, and CWSI and SWP had coefficients of multiple determination of 0.90 and 0.97, respectively. However, this strong correlation was not

found in vines subjected to the wetting cycle from high stress. Coefficient of determination values of 0.51 and 0.45 were found for MCWSI versus DSWP and CWSI versus DSWP, respectively. The project staff implemented irrigation management in grapes during the 2016 growing season. Although the relationship between CWSI and SWP was unclear in the beginning of the season, the trend showed promising results when the data was divided into periods that reflected different stages of fruit development. A slightly different relationship between CWSI and SWP was seen from early July until shortly after veraison ended. Comparison between CWSI and SWP from July 4th to July 26th showed a linear relationship with a coefficient of multiple determination of 0.78. For the combined periods of June 20th -July 2nd and July 29th to August 15th, a second order polynomial relationship was developed with a coefficient of multiple determination of 0.96. After all leaf monitors were installed with a fully mature leaf on a lignified vine in the shade, the relationship between CWSI and SWP was second order polynomial relationship with a coefficient of multiple determination of 0.83.

Analyses of quality and yield data indicate that deficit irrigation can be implemented in almonds without significantly affecting the yield or quality. In 2016, no significant differences were detected between the stress based managed zones and the grower managed zones in terms of the kernel characteristics or the yield. In grapes in 2016, yield was not significantly different between the stress based managed zones and the grower managed zones. In terms of quality, only malic acid was significantly different between the two treatments in grapes.

Water productivities and water savings were statistically significant between the stress based treatment and the grower based treatment in both almond and grape crops in the 2016 growing season. In almonds, the water productivity results were 1,905 lb/ac-ft in Zone 1; 1,610 lb/ac-ft in Zone 2; and 1,534 lb/ac-ft in grower zone. Analysis of the flow meter data indicated that 75% and 86% of the amount of water the grower applied were applied to Zone 1 and Zone 2, respectively. This is equivalent to 69% and 80% of ET_c applied to Zone 1 and Zone 2, respectively. In grapes, the water productivity was 24,385 lb/ac-ft in Zone 1; 28,061 lb/ac-ft in Zone 2; and 17,595 lb/ac-ft in the grower zone. The stress-based treatment received 69% of the amount of water the grower applied, which is equivalent to 31% water savings in grapes.

Beneficiaries

The primary beneficiaries are almond and grape growers. The results of this study were shared at the local level through field day demonstrations and the national and international level by presenting this work at national and international meetings. While the former was mainly intended for growers, farm advisors, and extension specialists, the latter was mainly directed towards scientists and researchers. In addition, both technical and nontechnical publications were written and made available to growers as well as researchers. The project also provided opportunities to train two undergraduate, two postgraduate, and four graduate students, thus preparing engineers of the future, who can continue to address the challenging problems of sustainable food production in the face of increasing demand and decreasing resources.

Between various demonstrations and presentations, project staff have been able to reach over 1,000 end-users, who may directly benefit from the outcome of this study. The potential to save a significant amount of water without affecting yield or quality can have major impact on conserving resources. It is difficult to estimate the amount of water savings based on this short duration study in which only a few acres of each crop has been studied. However, an estimation of amount of water savings for the whole state can be made by making certain assumptions. Assuming that average efficiencies found for both crops (74.5% of ET for almonds and

69% of ET for grapes) are reasonable estimates for the savings and applies to total bearing areas of the crop in the state (2015 areas for almonds is 890,000 acres and grapes is 560,000 acres; California Agricultural Statistics, 2016), a water savings of about 440,000 acre-ft for almonds and 186,000 acre-ft for wine grapes is had.

Lessons Learned

A wealth of lessons has been learned over the duration of this project. The potential to monitor plant water status through the continuous leaf monitor and make visualization of the data through the internet to the grower in the comfort of his/her office or through smart devices has made implementation of precision irrigation feasible. The collection of tedious and time-consuming SWP data in the field has revealed that plant's ability to acclimatize to the environment. It is also very clear that there is a wealth of information coming from the leaf monitor data that needs to be mined using Neural Network, deep learning and/or other artificial intelligence techniques to assist in making reliable decision. For example, the VPD, PAR, and T_{diff} data also contain a wealth of information which may be combined to develop a new plant water stress index instead of relying on conventional CWSI, which may not be uniquely related to SWP due to acclimatization issues.

Measuring the dry leaf temperature under the same conditions as each monitored live leaf rather than having one dry leaf monitor for an entire field has been shown to be a more accurate practice. Until the 2017 season, each leaf monitor had one IR sensor. A separate leaf monitor measured the temperature of a dry leaf. However, the 2017 version of the leaf monitor has two IR sensors, one for the live leaf and one for the dry leaf. By measuring a dry leaf in each leaf monitor where there is a live leaf, the incident radiation, air temperature, and relative humidity are the same for both leaves, resulting in more reliable comparisons between the two leaf temperatures than if they were located in separate parts of the field. In addition, the time stamps of the dry leaf and live leaf temperatures are exactly the same, which eases computing difficulties encountered when measurements are taken at slightly different times.

Other more qualitative observations have also been useful in understanding plant response to water stress. For example, trees seemed to adjust to a given level of stress. When trees were well-watered, they reacted more strongly to very hot, dry days. However, those trees subjected to water stress for a period seemed to acclimatize and react less strongly to the same very hot, dry days. It was as if these trees were less stressed on those days. This may merit further investigation to understand the physiological adjustments made by the trees to withstand water stress while maintaining other plant functions.

Since the plants appear to acclimatize due to stress history, it may be worth investigating ET based, SWP based, and leaf monitor response based irrigation schemes to see if leaf monitors can provide a more meaningful parameter for irrigation management that indicates how the stomata are responding in a given environmental condition.

Some of the lessons learned were more practical. The leaves monitored by the leaf monitors did not always remain alive during the growing season and when a leaf died it had to be replaced. For leaf monitor installation in grapes, one should choose fully mature fifth or sixth distal leaves on a lignified vine for the leaf monitors to avoid senescence during deficit irrigation. In almonds, most leaves remained alive for the entire 2016 growing season. However, in 2017, several almond leaves died after an herbicide spray application.

Further investigation of the impact of herbicide spraying on leaves inside the leaf monitor enclosure should be pursued in future projects using this technology.

The main result that was an effect of implementing this project is significant water savings can be achieved in grape and almond crops without affecting the yield and only affecting malic acid in grapes. Additionally, a different relationship between CWSI and SWP may exist during different stages of fruit development over the course of the growing season. Acclimatization of plant to stress made the research team look at the continuous leaf monitor data more closely and investigate the possibility of developing more meaningful stress indicators.

Additional Information

Recent Publications:

Dhillon, R., S. K. Upadhyaya, F. Rojo, J. Roach, R. Coates, and M. Delwiche. 2017. Development of a continuous leaf monitoring system to predict plant water status. Transactions of the American Society of Agricultural and Biological Engineers (Accepted for publication).

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 36	**Project Title:** Water Use Efficiency for Fruit Quality, Ecosystem Benefits and Resilience in Fresh Market Tomato Production	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB14036	**Date Submitted:** December 2017
Recipient Contact: Amanda K. Hodson	**Telephone:** (530) 752-2592	**Email:** akhodson@ucdavis.edu

Project Summary

Drought is the major obstacle for farmers in California and water scarcity is predicted to become more severe. Irrigation demand and groundwater pumping are expected to be substantial under a projected warmer and drier climate and the area's water district is likely to face more frequent years with water supply problems, e.g. years where water deliveries are either below full allocation and/or no-allocation. This study of several fresh market tomato production systems examined the effects of deficit irrigation and tradeoffs with other environmental variables, such as nitrogen retention and pest pressure. The study: 1) Established field trials in Merced, Yolo and Santa Cruz counties to test effects of plant density and irrigation on mature-green, organic heirloom and dry-farmed tomatoes, respectively; 2) Monitored how the treatments affected disease, pest and weed pressure; 3) Delivered information on management option tradeoffs for water conservation, and reduction of fertilizer and pesticides. Some levels of deficit irrigation were found to be a valuable tool to respond to limited water availability as water shortage allowed plants to use water more efficiently, with little decreases in yield. Water deficits also had consequences for insect herbivory, with some insect groups (such as planthoppers) increasing with drought stress, while other groups (like thrips) were more common on less water stressed plants, suggesting that savings in pesticide costs could be a side benefit in some cases but not others. Outreach engaged growers, crop breeders, farm service companies, environmental organizations, agencies, and farm advisors, through discussions, web postings, an extension booklet, and local and statewide meetings for industry adaptation.

California is in dire need of agricultural solutions that use less water. In the San Joaquin Valley, drip irrigated mature-green tomatoes can use as much water as furrow-irrigation, but typically produce more fruit of higher quality, achieving higher water use efficiency (WUE). The semi-determinant varieties are picked once at the mature-green stage of ripeness, then washed, sorted and gassed with ethylene before shipping. The impact on yields and quality of reducing evapotranspiration (ET) with lower plant density and/or deficit irrigation, and the need to reduce costs of other inputs to stay financially viable, is especially important because shippers have stringent quality guidelines for long-distance transport and storage. For example, knowing which factors most affect fruit quality under water deficits may help growers prioritize other inputs, such as pesticides.

This project builds upon 2009 Specialty Crop Block Grant Program Project 14: *Implementing the Partial Root Drying Technique to Increase Water Use Efficiency for Processing Tomatoes.* The project showed an irrigation method by which water inputs could be greatly decreased without yield loss. It also increased awareness for drought preparedness via management and crop breeding. This project also builds upon 2012 Specialty Crop Block Grant Program Project 39: *Cultivar Trait Selection to Improve Tomato Water Use Efficiency and Yield Under Low Water Availability.* The project focused on genetic traits to increase processing tomato production under water and heat stress. It investigated the effects of a severe water deficit

(80% reduction in applied water) on tomato physiological and morphological traits. The current grant is for fresh market tomatoes which are even more vulnerable to water stress due to the importance of cosmetic quality, turgor and storage losses. Previous projects provided experience which led to the successful completion of two field seasons in the current grant.

Project Approach

Objective 1. Establish and Conduct on-farm experiments on irrigation, cultivar and plant spacing.

In each year, seven trails were established on growers' fields or research stations examining the effects of plant spacing, cultivar and deficit irrigation techniques. The experimental design of each trail for is briefly outlined below focusing on the 2016 season, which generated the most robust data and is currently being prepared for publication.

1) Organic heirloom water deficit trial in Yolo County, Durst Organic Farm. An heirloom variety (Carolina Orange) was managed with two types of irrigation (12" subsurface drip at usual irrigation amounts which was named as the control treatment; 15% less water applied, two drip lines at 12" deep and at 4" deep, alternating deep and shallow lines every irrigation which was named as the Hi/Lo Deficit treatment).
2) Organic heirloom water deficit trial in Yolo County, Armstrong Ranch, University of California (UC) Davis Plant Pathology Field Station. This drip irrigation trial included similar treatments and the same variety as trial #1, but also included an alternating Hi/Lo well-watered control and 12" drip line treatment at 30% deficit.
3) Mature green research station drip-irrigated full-season water deficit trial in Yolo County, Armstrong Ranch, UC Davis Plant Pathology Field Station. The two treatments were grower standard and a 30% reduction beginning 5 weeks after planting. The cultivar was "Syngenta Q 47".
4) Organic dry-farmed trial in Santa Cruz County, Route One Farm. Two genotypes were planted of the Rio Grande variety (*rmc*=reduced mycorrhizal colonization vs. MYC+=full mycorrhizal colonization) with no irrigation after transplanting. This experiment was severely impacted by beet curly top virus and generated no useable data.
5) Conventional furrow-irrigated mature green full-season water deficit trial in Merced County, Scoto Brothers Farming. Treatments included: grower standard irrigation, skip-row, and skip-row with irrigation stopped at 80% of the run length. The cultivar was "Syngenta Q 47".
6) Conventional drip-irrigated mature green trial terminal water deficit trial in Merced County, Live Oak Farms. The three treatments were: grower standard, 15% reduction, 30% reduction, beginning 5 weeks after planting. The cultivar was "Syngenta Q 47".
7) Research station drip-irrigated full-season water deficit trial in Merced County, Merced Community College. The four treatments were: (100%, 90%, 80%, and 70% of crop evapotranspiration (Etc) as calculated using data a nearby weather station. The cultivar was "Syngenta Q 47".

Field measurements were taken three times for all field trials in both years. A sample for soil physical and chemical properties was taken before planting, then soil moisture and inorganic N availability (0-75 cm deep, 3 depths) were measured two or three times during the season. To take plant physiological measurements, three leaflets per plot were collected for analysis of relative water content (RWC), total C, total N, δ13C, specific leaf area (SLA), and specific leaf area nitrogen (SLAN). From the same plants, canopy temperature depression (CTD) was obtained using a dual laser video infrared thermometer.

Growth was determined by biomass at harvest. Trials differed in harvest methods depending on the variety planted. Heirlooms were harvested twice from each 10 foot plot to account for their longer period of ripe fruit production. Mature green tomatoes were harvested once. In both cases, biomass of fruits and shoots were weighed in the field (fresh weight) and then shoot subsamples were dried at 60°C and weighed, as was a subsample of marketable fruit. Mature greens were additionally sorted into size categories XL, L, M, S and Mini, where categories XL, L and M count as marketable.

At the Live Oaks Farm site in Merced County, deficit irrigation affected soil properties, crop yield and leaf nutrients. In 2016, deficit irrigation reduced soil moisture at 15-45 cm depth and also at 45-75 cm depth. Marketable fruit yield (sizes M, L, XL) tended to be lower in rows with 15% deficit irrigation and was significantly lower in 30% deficit irrigated rows compared to standard irrigation. Deficit irrigated plots had relatively more red tomatoes than standard irrigated plots for both the 15 % deficit and 30% deficit and fruit with sunburn symptoms and small sized tomatoes tended to me more with 30% deficit irrigation. The relative amount of culls harvested from rows was not affected by deficit irrigation, though. Deficit irrigation affected indicators of leaf water status such as leaf RWC, CTD and δ13C. Leaf RWC at harvest were significantly reduced in plants that had grown under deficit irrigation and mean canopy temperature depression across all sampling dates also tended to be lower in rows that were irrigated with 30% deficit irrigation compared to rows with standard irrigation.

At the Merced Community College site, deficit irrigation affected soil moisture and leaf water content, but did not influence yields. Gravimetric soil moisture at harvest tended to be lower with deficit irrigation in the top soil layer (0-15 cm) compared with plots with grower standard irrigation. The total yield and amount of marketable fruit harvested from rows were not affected by the deficit irrigation treatment. Aboveground biomass was unaffected by irrigation treatment and there were no differences in culls harvested from differently irrigated rows. Leaf relative water content at harvest tended to be lower in plants with 30 % deficit irrigation compared to plants from plots with control irrigation and 10% deficit irrigated plots.

At the UC Davis Armstrong field station trail, deficit irrigation affected soil moisture, but did not affect yield or plant traits. While total yield as well as marketable yield and aboveground biomass were not affected by deficit irrigation, the amount of culls relative to the total yield was significantly reduced with deficit irrigation and, in contrast to Live Oak Farms, there tended to be less red tomatoes in plots with deficit irrigation.

Examine tradeoffs in management inputs, practices and costs for all trials:

Deficit irrigation had few consequences in all production systems until 30 percent reductions in water were achieved, indicating that further water reductions are possible for growers to achieve decent yield in drought years. Using the data for each production system, the benefits and constraints for different types of ecosystem services were inferred in response to severe future drought. Ecosystem services are the full set of benefits derived from an agroecosystem.

1. Provisioning services (e.g. crop production per acre) appear highest in organic systems especially for dry-farmed tomatoes, but also with drip-irrigated romas.

2. Regulating and supporting services (e.g. environmental quality) may be higher in organic systems, since soil C storage is higher and pesticide use is lower, but nitrate leaching and nitrous oxide (a greenhouse

gas) emissions may be similar across systems (except for the dry-farmed system) due to high soil nitrate and irrigation. In intensively managed systems, deficit irrigation may reduce nitrate leaching.

3. Cultural services (e.g. social benefits) of conventional production offer more people access to fresh market tomatoes, while organic production supports local food systems.

It was not possible to obtain data on expenses for the trials. In fact, for 2015, even obtaining complete sets of management practices took weeks or months and the Principal Investigator (PI) and postdoc are still working with the FA and growers to get management practices for 2016.

Objective 2: Determine the pest pressures likely to increase or decrease with deficit irrigation:

Each year, field plots were scored for damage three times during the season for presence of weeds and disease or insect damage. For pests, two plants from each plot were randomly selected and surveyed on one side of the field row for damage due to insects or disease. Insects that fell into collection containers from leaves, stems or near the canopy after beating stems for one minute were counted and identified under a microscope. Yellow sticky cards were also used in 2016 to survey insects from each plot. Finally, insect damage was assessed qualitatively and scored based on the severity of visibly chewed leaves, and presence of rasp marks, dots from piercing, tracks or blotches, raised bulges, or honeydew. Damage due to disease both on leaves and fruits, when present, was similarly scored based on severity.

Although deficit irrigation had no consistent effects on insect communities, fewer insects were found on water stressed plants, indicating that deficit irrigation could have positive tradeoffs with pest damage. At Live Oak Farms, cooler leaves had more thrips and less planthoppers. Thrips were also associated with N15, an indicator of water based N cycling. At Merced Community College, total insect counts from plant shakes were significantly lower with 10% deficit irrigation compared to standard irrigation. Staff found on average 16 insects in 10% deficit irrigated plots compared to an average of 23 insects in standard irrigated plots. At the UC Davis Armstrong field station, planthoppers were more common in plant shakes from plants that were fully irrigated compared to deficit irrigated plots. In September, when temperatures were hottest, the abundance of most insects associated with more negative δ13C, indicating less discrimination against C13, lower WUE and greater plant water status.

The scope of the project did not benefit commodities other than specialty crops.

Participants of the on farm trials provided data on irrigation and pesticide practices for the previous season in cases where fields were not maintained directly by the FA.
Trial #1: Durst Organic Growers, Esparto, California: Organic drip irrigation site cooperator.
Trial #4: Route One Farms, Santa Cruz, California: Organic dry-farmed site cooperator.
Trial #5: Scoto Brothers Farming, Merced, California: Conventional furrow irrigation site cooperator.
Trial #6: Live Oak Farms, Le Grand, California: Conventional drip irrigation site cooperator.
Trial #7: Merced Community College, Merced, California: Drip irrigation research farm site.

Goals and Outcomes Achieved

Outcome 1: Identify at least two management practices for reliable production in dry years with lower inputs.

For organic heirloom production, high and low drip tapes were identified as a potential viable strategy to improve deficit drip irrigation. In the 2016 experiment with a 15% deficit treatment, no differences were seen in yield compared to fully irrigated controls, although aboveground biomass was less and so plants were less able to hold fruit compared to standard drip irrigation on yield. For mature green tomato production, a second strategy was deficit irrigation (by 10 or 20%) which only had minor effects on tomato yield and quality. However, reducing water application by 30% relative to grower standards significantly affected the tomato yield and impact of sunburn and prematurity of tomatoes at one site.

Outcome 2: Determine the pest pressures likely to increase and decrease under deficit irrigation in each system.

Although insect populations were monitored in detail during both field seasons, no consistent increases or decreases in pest pressures with deficit irrigation have been identified. While data from 2015 indicated that thrips increased with deficit irrigation compared to controls across multiple production systems, there was no differences in thrips between treatments in the 2016 field season. In fact, during the 2016 season, thrips were correlated with leaf characteristics indicating less water stress in the mature green production systems.

Outcome 3: Increase awareness of alternative planting and irrigation strategies.

Through presentations, as well as field days with farmers, their staff, industry representatives, associated stakeholders, and students, approximately 130 people have learned about the project and alternative irrigations strategies in 2015. In 2016, through a poster presentation, approximately 200 people learned about the project's results, and 50 copies distributed of an extension booklet, 'Preliminary Data: Managing for Drought in California Fresh Market Tomatoes.' In 2017, 100 growers learned about the project at an extension meeting and the postings about the project on the lab's website received over 100 views.

For measurable outcome 1, the results of two field seasons identified two strategies, high/low deficit irrigation as well as traditional deficit irrigation less than 30%, which did not result in significant yield decreases, reductions in fruit quality or adverse effects on plant nutrition.

For measureable outcome 2, conflicting results of the two years highlighted the complexity of interactions between water stress, plant chemistry and pest populations. Changes in plant chemistry likely mediate insect feeding preferences in response to changes in water status. For example, plants grown under drought stress can have greater nitrogen and carbon concentrations and generally have reduced water contents. These factors likely interact to affect plant communities, although our data suggest they are not always linear nor are they always consistent.

For measureable outcome 3, the grant's goal was to reach 50 growers, 100 affiliated stakeholders and >500 people statewide. Through the outreach detailed above, staff have exceeded this expectation. Data was collected by counting attendees at field days, presentations and conferences as well as by using built in analytics on the website. This data indicates that over 500 individuals learned about the project and alternative

irrigation strategies, in line with targets set in the scope of work. It is anticipated that this target will be further exceeded as manuscripts are published and presented at future conferences.

Two management practices were identified for reliable production in dry yields with low water allocations, drip irrigation at alternate depths (high/low systems) as well as standard deficit irrigation less than 30%. Pests likely to decrease with deficit irrigation include thrips, whiteflies and planthoppers, although results were variable between years. Through field days, presentations and postings on the lab's website, over 500 people gained awareness of alternative planting and irrigation strategies.

Beneficiaries

The California fresh market tomato industry was the direct beneficiary of this research. If the findings from the current study are extrapolated, the economic gain for the industry in dry years could be up to 25% with reduced irrigation costs as well as lower pesticide inputs. Three sectors of the industry specifically benefitted: 1) conventional mature greens for long-distance shipping and export; 2) organic Romas and heirlooms for regional shipping; and 3) dry-farmed hybrids for direct marketing. The current project's results on the effects of deficit water management on post-harvest quality are particularly important for shippers of mature green tomatoes, which are stored for long-distance transport. For example, while there were no differences in culls with deficit irrigation, deficit irrigated plots had relatively more red tomatoes than standard irrigated and also more fruit with sunburn symptoms.

In California, fresh market tomatoes are grown on over 30,000 acres with a total value of $369 million. The direct beneficiaries of this project were organic and conventional growers producing vine-ripe or mature green fresh market tomatoes, which number at least 350. Through presentations and field days, the project increased awareness of alternative irrigation strategies among at least 50 growers, 100 affiliated stakeholders and >500 people statewide.

Lessons Learned

Other lessons learned include how easy it is to damage drip irrigation systems that are buried below the surface. In both years, the drip tape was inadvertently damaged in the Durst Organic Farm trial. While the consequences were worse in 2015 (water application in this treatment was only about 20% of the grower's standard treatment), in 2016 the postdoctoral researcher noticed the damage immediately and notified the grower.

In Merced County, unexpected challenges included an irrigation tail water pump that failed which resulted in complete flooding of the furrow irrigated test location about one month prior to harvest in 2015. This essentially negated most of the deficit irrigation treatments that had been imposed up to that moment. Staff continued with the project as planned, but results were subdued. In 2016, soil at the same site was tilled when wet, resulting in very poor soil structure, which may have again affected treatment outcomes.

Despite some difficulties, the goals and outcome measures were largely achieved.

Additional Information

Attached is a draft manuscript planned for submission in 2018.

USDA Project No.:	Project Title:	
37	Novel Lye-Curing Replacement Process for California Olives to Eliminate Toxic Waste Chemicals and Conserve Water Resources	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB14037	**Date Submitted:** December 2017
Recipient Contact: Selina Wang	**Telephone:** (530) 219-1267	**Email:** scwang@ucdavis.edu

Project Summary

Lye is a hazardous caustic agent that removes the bitter compound oleuropein from olives, making the fruit palatable. Traditional lye processing of California-style olives has significant negative impacts. These include: 1) stripping the olive of nutritional content through non-specific degradation of beneficial compounds; 2) needing large volumes of water for repeated rinsing steps to remove lye from the fruit; 3) generating large quantities of wastewater as a by-product, which is hazardous and caustic to the environment. This project addressed the concern by mitigating these effects by developing an enzymatic debittering process that specifically degraded the compound primarily responsible for olive bitterness, oleuropein.

The project was timely, as consumption of California table olives has declined by 34 percent in the United States from 2006 to 2012 compared to the previous five-year period, according to the International Olive Council. California table olive acreage has declined commensurately, falling by 28 percent since the mid-1990s due to sagging sales. At the same time, foreign producers of California-style olives now dominate foodservice and restaurant channels, which is 72 percent of the United States market, because importers underprice domestic producers as a result of European subsidies and low United States tariffs. Replacing lye with an enzymatic treatment mitigated the issues, improving the nutrition and decreasing the environmental impact of California-style olives. This project aimed at reducing processing costs, improving sustainability, and boosting consumer demand for a healthier California-style olive.

Recent advancements in enzyme technology have revolutionized the biotechnology and pharmaceutical industries. This project technology does not only apply to olives, but by engineering new enzymes, the traditional lye peeling process for other specialty crops such as tomatoes, peaches, nectarines, apricots, and pears can also be innovated.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

A β-glycosidase enzyme was identified that degrades oleuropein to hydroxytyrosol within 24 hours. The degradation was identified and monitored according to the developed high performance liquid chromatography assay. Following this result, a panel of 22 β-glycosidases (including the initial hit) was analyzed for oleuropein degradation activity in this same manner with hopes to identify a faster candidate. Eight β-glycosidases were found to have varying levels of degradation activity against olueropein. A time point study was conducted to understand the varying speed at which the degradation occurs (2 hours, 6 hours, and 24 hours) to identify the fastest enzyme from this set. According to this study, the β-glycosidase from *Streptomyces* has been identified as the best candidate (pdb code: 1GNX). Computational modeling (docking

and design simulations) using the Rosetta Molecular Modeling Suite was performed on 1GNX, which guided in generating a list of mutants to be constructed for the first round of design. Eleven mutants were chosen and the plasmids were constructed by site directed mutagenesis. These mutants were then expressed, purified, and assayed. One mutant was found to improve activity two-fold over wild type.

Following an extensive literature review, methods for measuring the nutritional (phenolic) and sensory (volatile) profile of olives were identified. Multiple methods for extracting oleuropein and other phenolic compounds were compared and found to be unsatisfactory in terms of accuracy and consistency. Instead, a method for quantifying phenolics in olive fruit was developed, optimized and validated for fresh, brined and California-style olives. This method, which is in the process of being published, was used to measure the effectiveness of oleuropein degradation and to identify any resulting changes in the chemical/nutritional profile from enzyme treatment. A method for measuring the volatile profile of olive fruit was adapted from olive oil and used to assess changes in the sensory profile of enzymatically-treated olives.

Whole, pitted and crushed olives were treated with the best-candidate enzyme to observe oleuropein degradation *in vivo*. Preliminary trials with premature fruit showed potential enzyme effectiveness in pitted and crushed olives. However, after conducting a full-scale experiment with mature olives, no significant difference in oleuropein degradation was found in whole or pitted olives, and oleuropein concentration in crushed olives was negligible in both control and enzymatically-treated samples (likely caused by activation of natural enzymes upon crushing). From the experiment, project staff has concluded that the enzyme is not able to penetrate olive cells in order to react with oleuropein. Additional olive treatments may be necessary to allow the enzyme to access oleuropein. Re-engineering of the enzyme to increase cell penetration would potentially mitigate this problem as well.

Physical and chemical properties of wastewater generated from the previous experiment were analyzed. Analysis showed that enzymatic wastewater had a pH of 6 compared with lye treatment which had pH of 12. Other properties measured including chemical oxygen demand, total solids and turbidity had no significant difference between enzyme and lye processing. It was concluded that the enzymatic process would improve characteristics of the wastewater and make mitigation easier for producers.

This project did not benefit commodities other than California specialty crops.

The project staff have communicated with olive processors and visited their facilities to understand how and when the developed enzyme could be incorporated into their current procedures. These partners have provided fresh olives, brined olives, and wastewater samples for analysis. The project staff have also coordinated with the United States Department of Agriculture, Agricultural Research Service and performed wastewater analysis at their facility.

Goals and Outcomes Achieved

The nutritional and sensory profiles of different olive types, including fresh Manzanillo olives, brined olives and traditional California-style olives, were measured. This data provided a baseline for comparing increased nutritional content from the novel enzymatic process. An engineered enzyme that breaks down oleuropein, has been developed. In doing so, the nutritional value of olives will be retained relative to traditional processing methods. Project performance goals of: reducing volume of water utilized in processing and

reducing volume and toxicity of wastewater were assessed by analyzing the wastewater generated during a benchtop enzyme experiment.

An enzyme that degrades oleuropein on a usable time-scale has been developed. In doing so, progress toward the ultimate goals of retaining nutritional content of the olive and reducing wastewater amount and toxicity has been achieved. However, degradation of oleuropein in vivo was not accomplished by the end of this project. Analysis of wastewater from enzymatic processing showed a significant reduction in pH, demonstrating the potential for this processing method to reduce wastewater toxicity.

The nutritional profiles of different olive types, including fresh Manzanillo olives, brined olives and traditional California-style olives, were measured. This data provides a baseline to later assess increases in the nutritional content of the enzymatically-processed olives. Wastewater from traditional processing was measured as a baseline to compare with wastewater the enzymatic process.

An engineered β-glycosidase has been developed for the specific degradation of oleuropein, the compound primarily responsible for olive bitterness. An efficient method for quantifying phenolic compounds in olive fruit was developed. A manuscript on this method has been submitted to a peer-reviewed journal and is currently under review (Attachment 1).

The four measurable outcomes for this project were:

1.) Goal: Educate olive processors to master the new debittering process. Performance measure: Consistency in product quality. Benchmark: Standard deviation of physical and chemical product quality of lye-processed California-style olives based on statistically valid sampling. Target: Equivalent standard deviation in product quality for enzyme-debittered olives as for lye-processed olives.

Outcome: The project staff analyzed the physical and chemical parameter of the lye-processed California-style olives. The project staff were able to educate the processors on the potential of using other methods besides lye treatments to debitter olives through site visits. However sufficient degradation of oleuropein was not fully achieved, therefore enzymatic processing method was not finalized, and project staff were not able to measure consistency in product quality between enzyme and lye-treated olives.

2.) Goal: Reduce water used in California-style olive processing. Performance measure: Reports of the gallons of water used annually from processors. Benchmark: Amount of water used in lye processing by state olive processors in 2012-2013. Target: Reduce water usage by 30 percent below 2012-2013 levels when enzyme debittering is fully implemented by processors.

Outcome: The project staff were able to demonstrate that the potential of using enzymes to debitter olives other than the lye-treatment can reduce the water usage by at least 30 percent, mainly due to the lack of washing. In the benchtop experiment, 120 milliliters (mL) of water was used in the enzymatic processing, which was a two-step method involving enzyme treatment and a subsequent rinse. In the lye processing, which project staff developed based on industry practices, four steps were necessary including a lye treatment, rinse, ferrous gluconate/neutralization treatment and a final rinse, totaling 260 mL of water. By eliminating the need for a neutralization step, thus reducing water usage by 54 percent with the enzymatic process, was feasible with the enzymatic processing method.

3.) Goal: Reduce volume and toxicity of olive processing wastewater. Performance measure: Reports of the amount of wastewater discharged annually, in gallons, from processors and quantification of the wastewater's physical and chemical properties. Benchmark: Amount and quality of wastewater discharged by state olive processors in 2012-2013. Target: Reduce wastewater discharge by 60 percent, reduce the amount of toxic chemicals in wastewater and eliminate pollution load of lye by 100 percent, from 2012-2013 levels.

Outcome: The project staff were able to show that there are 60 percent chemical oxygen demand (COD) and biochemical oxygen demand (BOD) in the wastewater that was generated from the enzyme treatment comparing to the lye treatment. The project staff were able to completely eliminate the pollution of lye by replacing the whole process with enzymes. Wastewater toxicity was decreased, as the pH of the enzyme treatment and rinse steps were 6.0 and 6.1, respectively, compared with 12.6 and 9.0 in the lye process (Table 1). This also demonstrated a reduction in toxicity from industry wastewater, which had a lye pH of 13.2 and an average rinse pH of 9.2.

There was no significant difference in total solids between treatments. The higher COD in the enzyme treatment compared with benchtop lye treatment was likely caused by the presence of phenolics in the wastewater, which could represent a valuable waste stream. However, even the enzyme wastewater COD values were below those of the industry's current wastewater.

In the benchtop experiment, ferrous gluconate was added during enzyme treatment to reduce the number of processing steps. By eliminating the ferrous gluconate and subsequent rinse steps, the enzymatic process generated 120 mL wastewater, compared with 260 mL in the lye processing. The results suggest that a reduction of 54 percent or higher in wastewater volume was possible. Increased turbidity in the enzyme wastewater was caused by the insolubility of ferrous gluconate in the enzyme buffer, which would be eliminated if water was used instead during processing.

4.) Goal: Increase nutritional content of California-style table olives. Performance measure: Laboratory measurement of phenolic compounds from the University of California, Davis Olive Center. Benchmark: Phenolic content of fresh and unprocessed Manzanillo olives. Target: Retain 50 percent of phenolic content after enzyme debittering process.

Outcome: The project staff were able to show that more phenolics were retained using the enzyme treatment compared to the lye treatment. Sufficient degradation of oleuropein was not achieved with the enzymatic process; therefore, it was difficult to assess whether the finished product would retain 50 percent of the phenolic content as some loss due to diffusion into wastewater did occur. However, it was clear from the trials that removing lye from processing resulted in significantly higher retention of phenolic compounds (Table 2). The current California-style product was analyzed in the lab and only small amounts of hydroxytyrosol and tyrosol remained after the full processing method (51.3 ± 6.0 mg/kg and 7.8 ± 0.77 mg/kg, respectively).

The olive leaf extract experiment demonstrated that the enzyme specifically hydrolyzed oleuropein and had minimal effect on other classes of phenolics like flavonoids (ie: rutin) and phenolic acids (ie: caffeic acid). Hydroxytyrosol, which is noted for its health properties, showed a dramatic increase upon degradation of oleuropein. With further enzyme optimization, it is likely that enzymatically-debittered olives would have increased nutritional content compared with the current product.

Beneficiaries

California produces all of the United States commercial table olives. The project will benefit the specialty crop industry by associating California-style olives, one of the state's oldest specialty crops, with a modern image as a wholesome, nutritious product. The state economy will benefit by preserving and possibly increasing jobs in the California table olive sector. A 2011 study by the California Olive Committee found that California table olive growers generate nearly a half-billion dollars annually in economic output, with more than $135 million in labor income and nearly $14.7 million in indirect business taxes.

The number of specialty crop beneficiaries of this project is an estimated 7,000 jobs in table olive growing, processing, packing, and nonfarm sectors.

Lessons Learned

One major difficulty in this project was working around the seasonal olive-growing schedule. Olives were only available for three to four months out of the year. Finding a way to have samples available year round, whether by preserving olives or sourcing from another location, would have greatly improved productivity. The inherent variability of live, biological samples was another challenge and experiments had to be designed with sufficient replicates to accurately assess the significance of results.

The project staff had to wait until October to conduct the first large-scale trials. After realizing that the enzyme could not work in vivo, the opportunity for revising the experiment or re-engineering the enzyme was lost.

One lesson that project staff have learned is to make sure that the grant period matches with the harvest time so they can maximize number of experiments conducted during the harvest time.

Additional Information

Attachment 1: Draft Manuscript. Final Submission is in progress.
Attachment 2: Data tables.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
38	Accelerating Adoption of Innovation and Sustainable Best Management Practices	
Grant Recipient: California Sustainable Winegrowing Alliance	**Grant Agreement No.:** SCB14038	**Date Submitted:** December 2017
Recipient Contact: Allison Jordan	**Telephone:** (415) 356-7535	**Email:** ajordan@wineinstitute.org

Project Summary

California wine grape growers and wineries must respond to increased market pressure to improve environmental practices from retailers and consumers and ever-growing environmental regulations. To respond to these pressures, growers must evaluate and choose the most efficient and effective sustainable and environmental practices to implement in their operations. Although the importance of sustainable practices for maintaining competitiveness is well established, studies show that winegrowers would be more likely to choose sustainable practices if they had the resources to predict and track the economic impacts of adopting the practices. This project directly addressed the key barriers to sustainable practices adoption, economic concerns.

The purpose of the project was to increase adoption of sustainable winegrowing practices by grower participants in the California Sustainable Winegrowing Alliance's (CSWA) Sustainable Winegrowing Program (SWP) through development, implementation and dissemination of new Economic Cost/Return Assessment Tools (Economic Tools). The Economic Tools are used by winegrowers to evaluate costs, returns and environmental benefits of practices in order to assess which practices they want to implement. The project's additional educational resources and workshops further assisted winegrowers in adopting sustainable practices.

While the SWP has over 2,000 winegrowers utilizing the *California Code of Sustainable Winegrowing* self-assessment tool to assess their current use of sustainable practices, more economic information about the practices promoted in the Code, is needed for increased adoption. The project's timely new tools and resources helped growers and vintners better understand the true costs and returns of conservation practices that result in water and energy efficiency, better soil health, efficient use of nutrients, and other benefits. Sharing the tools and resources via workshops, webinars, websites and newsletters informed winegrowers and other specialty crop producers statewide. The project goal and purpose was to increase adoption of sustainability practices that will improve resource economic efficiency and conservation. The project built on CSWA's innovative SWP "continuous improvement" model, which includes self-assessment, benchmarking of practices, and targeted education workshops developed with the assistance of 2010 Specialty Crop Block Grant Program (SCBGP) Project 23: *Data-Driven Targeted Education to Speed Adoption of Sustainable Winegrowing Practices.* It focused on workshops targeting all wine regions in areas of sustainable practice improvements building upon tools and resources then available in the SWP online system, and a 2010 SCBGP Project 50: *Field Testing a Carbon Offset and Greenhouse Gas Emissions Model for California Wine Grape Growers to Drive Climate Protection and Innovation*. It focused on a carbon offset greenhouse emissions model integrated into the SWP online system.

These prior SCBGP projects helped grow SWP participation significantly and the projects' tools and resources are in use and maintained by CSWA through contributions from CSWA partner organizations Wine Institute and California Association of Winegrape Growers (funded by membership dues). This project built upon these prior projects with the integration of the Economic Tools into the SWP online assessment system, allowing growers to predict and track the economic costs and benefits and environmental impacts of implementing sustainable practices. The new Economic Tools and educational resources directly responded to SWP participants' requests for more economic information about practices and act as decision support tool allowing participants to prospectively look at different practices and how they could impact their operation and the environment. #

Project Approach

Work Plan Activity 1- Evaluate criteria for developing an Economic Tool for assessing costs, returns, and environmental benefits of conservation practices by hosting in-person meetings and webinars seeking input from the Economic Advisory Group:

CSWA held five webinar and three in-person meetings with the full Economic Advisory Group to seek input on the development of the various Economic Tools for assessing costs, returns, and environmental benefits of sustainable winegrowing conservation practices. The project staff also held 10 planning meetings and conference calls with the other project leads to review the project progress and plan for the Advisory Group meetings.

CSWA and the Advisory Group members conducted a literature review of existing tools, calculators and methodologies for valuing sustainable practices which were each discussed and evaluated during the meetings. As a result of these meetings, the project staff developed a multi-pronged approach that included four phases for determining the costs and returns of sustainable practices that utilizes current industry knowledge, available calculators and methodologies for quantifying the costs/benefits of sustainable practices and draws from the broad expertise of the Economic Advisory Group.

Phase One of the approach utilized a project partner's methodology as a means to select the top 10 practices that have the biggest return on investment with regards to the triple bottom line (i.e., healthier environment, stronger communities and workforce and vibrant businesses) out of the 200 and more, best management practices included in the *California Code of Sustainable Winegrowing* workbook. Through this process the Advisory Group identified the top 62 sustainable practices included in the Code that have the biggest return on investment with regards to the triple bottom line (i.e., healthier environment, stronger communities and workforce and vibrant businesses). Phase Two of the approach was led by another partner and included a quantitative analysis of the top 10 practices and the development of the Economic Tools and integration into the SWP online system. Phase Three utilized a quantitative cost study methodology to analyze and report costs of sustainable practices. Phase Four of the approach utilized project partner's "Business Value" methodology to analyze the return on investment of sustainable vineyard and/or winery certification.

Work Plan Activity 2 - Develop and Implement Economic Tools customized for California winegrowers and replicable for other specialty crop industries:

CSWA worked with project partners and the Economic Advisory Group to develop and finalize the suite of Economic Tools that enable growers to evaluate the costs and benefits of specific sustainable practice

adoption. The final tools are based on the list of the sustainable practices that have the biggest return on investment with regards to the triple bottom line. CSWA also addressed grower feedback received during the first workshop in 2016 for all of the tools to follow a similar format to make them easier to use and allow growers to get familiar with the tools to be able to easily switch between using multiple tools. The project staff hired a consultant to develop formatting guidelines for the tools, integrate CSWA and project partner feedback, and to reformat all of the tools following the agreed upon guidelines to have a consistent look and feel.

The final Economic Tools are listed below. The Advisory Group provided detailed feedback on all of the tools during multiple meetings, and experts, growers, and CSWA's Sustainable Winegrowing Joint Committee, a 50-member group of growers and vintners, also reviewed the draft tools and provided suggestions for revisions and improvements. The final Economic Tools are integrated into the SWP online system and available for download on the CSWA website at: http://www.sustainablewinegrowing.org/economic-tools.php

- Vineyard Sustainable Water Management Tool
- Trunk Disease Management Tool
- Winery Water Efficiency and Hot Spots Tool
- Winery Water Budgeting Tool
- Solid Waste Audit Tool
- Certification Cost Benefit Evaluation Tool
- Sprayer Decision Tool – Air Blast vs. Electrostatic Sprayers
- Dust Mitigation Methods Comparison Tool

Work Plan Activity 3- Integrate Economic Tool into existing online SWP practices and metrics system to provide a user-friendly decision tool to determine which conservation/sustainable practices are feasible and desirable from an economic and environmental perspective:

CSWA worked with a project partner to integrate the Economic Tools and other project findings into the SWP online assessment system. A new Economic Tool icon was created and was added to 53 assessment criteria that were identified as specifically relevant for one of the Economic Tools. As a grower goes through the sustainability self-assessment, the Economic Tool icon (and associated hover text and link to the tools) indicates to growers which sustainable practices have associated Economic Tools that can be used to evaluate the costs and benefits of adoption. In addition, a new reporting functionality was added to the SWP online system which enables winegrowers to run a report that includes their current self-assessment scores for the top 62 sustainable practices that have the biggest return on investment with regards to the triple bottom line (i.e., healthier environment, stronger communities and workforce and vibrant businesses). The new report, titled "High Impact Practices Report," helped growers and vintners better understand the practices that have the biggest positive impact on their triple bottom line and provided clear guidance for improving steps so they can focus their continuous improvement efforts on those practices. A "High Impact Practices" icon was also created and was added to the 62 criteria (49 vineyard criteria and 27 winery criteria, with some relevant to both vineyard and winery operations) to highlight practices with high impact for winegrowers. The icon also links directly to the new report webpage. In addition, the online metrics system was also updated to make it a more user-friendly tool for growers and includes additional information about the Economic Tools and the new High Impact Practices report. A new tour feature was also added to the SWP online system that allows

growers to "Take a Tour" of the online system so they can learn how to easily navigate the system and find and run the new "High Impact Practices" report.

Work Plan Activity 4- Develop and disseminate other resources, including educational hand-outs to address the following: a) case studies showing costs/returns and environmental benefits for at least ten winery/ vineyard sustainable practices b) opportunities for sustainability programs to address regulatory challenges, as well as cost-share and incentive programs (e.g. water quality Ag Waivers, ecosystems services payments) and c) prospects for sustainability programs to address market needs:

CSWA and project partners identified sustainable winegrowing topics to be covered by educational materials that are better suited to educational handouts rather than an Economic Tool. The following educational resources were developed with assistance from the project partners and have been shared with winegrowers during educational workshops, shared via electronic newsletters with over 6,200 recipients including all SWP participants and others in the wine industry, and are all available on the CSWA website at http://www.sustainablewinegrowing.org/economic-tools.php.

- Cost and Benefits of Sustainable Winegrowing: A four-page informational handout promoting use of the eight new Economic Tools, some of which cover multiple practices, and other project resources.
- Top 62 High Impact Practices: This document identifies which sustainability practices have the highest impact on the triple bottom line (i.e., vibrant businesses, healthier environment, and stronger communities and workforce) and guides winegrowers to the new report functionality in the SWP online system.
- New CSWA Research Shows Sustainability, a Growing Factor in Wine Trade Purchasing: A summary of the research study completed by project partner Wine Opinions. The online research sought to understand the wine trade (retailers, restaurateurs, distributors, etc.) opinions on sustainable winegrowing and certification and to determine the market needs for sustainably grown and produced wine. The results of the study were included in several outreach activities to help growers and vintners better understand the marketplace trends and opportunities for sustainable winegrowing including an educational session at the Unified Wine and Grape Symposium (attended by an estimated 200 winegrowers), and a press conference held during the Unified Symposium (attended by an estimated 50 winegrowers). The results of the study were included in a press release that was sent to over 6,200 winegrowers and interested stakeholders and is posted online on the CSWA website at: http://www.sustainablewinegrowing.org/articletype/4/Press_Releases.html#122
- How to Conduct a DIY Vineyard Energy Audit: This educational handout allows the individual winegrower to assess energy-consuming processes and equipment in order to discover potential changes in behavior or technology that can reduce energy consumption on their vineyard.
- The Value of Certification: An educational handout that details the new Economic Tool for evaluating the costs and benefits of sustainable certification provides a summary of the trade research and includes other value propositions to assist winegrowers in evaluating if certification is right for their operation.
- Economic Thresholds for Pest Management: An excel-based scouting template and a handout on the importance of using economic thresholds and monitoring to guide pest management decisions.
- Prevention and Treatment of Trunk Disease: A handout that details the importance of early implementation of trunk disease prevention practices.

- Weed Scouting: An excel-based template and handout to help growers assess and identify their weeds and assist in building a weed management plan.

In addition, project partners completed a cost and return report for a sustainable vineyard in Sonoma County. They also gave a presentation on the report at one of the educational workshops. CSWA also worked on opportunities for the Code workbook to help address upcoming water quality ag waivers and general permits in Regional Water Quality Control Board Regions 1, 2 and 3. In addition, to assist in addressing regulatory challenges, CSWA developed a new environmental compliance criterion and educational materials for the Code self-assessment workbook (included in the Appendix). As mentioned above, additional resources were also integrated into the SWP online system including the Economic Tool and High Impact Practices icons viewable through the self-assessment, the new High Impact Practices report, updated online metrics for better usability, and the "Take a Tour" feature.

Work Plan Activity 5 - Analyze assessment scores of SWP and the Economic Tool participation and implementation of sustainable practices:

CSWA worked with a project partner to complete a data extract of the self-assessment scores from the SWP online system in December 2015 and June 2017. As described in the project proposal, CSWA wanted to grow implementation of its SWP and improve self-assessment scores overall.

The participation target was to achieve 80% of total California winegrape acres, or 436,000 acres participating in the SWP, to help growers address increasing regulatory/market pressures by implementing best management practices to improve farm viability, the agriculture economy and the environment. During the course of this project, CSWA added 40,000 acres and 506 new winegrower participants, bringing the total farmed acres by organizations participating in the SWP online system to 476,652 acres, approximately 77.5% of the total 615,000 statewide acres. In addition, 211,219,340 cases of California wine were made by participating wineries in the online system, or 78.5% of the 269 million statewide acres.

Adoption of the over 200 sustainability practices included in the Code workbook is scored on a 1-4 scale with 1 meeting existing regulations or minimal sustainability practices and 4 being most sustainable. The target of the project was to improve SWP assessment scores to 1) 10%; 2) 25%; 3) 35%; 4) 30%. (The benchmark at the time of proposal submission for SWP assessment scores were 1) 17%; 2) 28%; 3) 29%; 4) 26%.)

A data extract was completed one year into the project (December of 2015) to help measure the progress towards achieving the goals for improved SWP assessment scores. In December 2015, the SWP assessment scores were 1) 9%; 2) 28%; 3) 32%; 4) 25%, with 6% Non-Applicable. At the close of the project in June 2017, another data extract was completed which showed SWP assessment scores of 1) 6%; 2) 30%; 3) 33%; 4) 26% with 5% Non-applicable. The target was exceeded for categories 1 and 2, and was slightly under for categories 3 and 4; yet the assessment scores demonstrated that progress has been made to the improvement of sustainability practices along the sustainability continuum (moving towards increasingly more sustainable practices).

In addition to utilizing the assessment scores for the purposes of this project, CSWA utilized the data to publish the 2015 California Wine Community Sustainability Report: (http://www.sustainablewinegrowing.org/docs/2015_CSWA_Sustainability_Report.pdf). In-depth analysis of

assessment data for each of the 200+ best management practices was also posted as a report Appendix on the CSWA website: (http://www.sustainablewinegrowing.org/docs/2015_Report_Appendix.pdf).

Work Plan Activity 7 - Produce at least six videos and written case studies to CSWA YouTube Channel and on CSWA website via Vimeo (targeting at least 2,000 growers and vintners) that demonstrate costs savings, reduced risks, employee retention, etc. to educate growers and vintners about key conservation and sustainability practices: The following videos and case studies were developed and shared electronically with over 6,200 winegrowers and interested stakeholders.

Videos:

- What is Sustainable Winegrowing and Certification? An overview of the key elements of sustainable winegrowing and Certified California Sustainable Winegrowing.
- The Value of Certification: Francis Ford Coppola Winery discusses the value, commitment and benefits of becoming Certified California Sustainable Winegrowing.
- The Importance of Distribution Uniformity: Why conducting regular Distribution Uniformity (DU) tests is an important practice for winegrape quality.
- How to Conduct a Distribution Uniformity Test**:** How a Distribution Uniformity (DU) Test is completed in the field.
- Seven (7) "How To" Demonstration Videos for each of the Economic Tools hosted by the lead tool developer that clearly shows growers how to navigate, use and interpret the results of each tool.

Case-Studies:

- Coppola Sees Value in Certification: This case study featured an interview with Francis Ford Coppola Winery discussing why CERTIFIED SUSTAINABLE is important to them.
- Creek Restoration Pays Big Benefits: This case study featured an interview with Beth Novak, President of Spottswoode Winery discussing the benefits of restoring a year-round creek on their property.
- Survey Reveals Wine Trade Views on Sustainability: This case study discussed the key take-away from the wine trade survey on sustainability and ways to communicate to trade.
- Winery Innovates with Solar Power Microgrid: This case study explained how a solar panel microgrid helped with the energy efficiency of Alpha Omega.
- New Ways to Save Water: This case study examined the evolution of good water management decisions at Ridge Vineyards.
- Winery Practices Mitigate Risk: This case study explored the connection between risk management and sustainable practices at Rodney Strong Vineyards.

Work Plan Activity 8 - Plan, facilitate and develop educational content for at least six educational workshops for 200 growers, in addition to presentations at industry events, articles in trade publications and dailies in winegrowing regions (e.g. Wine Business Monthly, Practical Winery & Vineyard, Wines & Vines), and other forms of outreach to disseminate project findings of sustainability scoring to 2,000+ winegrowers and other specialty crop producers in the US:

CSWA worked with project partners to plan, organize, conduct outreach, and facilitate seven educational workshops for growers to feature the Economic Tools and associated educational resources. Workshops were

held via webinar (7/20/16 and 5/31/17), in Sonoma (4/25/17), Fresno (4/25/17), Napa (6/15/17), UC Davis (6/16/17) and Lodi (6/27/17). In total, 293 growers attended the educational workshops, surpassing the target number of participants by 46.5%.

Work Plan Activity 9 - Conduct outreach to share project process and results with all collaborating organizations, vintners and growers, National Grape & Wine Initiative (NGWI) and other specialty crop industry associations:

Project results were shared at CSWA, Wine Institute, California Association of Winegrape Growers and National Grape & Wine Initiative Board of Directors meetings and via a news release to attract trade media coverage. Key project results were shared with nearly 1,000 Wine Institute members and 57 California regional winegrowing associations via e-newsletters. As mentioned before, project results including the Economic Tools and were shared with over 6,200 wine industry stakeholders via e-newsletters. Information about the Economic Tools was also featured in an ISEAL Alliance website news item and included in a Sustainability Management Association e-newsletter reaching over 2,300 stakeholders.

The project funds were only used to enhance the competitiveness of specialty crops.

Project partners played a key role in the project's success. Project partners and the Economic Advisory Group guided the development of the Economic Tools, integrated project findings into the SWP online system, helped to develop educational materials, videos and resources, and helped plan and organize the educational workshops. Project partners all provided invaluable input into the Economic Tools and related educational materials throughout the project. All of the tool leads presented at various workshops and recorded the "How to Use" the tool demo videos.

Goals and Outcomes Achieved

As detailed in the above Project Approach section, all of the Performance Indicators were either met or exceeded for the project, specifically:

- Activity 1 Performance Indicator – Goal: Three in-person meetings and three webinars held with the economic Advisory Group. Outcome: CSWA held five webinars and three in-person meetings with the full Economic Advisory Group. (Outcome exceeded goal).
- Activity 2 Performance Indicator - Goal: Economic Tool(s) developed. Outcome: Eight Economic Tools were developed with most tools integrating many sustainable practices. See https://www.sustainablewinegrowing.org/economic-tools.php (Outcome met goal).
- Activity 3 Performance Indicator - Goal: Economic Tool integrated into online SWP practices and metrics system. Number of participant hits on Economic Tool in the online system. Outcome: Economic Tools added to SWP online system with new Icons and reporting features, 491 unique visitors to the new Economic Tools webpage visiting 700 times. (Outcome met goal.)
- Activity 4 Performance Indicator - Goal: Completion of at least three user-friendly educational handouts on best practices, regulatory and market opportunities, documents posted on website, and number of participant hits handouts. 2,000 copies of handouts printed and disseminated at workshops and industry events. Outcome: Eight educational handouts developed and disseminated electronically to over 6,200 winegrowers and industry stakeholders. 2,000 copies printed of two handouts which were disseminated at workshops and events. (Outcome exceeded goal).

- Activity 5 Performance Indicator - Goal: Run analytical reports showing assessment and participation rates through SWP system. Outcome: Reports run and analyzed showing increase in participation rates. (Outcome met goal).
- Activity 7 Performance Indicator - Goal: Six videos produced and posted and case studies written and posted. Outcome: Number of views tracked via website google analytics and YouTube view statistics, 11 videos produced and posted and six case studies posted and disseminated electronically. (Outcome exceeded goal).
- Activity 8 Performance Indicator - Goal: Six educational workshops held for 200 growers. Outcome: Press releases issued to at least five trade publications and dailies in winegrowing regions and outreach conducted via CSWA, Wine Institute and CAWG member communications and meetings, reaching over 2,000 winegrowers seven workshops held with 293 grower participants. Press release shared with extensive media list and project outreach shared with over 6,200 winegrowers and industry stakeholders. (Outcome exceeded goal).
- Activity 9 Performance Indicator - Goal: Information shared with more than 2,000 specialty crop producers and at least ten specialty crop associations. Outcome: Electronic newsletters reached 6,200 winegrowers and industry stakeholders. Project results were also shared at CSWA booths at the Unified Wine and Grape Symposium in Sacramento, the Sustainable Ag Expo in San Luis Obispo, the WIN Ag Expo in Sonoma and other viticultural fairs, as well as through presentations at various regional meetings, viticulture fair, the Wine Institute board of directors meeting and industry events. In addition, information was shared with more than a dozen other California specialty crop associations through the National Grape & Wine Initiative and Stewardship Index for Specialty Crops. (Outcome exceeded goal).

The overall project goal and purpose was to increase adoption of sustainability practices that will improve resource economic efficiency and conservation, as measured by improvement in self-assessment data analyzed at the start of the project and again in June 2017. Adoption of sustainability practices is assessed and scored on a 1-4 scale, with 4 being most sustainable. Goal: The target was to improve SWP assessment scores to (1) 10%, (2) 25%, (3) 35%, (4) 30% and add 196,000 new acres to the program by March 2017 (achieving 80% of total California winegrape acres, or 436,000 acres) to help growers address increasing regulatory/market pressures by implementing BMPs to improve farm viability, the ag economy and the environment. The benchmarks at the start of the program were SWP assessment scores of (1) 17%, (2) 28%, (3) 29%, (4) 26% and 240,000 participating acres. Outcome: By the end of the project, the SWP assessment scores were: (1) 6%, (2) 28%, (3) 35%, (4) 31%. The assessment data showed a slight increase in self-assessment scores, indicating an improvement (i.e., exceeding the target for reducing the percentage of growers scoring the lowest category score (1) from 17% to 6%, and increasing the highest category score (4) from 26 % to 35%).

In addition, there were 506 new winegrower users in the SWP online system and an additional 40,000 acres assessed (with a total of 151,708 participating acres using the 3rd Edition Code self-assessment). Combined with the assessed acres using the earlier additions of the Code self-assessment, the total assessed acres at the end of the project was 280,000. The participating winegrowers who completed assessments farm a total of 447,665 winegrape acres. (While CSWA set the target for self-assessed acres, BMP information can be applied to all acreage farmed by the participating winegrowers as knowledge about BMPs can be transferred to the properties that did not undergo an actual assessment). Furthermore, as mentioned in the Performance Indicators above, CSWA reached a vast majority of the California wine industry via workshops, educational

resources, videos, and industry outreach. CSWA also tracks website hits to measure interest in the SWP, certification programs and educational materials. During the project period, there were 47,912 unique visitors (62% returning visitors and 38% new visitors) to the website visiting 76,898 times. The project staff also tracked 3,727 unique visitors to the CSWA resources page, 967 unique visitors to the video page visiting 1,265 times, and 491 unique visitors to the new Economic Tools webpage (added in March 2017) visiting 700 times.

CSWA will continue to encourage self-assessment and use of the Economic Tools and associated resources long after the project is completed. The project staff will continue to track assessment scores and looks forward to demonstrating continued improvement in adoption of sustainable practices in future statewide sustainability reports. The Economic Tools and associated resources will also be featured in future targeted education workshops co-hosted with regional winegrowing associations. As funding permits, CSWA will consider adding new Economic Tools and potentially turning some of the excel-based tools into web-based tools.

As noted above, all of the performance indicators included in the project's work plan activities #1-9 were completed or exceeded. While some of the timelines for the activities took longer than originally anticipated due to the complexity of the project and multiple project collaborators, they were all completed in a timely manner within the project timeframe.

Beneficiaries

The project has the opportunity to benefit the 4,600 California wine grape growers representing 615,000 acres statewide, plus 3,800 wineries and 330,000 full time equivalent wine industry employees, and the project outcomes were communicated a vast majority of the industry through partner websites, newsletters, presentations and other channels. Direct beneficiaries are the 293 participants in the seven workshops. All project beneficiaries have access to the SWP online system, the Economic Tools and associated educational materials. Growers and wineries will have unlimited access to the project results to inform their decision making about sustainable practices for adoption. Future progress will be measured and publicly reported using the SWP online system and statewide sustainability reports.

CSWA had 293 winegrower beneficiaries attend the educational workshops, 506 winegrowers requested SWP online system access during the course of the project to complete new self-assessments, and 491 unique users accessed the Economic Tools webpage. Over 6,200 winegrowers, including all SWP winegrower participants, and industry stakeholders were reached many times throughout the project with electronic newsletters, educational resources and communications.

Lessons Learned

During the course of the project, CSWA staff had the opportunity to collaborate with and learn from other experts to effectively leverage expertise and resources. While careful consideration was given to project advisors and contractors in the proposal and project planning phase, CSWA continued to learn about additional work and experts that could benefit the project. For instance, during the initial stages of the project, CSWA learned of similar work taking place at the California State University, Sacramento and was able to add the researcher to the project and develop the online trunk disease Economic Tool in a much more cost-effective and efficient manner. While the collaborative nature of the project was its strength, having so many project partners and deliverables being managed by different entities made the project more complex and

meeting timelines more difficult. Even so, CSWA was able to manage the project successfully and complete it on time and within budget. In addition, during the course of the project it became clear that many sustainable practices, while beneficial, may be difficult to quantify in terms of costs and benefits and in particular environmental benefits (or ecosystems benefits).

CSWA benefited greatly from working with a dedicated and experienced group of project partners. The few gaps in expertise were able to be filled during the course of the project by adding several new project partners. As a result, the outcome measures were all achieved or exceeded during the course of the project.

Additional Information

Please visit the CSWA website for access to the Economic Tools and educational resources: http://www.sustainablewinegrowing.org/economic-tools.php

See the attached Appendix which includes sample workshop agendas, sample electronic newsletters and the new environmental compliance criterion and educational materials developed for the Code self-assessment workbook.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 39	**Project Title:** Characterizing and Breeding Drought Tolerance in Lettuce	
Grant Recipient: United States Department of Agriculture, Agricultural Research Service	**Grant Agreement No.:** SCB14039	**Date Submitted:** December 2017
Recipient Contact: Beiquan Mou	**Telephone:** (831) 755-2893	**Email:** Beiquan.mou@ars.usda.gov

Project Summary

The initial purpose of the project was to study the physiological and molecular traits in lettuce that allow some cultivars to be slightly more tolerant of drought than others. For six years, supplies of irrigation water for leafy vegetable production in California were constrained due to the historic drought. Reduced water availability has been a statewide problem affecting all major lettuce producing regions, but reductions in available irrigation water eliminated lettuce production in the Central Valley. Although the drought has officially been declared "over," growers and climate researchers in California expect increasingly limited water resources in the future. As a leafy green crop consisting of 95-97% water that depends on high soil water potential to maintain cell turgor for palatability, lettuce production has been and could continue to face costly yield losses as water supplies diminish.

Lettuce (*Lactuca sativa* L.) is the second largest vegetable crop produced in the United States with 261,000 acres of head, leaf, and cos (romaine) lettuce harvested in 2014. Slightly more than 75% of the lettuce grown in the United States last year was grown in California with a value to growers of over $2 billion (United States Department of Agriculture, National Agricultural Statistics Service [USDA, NASS], 2015). Water use in lettuce varies with planting time, proximity to the coast, and irrigation method. Irrigation requirements range from 1 to 2.5 acre-feet of water per acre in the Central Coast region to 3.5 acre-feet per acre in southern desert regions at an estimate of $270 per acre-foot in Monterey County. These water requirements are becoming more difficult for growers to meet during droughts and when water supplies are limited. Because lettuce consists of 95-97% water, and depends on large amounts of irrigation water to maintain cell turgor for palatability, lettuce production could face costly yield losses as water supplies continue to diminish. Improving lettuce tolerance to low water conditions is thus becoming a priority to reduce lost revenue due to limited water supplies.

This project built upon results from a previously funded 2011 Specialty Crop Block Grant Program (SCBGP), Project 19: *Drought-tolerant Lettuce and Spinach Varieties for Adaptation to Climate Change*. In 2011 SCBGP Project 19, nearly 2,000 varieties from the USDA lettuce germplasm collection were screened in the greenhouse under water stressed conditions for preliminary drought-tolerance. Approximately 200 cultivars were selected for field trials where they were grown under 150% evapotranspiration (ET) rates (controls), and 50% ET rates (drought). Putative drought-tolerance was determined by statistically insignificant differences in fresh weight among treatments in two of three field trials. Three of these putative-drought tolerant cultivars (Australian, Slobolt, and Western Green) were used in this project to describe physiological and molecular traits of drought-tolerance, and compared to cultivars with similar morphologies but with very significant differences in fresh weight (Green Salad Bowl, Black Seeded Simpson, and Xena).

Project Approach

In 2011 SCBGP Project 19, 200 candidate lines were selected for field trial testing of drought tolerance. Three of the most drought-tolerant cultivars and three similar drought-sensitive cultivars identified from the field trials were chosen for further testing in this project, in order to understand the physiological and molecular mechanisms of drought tolerance. Drought-tolerant cultivars included Australian, Slobolt, Western Green, and the wild progenitor of cultivated lettuce, *Lactuca serriola*. Most lettuce is drought-sensitive, and most of the cultivars tested did not meet the criteria for drought-tolerance (minimal reductions in fresh weight across multiple field trials). The drought-sensitive cultivars chosen included cultivars with similar leaf morphologies as the drought-tolerant cultivars: Green Salad Bowl has a similar deeply pinnate shape as Australian, Black-Seeded Simpson has a similar pale, wide leaf as Slobolt, and Xena has a similar think, fleshy green leaf as Western Green. The cultivar Hacienda was used for some trials in place of Green Salad Bowl, though its leaf morphology is more similar to Slobolt and Black-Seeded Simpson. Physiological traits were examined in detail first, in order to make hypotheses about candidate genes to understand the molecular traits involved in drought tolerance. Physiological traits studied included carbon assimilation, stomatal conductance, water use efficiency (WUE, calculated as the ratio of carbon assimilation to transpiration), and chlorophyll fluorescence. In all cultivars, WUE was negatively correlated to soil water content, as efficiency increases under drought. *Lactuca serriola* consistently had higher carbon assimilation and stomatal conductance than *L. sativa* cultivars. Average WUE was significantly higher ($F_{(1,5)} = 6.6$, $P = 0.01$) in drought-tolerant cultivars than in drought-sensitive cultivars, even when *L. serriola* was removed from the data set, due to higher carbon assimilation under drought. Generally, carbon assimilation was higher in the putatively drought-tolerant cultivars Australia and Slobolt under control irrigation. The relationship between carbon assimilation and soil moisture content was not strictly linear in most cultivars. Carbon assimilation is dependent on CO_2 concentration, light, and biochemical processes which all combine to limit carbon assimilation in different ways, such that under the experimental conditions, carbon assimilation reached maximum levels at relatively low soil moisture contents (~ 0.1 VWC m^3/m^3). This suggests that differences in WUE, carbon assimilation, and therefore biomass production among putatively drought-tolerant and drought-sensitive cultivars may be the result of other physiological factors aside from differing access to water. Total nitrogen content was higher in putatively drought-tolerant cultivars ($F_{(1,1)}=7.0$, $P = 0.01$) than in drought-sensitive cultivars, though there was no linear relationship between carbon assimilation and Total N content. Emerging data from the research group at Pennsylvania State University suggests that deep taproots expand a plant's access to water as well as nitrogen. Quantitative trait loci mapping by the University of California (UC), Davis researchers and others have found that deep taproots in lettuce co-localize in the genome with drought-tolerance. All these data suggest that further work to tease apart the correlationary relationships between drought tolerance, carbon assimilation, and nitrogen acquisition are necessary in lettuce. Stomatal conductance also appears to be important to putatively drought tolerant cultivars. The relationship between stomatal conductance and soil moisture content is linear in putatively drought tolerant cultivars, with steeper slopes suggesting tighter regulatory control in *L. serriola* and Slobolt.

Samples were also submitted for RNA-seq from these cultivars for gene expression patterns. The original project called for qPCR, however, qPCR is a hypothesis-dependent method. It requires specific hypotheses regarding specific genes that may or may not promote drought tolerance, however initial physiological studies of photosynthesis traits and chlorophyll fluorescence traits did not suggest many very likely candidates. RNA-seq samples gene expression in a hypothesis-independent manner, that is, it samples all the genes being expressed in the plant tissue at a particular time, and does not require candidate genes for sampling that may or may not be related to drought tolerance. This was a better approach to identifying molecular traits related to

drought tolerance than qPCR. The transcriptome was sequenced of the above-mentioned putatively drought tolerant cultivars (Australian, Slobolt, Western Green), *L. serriola*, and the above-mentioned drought sensitive cultivars (Green Salad Bowl, Black Seeded Simpson, and Xena) from control and drought treated plants. The dataset consists of 42 libraries from these seven cultivars, two treatments, with three replicates of each. In addition, each biological replicate contains pooled tissue from three plants. The resulting dataset contains 2,091,311,258 raw sequence reads. The average number of clean sequence reads from each of these 47 libraries is 47,480,934. This experimental design allows for sufficient replication within comparisons of gene expression among cultivars in control and drought treatments, as well as among each putatively drought-tolerant and drought-sensitive cultivar under drought treatments. The data analysis is preliminary, and data analysis will be ongoing until publication, however the preliminary results are interesting, and should be prefaced with the statement that soil moisture content among treatments at the time of tissue collection was very significantly different ($F_{(1,174)}$=314.6, P< 2^{e-16}), therefore drought treatments were certainly imposed. The fewest number of differentially expressed genes are found in library comparisons within lettuce cultivars and among treatments. For example, there are no genes that are differentially expressed in Western Green samples under control and drought treatments, suggesting that Western Green does little to change gene expression under drought. This may result in similar growth patterns under drought and control (reminder: the criteria for selection of putatively drought-tolerant cultivars was similar fresh weights under control and reduced irrigation). It can be hypothesized that for the plant, the "strategy" of doing nothing to change gene expression under drought may lead to premature death under drought, however it appears to lead to similar biomass production under reduced irrigation (Eriksen et al. 2016), and leads to only a marginally significant difference in carbon assimilation under control and drought treatments ($F_{(1,71)}$=4.23, P = 0.04). For growers, it may mean that Western Green can be grown under reduced irrigation at minimal cost if harvested relatively early (though statistically insignificant differences in fresh weight may not necessarily mean statistically insignificant differences in value of heads). For the other putatively drought-tolerant cultivars such as Slobolt, there are three genes that are differentially expressed under control and drought treatments: two of these genes have no identity match in the database (i.e. no information is had on which to base a hypothesis about the function of these genes), and the third is a relatively unknown gene with a copper-binding motif. None of these genes have more than 2-fold difference in expression levels among treatments. This remarkably small number of differentially expressed genes, the relatively small difference in expression, and their unknown function, suggests that Slobolt adopts a similar "strategy" to cope with drought as Western Green: it does not drastically change gene expression patterns. For Australian, there are 41 genes that are differentially expressed among control and drought treatments, and most are down-regulated in drought treatments, which could simply be the result of senescence. Of the drought-sensitive cultivars, Xena and Black-Seeded Simpson had 3 and 350 genes, respectively, that were differentially expressed, most of which were down-regulated under drought, possibly indicating senescence. Green Salad bowl had 15 genes that were differentially expressed, most of which were up-regulated under drought, though at less than 3-fold differences in expression. Preliminary analysis of the transcriptome data suggests that cultivated lettuce, particularly cultivars with minimal differences in biomass under reduced irrigation (i.e. "drought tolerant" cultivars), appears to have relatively few differences in gene expression under control and drought treatments. Drought-sensitive cultivars tend to have more genes significantly down-regulated which might indicate senescence, however more work is necessary to confirm these patterns in drought-sensitive cultivars and to understand gene expression patterns in Green Salad Bowl. It might be hypothesized that cultivated lettuce has lost an ability to adapt to drought by changing gene expression patterns for prolonged survival during the cultivation (irrigation) process. Adaptation or acclimation to drought may involve more metabolomic and proteomic changes by genes that are transcribed similarly under control and drought treatments, however, and

metabolomics nor proteomic changes were not tested in this project. As stated above, this "strategy" may not benefit a plant during long-term drought, however it may benefit growers as it results in fewer differences in fresh weight under reduced irrigation if the crop is harvested before senescence. Drought-tolerance in cultivated lettuce may be a factor of high carbon assimilation and growth under any and all conditions, and selection for additional drought-tolerant cultivars may simply involve screening for high carbon assimilation under control conditions. In contrast to cultivated lettuce, wild and weedy *Lactuca serriola* is more transcriptomically active and has 1,362 genes that are differentially expressed under drought compared to control conditions. Two of the most significantly differentially expressed genes are related to the plant stress hormone ABA. This hormone is known to be responsible for stomatal closure in plants, which decreases transpiration and water loss. The list of differentially expressed genes contains a significant number of genes involved in oxidation-reduction pathways, that is, genes that are involved in dealing with stress in the plant due to free radical production. As a wild plant not adapted to regular irrigation, *L. serriola* appears to respond transcriptomically to drought by up-regulating stress-response genes like ABA (in order to speed closure of stomata), and stress response genes involved in free radical protection. Cultivated lettuce does not appear to respond to drought in this way.

Another approach took to understanding drought response in lettuce involved a daily comparison of photosynthetic traits of drought-sensitive *L. sativa* c.v. Salinas and drought-tolerant *L. serriola*. In these experiments, plants were grown in gallon pots in the greenhouse, and water was completely withheld until carbon assimilation ceased. The benefit of using pots in this experiment is that it normalized differences in tap root structure and root depth. Physiological traits such as carbon assimilation, total relative water content, stomatal conductance, and chlorophyll fluorescence were measured daily. These studies revealed that stomatal conductance drops earlier in drought-treated *L. serriola* than in *L. sativa*, which allowed *L. serriola* to maintain relative water content of the leaf longer than *L. sativa*. A combination of shallow roots and looser control over stomatal conductance and transpiration in *L. sativa*, as well as a relative lack of transcriptomic response, may make it more susceptible to drought than its wild, weedy progenitor.

The research team also worked in collaboration with researchers at UC Davis to understand drought response in lettuce, more specifically to tease apart correlations between WUE and nitrogen use efficiency (NUE) in c.v. Salinas. Collaborators at UC Davis conducted field trials during which lettuce (c.v. Salinas) was treated with high water and high nitrogen, high water and low nitrogen, low water and high nitrogen, and low water and low nitrogen. Differential expression analysis and GO (Gene Ontology) Enrichment analysis of these data suggest that stress response pathways such as the protein ubiquitination and oxidative response pathways are up-regulated in plants exposed to all low nitrogen treatments. Genes annotated as coding for the nuclear-encoded small-subunit of the protein rubisco, which is responsible for the first step of carbon fixation were up-regulated in plants exposed to high nitrogen treatments, which the research team hypothesized leads to higher carbon assimilation and less physiological stress during drought treatments. Rubisco has been identified as one of the targets for genetic engineering in plants for increased drought tolerance. Three greenhouse trials were conducted to test this hypothesis by growing plants under similar treatments as the UC Davis field trials and measuring carbon assimilation, stomatal conductance, rubisco quantities, and NUE (measured as carbon assimilation per unit of nitrogen in the leaf tissue), and two trials produced potentially publishable data. Plants receiving both sufficient water and high nitrogen fertilizer had the highest rates of carbon assimilation (9.4 µmol CO_2 $m^{-2}sec^{-1}$ after 4 weeks of treatment). Low nitrogen appears to limit carbon assimilation similarly, regardless of associated water treatment (high water: 5.9 µmol CO_2 $m^{-2}sec^{-1}$; low water: 5.4 µmol CO_2 $m^{-2}sec^{-1}$). Contrary to the team's hypothesis, the plants receiving low water and high

nitrogen reduced carbon assimilation to a much lower level (2.5 µmol CO_2 $m^{-2}sec^{-1}$). This is likely due to differences in stomatal conductance, patterns of which mirrored carbon assimilation in that stomatal conductance of high water/high nitrogen plants was highest (0.45 mol H_20 $m^{-2}sec^{-1}$), while low nitrogen treatments had similar stomatal conductance regardless of water treatment (high water, 0.25; low water 0.18), and low water high nitrogen was able to reduce stomatal conductance to (0.05 mol H_20 $m^{-2}sec^{-1}$).

This project did not benefit commodities other than the specialty crop lettuce.

The project director provided supplies and assistance with experimental design and manuscripts. The postdoctoral associate designed and implemented all experiments, completed the manuscript, and completed all data analysis. Project associate provided manuscript review and advice in a previous project.

Goals and Outcomes Achieved

Measureable outcomes were identified as follows:

The identification of traits at the physiological and molecular level that impart drought-tolerance in lettuce, measured by the number of traits identified as well as the impact of specific traits:

A number of greenhouse experiments were completed to identify traits at the physiological level that impart drought tolerance in lettuce. In experiments comparing putatively drought-tolerant and drought-sensitive cultivars, the data suggest that high carbon assimilation rates generally lead to more drought tolerance, because they can be reduced during drought but still remain at high levels. High total N content in control plants also appears to predict drought tolerance. The identification of traits at the molecular level is still ongoing, but expression of genes involved with ABA production and signaling, and within oxidation-reduction pathways appears to be up-regulated in drought-tolerant *L. serriola* under drought. However, these molecular traits may not result in minimal loss in fresh weight under drought (indeed, *L. serriola* lines tended to have large reductions in fresh weight under reduced irrigation [Eriksen et al. 2016]).

The development of breeding lines (with yield at least 20% more than the current commercial cultivars under water-stress conditions) incorporating traits identified through this project for use in the development of drought-tolerant cultivars in both an internal breeding program and more than 30 seed companies, through which seeds of drought-tolerant cultivars will be disseminated to growers. This will be measured by the number of drought-tolerant lines made publically available and distributed to seed companies at the completion of this study:

This is a long term goal. Putatively drought tolerant cultivars have been identified with minimal reductions in biomass under reduced irrigation. Crosses of these cultivars have been made with drought-sensitive cultivars for mapping in order to identify molecular markers, however production of recombinant inbred lines of these cultivars is a long-term process. A number of physiological traits have been identified, such as high carbon assimilation and total N content, that appear to be common among putatively drought-tolerant cultivars, and selection could conceivably occur of lines with high carbon assimilation and N content, however breeding is a long-term project that is only in its early stages.

Publication of new knowledge and results generated through the identification and study of drought-tolerance traits in peer-reviewed journals along with professional and grower meetings including the biannual meetings

of the California Leafy Greens Research Program (CLGRP) which is regularly attended by more than 250 growers and industry personnel. Success will be measured based on the number of publications generated along with the number of citations after publication and requests for further information received in response to presentations at professional/grower meetings:

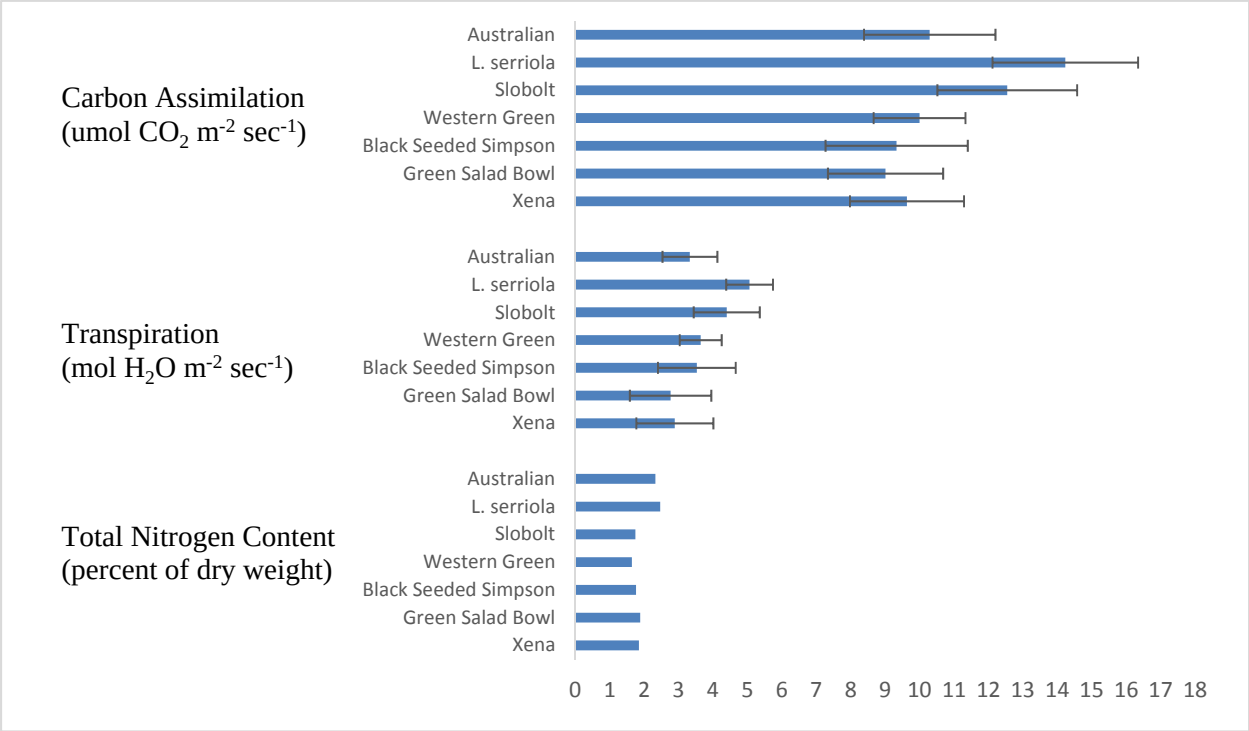
One manuscript has been published to date, and the project director has presented results at the biannual meetings of CLGRP twice. The postdoctoral researcher also presented results at the American Society of Plant Biologists meeting. Three additional manuscripts are in various stages of preparation: one will focus on the RNAseq data on WUE/NUE by collaborators at UC Davis; another will explore the differences in physiological traits in *L. serriola* and *L. sativa* c.v. Salinas; and a third will explore differences in physiological and molecular traits among putatively drought tolerant and drought sensitive green leaf cultivars.

Field evaluation trials and demonstration plot of breeding lines/cultivars incorporating drought-tolerant traits during the final year of this project to demonstrate the impact of the traits identified to growers and seed companies. This will be measured by the number of people attending the demonstration:

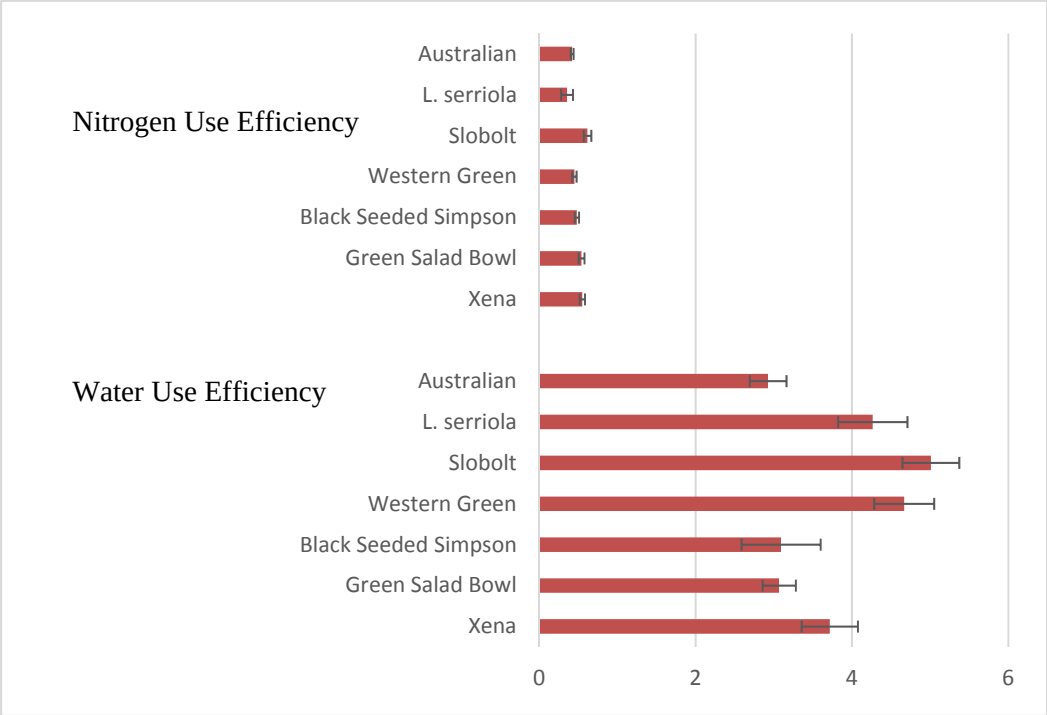
Because breeding is a long-term project, field trial evaluations and demonstrations of breeding lines are also a long-term project.

The development of breeding lines with increased drought tolerance is a long-term outcome measure. Progress toward achieving this outcome measure has been made in the identification of putatively drought-tolerant cultivars, and a number of physiological traits that appear to promote increased photosynthesis and carbon assimilation under drought. The sequencing of the transcriptome of these cultivars, along with drought-tolerant and weedy *L. serriola*, and with several drought-sensitive cultivars, may allow for the identification of genetic markers for marker-assisted selection of drought-tolerant cultivars. At this time, however, the analysis is still ongoing. In addition, the genome of the drought-tolerant cultivars are being sequenced by collaborators at University of California, Davis.

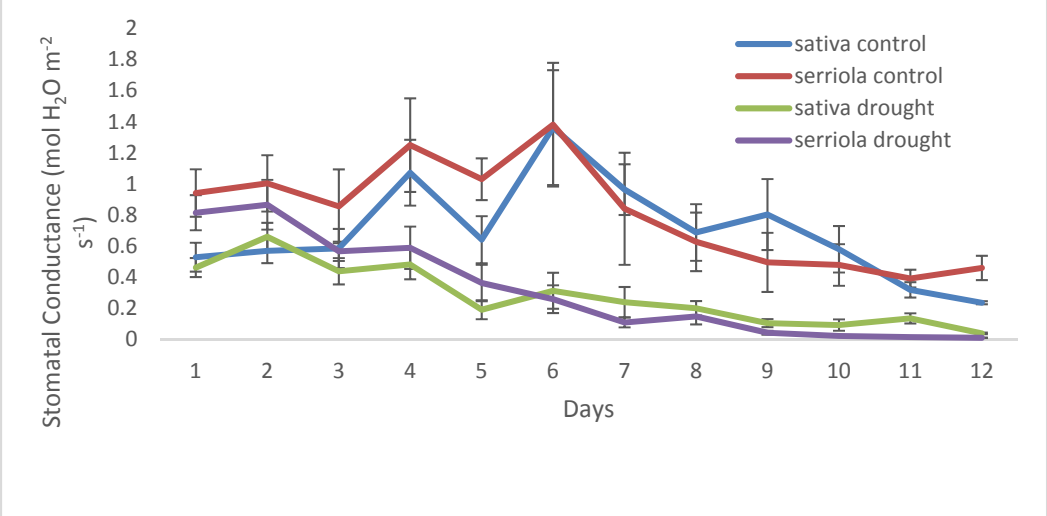
Goals established include significant progress toward the identification of traits at the physiological and molecular level that impart drought-tolerance in lettuce, particular traits at the molecular level, through the transcriptome sequencing of leaf tissue from six different cultivars and *L. serriola* under drought and control treatments. This includes the description of physiological traits that impart drought tolerance. Significant progress has been made toward this outcome, as illustrated by the following data:



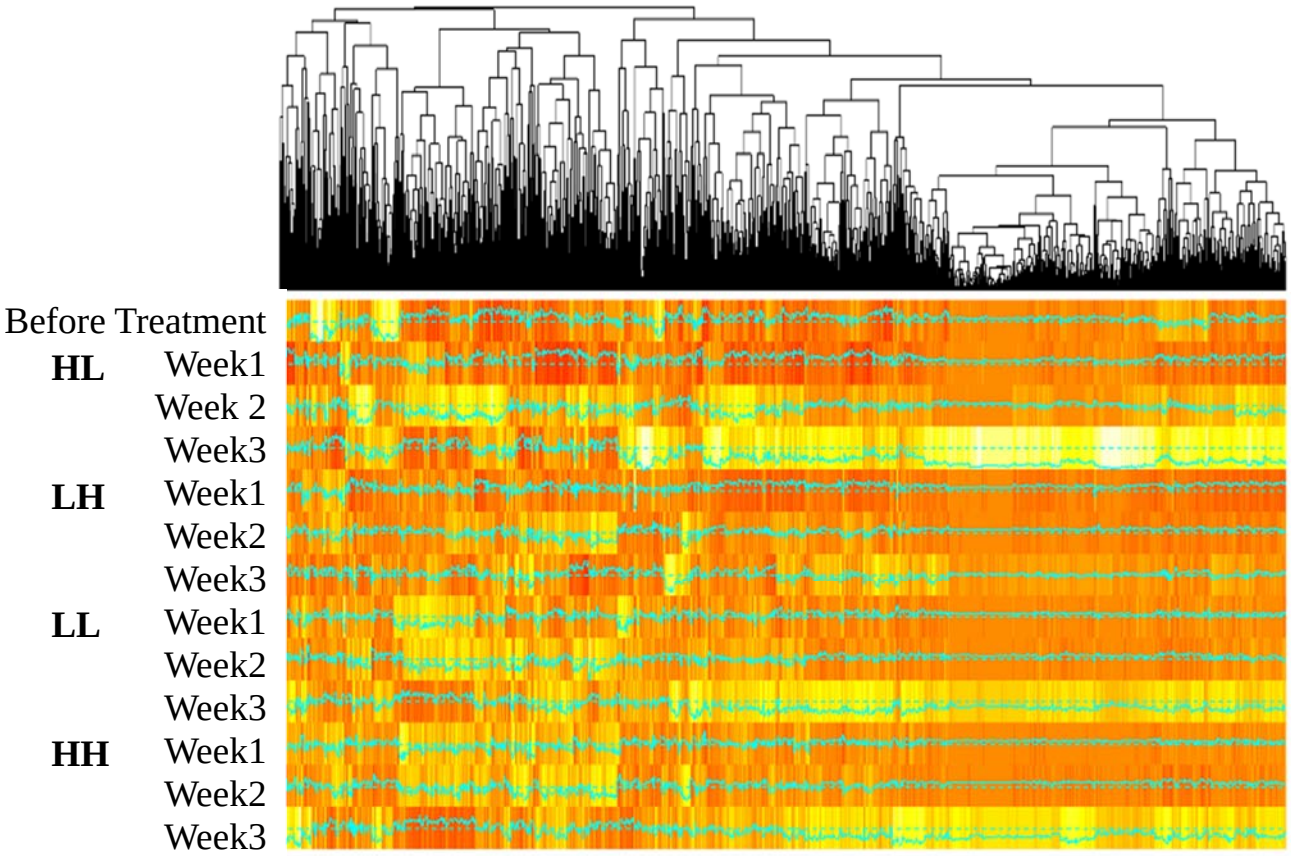
These are baseline data of carbon assimilation, transpiration, and total nitrogen content under control conditions. Putatively drought-tolerant cultivars tend to have higher carbon assimilation, slightly higher transpiration, and slightly higher total nitrogen content than drought-sensitive varieties. Error bars represent the standard error of the mean of three trials.



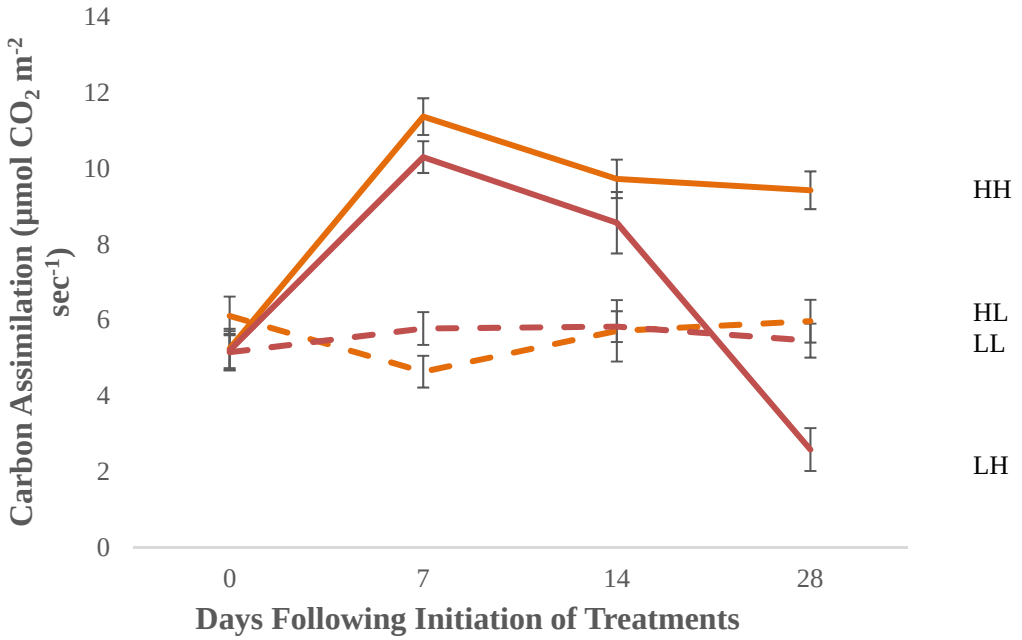
These are baseline physiological data under drought conditions. Putatively drought-tolerant cultivars tend to have slightly higher NUE (not statistically significant, however), and tend to have higher WUE under drought. Error bars represent the standard error of the mean.



Comparisons of physiological traits of *L. sativa* c.v. Salinas and *L. serriola* under drought suggest that *L. serriola* has tighter control over stomatal conductance, and reduces stomatal conductance under drought earlier than *L. sativa*. Error bars represent the standard error of the mean. There is a significant difference in stomatal conductance in *L. serriola* from day 2 to 3, but not in *L. sativa*. Stomatal conductance in *L. sativa* does not differ significantly from day 1 until day 5.



This is a heatmap showing expression levels of genes within the oxidation-reduction stress response pathway in *L. sativa* c.v. Salinas exposed to high water and low nitrogen (HL), low water and high nitrogen (LH), low water and low nitrogen (LL), and high water and high nitrogen (HH) treatments. Yellow and white colors represent high expression, orange and red represent reduced expression. Low nitrogen treatments have more yellow and white colors during week 3, indicating increased expression of genes within this stress response pathway. High nitrogen fertilizer appears to partially mitigate the effects of drought stress by causing a reduction in expression of these stress response genes during week 3. The research team hypothesized this was due to an increase in expression levels of the enzyme rubisco which is a critical enzyme in carbon assimilation under high nitrogen conditions, however, greenhouse experiments suggest that carbon assimilation goes down significantly more in LH treatment by week 3 (day 28 after initiation of treatments).



Comparison		Designation	Number Differentially Expressed Genes	Proportion of Genes Down-Regulated	Proportion of Genes Up-Regulated
Australian_C	Australian_D	tolerant	40	0.70	0.30
*L. serriola*_C	*L. serriola*_D	tolerant	1362	0.49	0.51
Slobolt_C	Slobolt_D	tolerant	3	0.00	1.00
Western Green_C	Western Green_D	tolerant	0		
Black Seeded Simpson_C	Black Seeded Simpson_D	sensitive	350	0.61	0.39
Green Salad Bowl_C	Green Salad Bowl_D	sensitive	15	0.20	0.80
Xena_C	Xena_D	sensitive	3	0.67	0.33

This table summarizes the numbers of differentially expressed genes within cultivars among control (_C) and drought (_D) treatments. There tend to be fewer differentially expressed genes among treatments in putatively drought-tolerant (tolerant) cultivars than in drought-sensitive (sensitive) cultivars. Most of the genes that are differentially expressed in drought-sensitive cultivars (with the exception of Green Salad Bowl), are down-regulated from control to drought treatments, suggesting senescence. There are considerably more genes that are differentially expressed among treatments in *L. serriola*.

The major successful outcomes of the project include: The project produced data for a minimum of three manuscripts to shed light on drought response in lettuce, as well as 42 libraries of transcriptome data with an average of 47,480,934 sequence reads per library, totaling 2,091,311,258 raw sequence reads.

In general, the research conducted found that high rates of carbon assimilation appear to predict drought-tolerance because it leads to higher WUE better than any other physiological trait. Access to nitrogen may mitigate the negative effects on drought, though probably not by increasing carbon assimilation due to increased production of the enzyme rubisco. Isohydric and anisohydric are terms used to describe plant strategies and "behaviors" in dealing with drought. Isohydric plants maintain constant leaf water potential throughout periods of drought by closing off stomata and consequently limiting carbon assimilation and biomass production. Anisohydric plants maintain higher stomatal conductance and transpiration, and therefore are able to maintain higher carbon assimilation and biomass production under mild-to-moderate drought, but at the risk of losing leaf water potential too quickly if water does not become available. Stomatal conductance and transpiration tends to be higher in the putatively drought-tolerant cultivars than in drought-sensitive cultivars across all trials, but these differences are not necessarily statistically significant when data are averaged across all trials. The data to support the hypothesis that putative drought-tolerant cultivars are anisohydric are strongest from trial 1. During trial 1, stomatal conductance was significantly lower in drought treatments than in control treatments in the drought-sensitive cultivars only (Black Seeded Simpson, Hacienda, and Xena, Tukey HSD test $P < 0.04$), while there were no significant differences among treatments in stomatal conductance in the putative drought-tolerant cultivars (Australian, Slobolt, and Western Green, Tukey HSD test $P > 0.95$ for all but Western Green, $P=0.07$). These data support the hypothesis that drought-tolerant cultivars are anisohydric, meaning they maintain relatively high levels of stomatal conductance and carbon assimilation which allows them to grow continuously and maintain biomass during periods of mild-to-moderate drought such as those imposed during these trials. The data were not necessarily replicated during later trials, however, probably due to differences in length of day and greenhouse temperatures. Lack of differentially expressed genes among control and drought treatments in putative drought-tolerant cultivars might also support the hypothesis that these drought-tolerant cultivars are anisohydric. The research team believes this project has resulted in the first evidence that lettuce utilizes both isohydric and anisohydric strategies to deal with mild-to-moderate drought, similar to grapes and poplar. Recent work has demonstrated that genetic modification of isohydric tomatoes can result in anisohydric tomatoes (Sade et al. 2009), so characterizing lettuce as anisohydric or isohydric may offer opportunities in the future for selection or genetic engineering of more anisohydric lettuce.

Beneficiaries

Lettuce, spring mix production companies, seed companies, and academics will benefit from the completion of this project's accomplishments. Molecular markers eventually identified by this project will be disseminated to researchers and breeders for marker-assisted selection or for using cutting-edge gene-editing technology to develop new cultivars. New water efficient lettuce cultivars could then increase sales of seed companies in global markets. Growers and producers will be able to use the new cultivars with increased drought tolerance to reduce irrigation accordingly to reduce production costs. Decreased irrigation of new lettuce cultivars may enable producers to maintain or increase lettuce acreage. Results, including the names of drought-tolerant, differential gene expression data, and genetic markers have been and will continue to be disseminated through conferences (American Society of Plant Biologists), publications (HortScience), and industry meetings (California Leafy Greens Research Program). RNA-sequencing raw data will be uploaded to the National Center for Biotechnology Information (NCBI) Sequence Read Archive database for use by agricultural biotechnology companies, academics, and the public.

The baseline data collected in this project may benefit 107 lettuce and 25 spring mix production companies, and over 30 seed companies involved in growing, processing, and distribution of lettuce products and seeds in

California. Once analyzed and published, transcriptome data will be made available on the NCBI Sequence Read Archive and will then be accessible to any interested academic or researcher anywhere.

Lessons Learned

Significant delays were caused by a slow hiring process, and the project team learned that this cannot be avoided. Delays are likely to be significant in the future as well due to government security clearances. A delay in identifying molecular traits also occurred. Too much time was spent trying to identify candidate genes in order to assess these by qPCR as the project was originally written. When the identification of these genes appeared to be too slow, plans were made to take a hypothesis-independent approach by RNA-seq. Plans should have been made earlier to conduct an RNA-seq experiment so candidate genes could have been identified from this hypothesis-independent approach. Drought has a very complex effect on a plant, affecting a number of physiological traits. It is likely a quantitative trait, meaning it is controlled by a significant number of genes, and drought tolerance itself exhibits quantitative variation among cultivars. There will be no single gene that imparts drought tolerance in lettuce, and only a hypothesis independent approach and pathway analysis of transcriptome data will shed light on the multiple genes involved. Quantitative trait mapping may also shed light on the multiple genes involved, and construction of recombinant inbred lines of drought tolerant and drought sensitive cultivars is underway.

It was not expected that so few differences would be found in gene expression among control and drought treated plants. Western Green, for example, had no significantly differentially expressed genes in control and drought treatments. This could be an error of statistics, however replication of this experiment was good considering the high cost of sequencing. It suggests that lettuce may have lost an ability to respond to drought, at least through transcription of new genes, during its cultivation. This does not mean that small traits can't be identified that allow lettuce to grow sufficiently under reduced irrigation: the agricultural meaning of "drought tolerant" is slightly different than the standard ecological meaning. In natural populations, being drought tolerant means that a plant can survive until the next rain. In agriculture, being drought tolerant means a plant produces similarly under reduced irrigation. Most lettuce cultivars have reduced biomass under reduced irrigation (Eriksen et al. 2016), but some appear to have less reduced biomass than others and were labeled drought tolerant. These may be the plants that simply don't respond to changes in irrigation, and grow similarly under control and reduced irrigation treatments. In which case, and in the case of Western Green, no molecular trait actually imparts drought tolerance, because the plant simply continues growing as if under control conditions until death. Traits such as carbon assimilation and nitrogen uptake efficiency may generally be traits that increase biomass under control conditions, and therefore reduced irrigation conditions as well.

Additional Information

Publications:

Eriksen, R.L., C. Knepper, M. Cahn, B. Mou. 2016. Screening of Lettuce Germplasm for Agronomic Traits under Low Water Conditions. HortScience 51(6):669-679

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SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 40	**Project Title:** Measuring Climate-Driven Shifts in Evapotranspiration, Water Balance and Depth of Water Uptake to Improve Efficiency and Resilience of California's Tree Crops	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB14040	**Date Submitted:** December 2017
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Project Summary

Water shortages are forcing California tree growers to more optimally manage water resources. From individual trees to the farm level, management for water conservation is currently hindered by the lack of quantitative knowledge of mechanisms linking leaf carbon assimilation, kernel production, and evapotranspiration (ET) replenishment under increasing climatic pressures. The sustainability of California tree crops has been historically associated with intensive management and water availability. In the 1980's and 1990's ET for micro irrigated almond orchards in the Central Valley was estimated to be about 42 inches with average yields of less than 1,500 pounds per acre. Growers adopted closer spacing and post-harvest irrigation in the mid 1990's. As a result, average yields surpassed 2,000 pounds per acre in the early 2000's reaching over 2,500 pounds per acre for 2010-11. Despite improved irrigation, orchards now use over 56 inches of water and expanding acreage increases water demand. To decide when and how to irrigate, producers use ET replenishment estimates from a standardized grass reference surface. However, these areas are not representative of tree carbon-water relations. The goal of this project was to validate a method to measure plant to field level water balance, refining ET estimates and determining the effect of different practices on the intrinsic water-use efficiency (iWUE) of California's tree crops. Almond orchards were used as a model system to: (1) compare the isotopic composition of xylem and soil water to determine the contribution of deep and shallow roots to total plant water uptake under different climates and management; (2) develop empirical relationships between ET-driven leaf hydrogen (δD) and oxygen (δ18O) isotopic enrichment and WUE (measured using carbon isotope - $\delta^{13}C$); and (3) compare these with standard physiological measurements to determine water stress and improve management based on new ET estimates and Kc coefficients.

The 2012-2016 California drought was one of the most severe on record and impacted the state's agricultural sector through severe water shortages, groundwater overdraft, and economic losses estimated to total 1.7 billion in 2014, 2.7 billion in 2015, and 603 million in 2016 (Medellín-Azuara et al. 2016). Although precipitation in 2017 replenished the surface water deficit and restored the Sierra snowpack, groundwater reserves remain depleted (U.S. Department of the Interior 2017). Climate models predict drought will continue to occur in California due to anthropogenic warming coupled with increasingly low amounts of precipitation (Diffenbaugh et al. 2015). These predictions in conjunction with the economic impacts of drought on agriculture underscore the importance of designing agricultural management strategies that conserve water. Examining water-efficient irrigation techniques is essential to ensure agricultural systems will be resilient under projected water shortages.

Myriad climatic, economic, and social incentives to improving water management in orchards have given way to research emphasizing irrigation efficiency. Current management recommendations suggest replacing 100% of water lost through orchard ET to satisfy tree water requirements. Deficit irrigation is a management strategy that replaces less than 100% of ET, inducing water stress while maintaining crop productivity. Physiologically, tree water stress limits leaf growth while maintaining kernel growth due to inherent differences in stress sensitivity between leaves and nuts. Under ideal deficit irrigation management, water-stressed trees allocate a larger proportion of physiological resources to kernels over vegetative growth, and farmers conserve water with little to no reduction in orchard yield. Almonds are particularly well suited to deficit irrigation management because of their drought tolerance, and researchers aim to find the optimal range of water-stress to maximize yield and water savings. Previous studies by the Principal Investigator (PI) and Co-PIs of this project have found no significant impact on almond yield due to deficit irrigation, but others found that deficit irrigation leads to varying degrees of yield reduction. Divergent responses are linked to both seasonal and multi-year stress levels, such that the effects of deficit irrigation can compound over multiple years and reductions in yield, for instance, may not be apparent until two years after deficit irrigation treatment commences. This project is timely and unique in that it combines physiological and orchard-level stress responses at three different sites, spanning the range of almond distribution in California, examining the impact of irrigation treatments on yield over multiple years.

Medellín-Azuara J, MacEwan D, Howitt R, Sumner DA, Lund JR. 2016. Economic Analysis of the 2016 California Drought on Agriculture. CDFA Report 17 pg.

Diffenbaugh et al. (2015) Anthropogenic warming has increased drought risk in California. Proceedings of the National Academy of Science. 112 (13) 3931–3936

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

This project combined field experiment, laboratory studies, and greenhouse manipulations of specialty tree crops in California. The overarching goal of the project was to quantify changes in carbon-water relations induced by different ET replenishment levels and their consequences for yield sustainability. To achieve this goal a number of different techniques were used, as follows:

Field experiments - Experiments took place in three almond orchards (*Prunus dulcis*) in the central valley of California, characterized by a Mediterranean climate with a predominant substrate of alluvial sedimentary deposits. The orchards were located in Kern, Merced, and Tehama counties and span a latitudinal gradient representative of the typical range and climatic conditions of almond production in California. Air temperature was relatively similar between orchards, but precipitation varied, with the northernmost site, Tehama, receiving the most rainfall. The experiment coincided with a severe drought (2013-2015) marked by higher than average temperatures and lower than average precipitation. Three tree varieties (Non-pareil, Monterey, and Carmel) alternate by row within each orchard. Fertilizer and pest management was administered according to common growing practices in the region. Orchards received 225 ± 55 kg N/ha each year and were managed for Navel Orangeworm, Spider Mites, Brown Rot, Blossom Blight, and Shot. Orchard canopies were fully developed and trees were not pruned. Study sites were selected to minimize differences between orchards, which had similar management approaches.

Kern County - In Kern county orchard (35° 30' 36" N, 119° 10' 12" W, 140 m elevation), Non-pareil trees are 11 years old, grafted on Nemagard rootstock, spaced 6.4 X 7.3 m, and under double-line drip irrigation. Soil is categorized as well-drained Driver coarse sandy loam, low available water storage, and 50-75 cm to abrupt textural change. Climatic data based on CIMIS station ID 5.

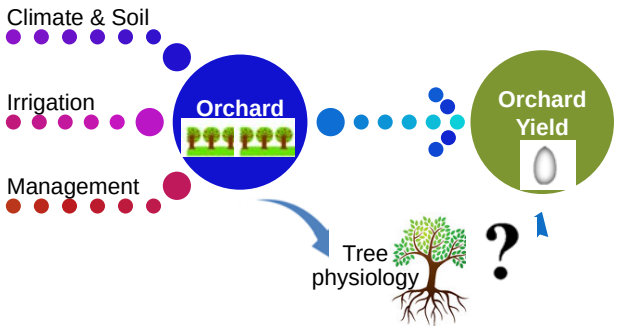
Merced County - In Merced county orchard (37° 29' 24" N, 120° 38' 24" W, 70 m elevation), Non-pareil trees are 17 years old, grafted on Lovell rootstock, spaced 5.5 X 6.1 m, and under Micro-sprinkler irrigation. Single-line drip irrigation is used for 2 weeks after trees are shaken for harvest, to enable drying of fallen kernels. Soil is categorized as well-drained, Rocklin Loam or Whitney and Rocklin soils. There are 50-100 cm to a duripan layer and low available soil water storage. Climatic data based on CIMIS station ID 206.

Tehama County - Tehama county orchard (39° 57' 36" N, 122° 16' 12" W, 110 m elevation), has 12-year old Non-pareil trees with a double graft of Marianna 2624 plum rootstock and Padre interstem. Trees are spaced 3.4 X 6.7 m, and under Nelson R-5 mini sprinkler irrigation. Single-line drip irrigation employed for 2 weeks after trees are shaken for harvest, to enable drying of fallen kernels. Soil is spatially heterogeneous and classified as either Tehama silt loam or Arbuckle gravelly sandy loam. Both soil classes are well-drained, with moderate to high water storage capacity and over 200 cm in depth to first restrictive feature. Climatic data is based on CIMIS station ID 12 for dates prior to and including 8/12/2014 and Station ID 222 for dates past 8/12/2014.

Three irrigation treatments were applied in a randomized control block design, with three block replicates in each orchard, 0.2 - 0.4 ha in size. Deficit treatment, T1, replenished ~70% of water lost to crop-specific evapotranspiration (ETc), control treatment, T2, replenished ~100%, and surplus treatment, T3, replenished ~110% of ETc loss. Irrigation amounts were determined as an estimated percentage of ETc using Kc coefficients calculated monthly at each site and reference ET derived from the CIMIS station closest to each orchard. In-situ measurements at each orchard were used to refine estimates and manage irrigation timing and amount to produce desired water deficit, control, and surplus conditions in experimental blocks. Irrigation was therefore modified according to tree stem-water potential, dendrometer measurements and soil moisture content and did not always satisfy the target amount of ETc replenishment. In-line flow meters measured the amount of water applied on a weekly time interval. ETc replenishment was calculated on two distinct time intervals. March-October represents the entire duration of the irrigation period, and April-August represents the period in the season when maximum tree productivity and transpiration occurs, up through tree harvest. The % replenishment of ETc for both periods is useful to describe a) the general seasonal water replenishment (March-October) and b) the water replenishment during a temporal subset with hotter and drier climatic conditions (April-August). Experimental measurements were taken only on Non-pareil trees during the 2015/2016 growing seasons.

Greenhouse experiments – To supplement field data and elucidate the tree-level mechanisms behind orchard-level responses to treatments staff replicated the experiment at the University of California, Davis (UCD) greenhouses. These experiments involved other specialty crops; namely: walnut trees (*Juglans regia L.*) and pistachio (*Pistacia integerrima*). These greenhouse experiments used the same methods described above and generally confirmed the results of the field trials.

How does tree physiology relate to orchard yield under different irrigation strategies?



Variables by Scale

Physiology	Orchard	Regional
iWUE	Yield (kg/ha)	Temperature
SWP	Soil Moisture	ET
Root Uptake Depth	Soil Properties	VPD





Two levels of water-use efficiency

1. Orchard-level:

- Water-use efficiency = $\frac{\text{Orchard Yield}}{\text{Water applied}}$
- "Crop per drop"

2. Physiological or tree-level:

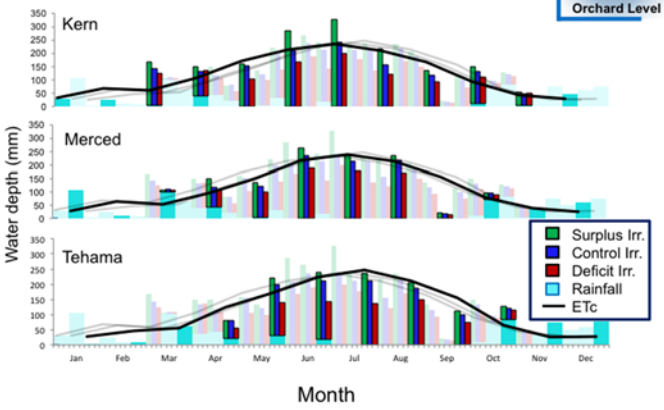
- ${}_{i}\text{WUE} = \frac{\text{tree assimilated C (µmol)}}{H_2O \text{ transpired (mol)}}$
- Regulated by tree stomata
- Measured using $\delta^{13}C$ of leaf tissue

Hypothesis:

Deficit irrigation will:

- Reduce yield
- Increase iWUE
- Minimally affect "crop per drop"

Precipitation and Irrigation



Measurements:

Soil Water Content - Soil neutron probes were used to record moisture by depth in the soil column in the center of each experimental row of trees located in the middle of each replicate, reducing potential border inconsistencies. Volumetric water content of soil was recorded in 30 cm increments up to a maximum depth of 275 cm. Temporal resolution varied by orchard from four measurements per season in Merced, 10 per season in Kern, and 16 per season in Tehama. Data was temporally 'binned' to evaluate moisture conditions representative of early (February-April), mid (May-July), and late (August-October) season periods.

Stem water potential - Midday stem water potential measurements were taken on X number of leaves on X number of trees directly adjacent to the neutron probe column in each replicate. Leaves were encapsulated in an aluminized mylar bag for approximately one hour between 1pm - 4pm and then evaluated for water potential using a pressure bomb. In Merced and Kern, measurements were taken twice per month and in Tehama, measurements were taken eight times per month throughout the growing season.

Stable Isotope Analyses - Stable isotope analyses were used to determine water-use efficiency and changes in transpiration induced by changes in stomatal conductance and transpiration in response to deficit and excess irrigation as follows. Leaves were harvested throughout the growing season and water was extracted using a custom-made cryogenic distillation system suitable for isotopic analysis, adapted from previous studies of this kind (e.g., Vendramini and Sternberg, 2007). Briefly, the leaves were transferred to individually cut 1.27 cm diameter pyrex tubes (Wale Apparatus) where the leaf material was held in place by stainless steel wool. After attachment to a vacuum manifold, leaves were frozen in liquid nitrogen and air evacuated to 100 mTorr. The tube was then flame sealed to preserve the vacuum, and subjected to gravity assisted cryogenic distillation, the top of the tube at 110˚C, bottom at -20˚C. After distillation, the tube was removed and ice water isolated by flame sealing the tube again to separate water and leaf material. Leaf material was separated and ground to a powder using liquid nitrogen in a mortar and pestle. Three mg samples were submitted for $\delta^{13}C$ determination at the UCD Stable Isotope Facility by continuous flow GC-IRMS on a PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20-20 isotope ratio mass spectrometer (Sercon Ltd., Cheshire, UK). The water samples were transferred to 2 mL vials and was analyzed for δD by equilibration with water vapor and added hydrogen gas, assisted by a platinum black powder catalyst. Next, CO_2 was added to the system and equilibrated with water vapor for $\delta^{18}O$ analysis. Water analysis was performed at the University of Miami by using multiflow system connected to an Isoprime mass spectrometer (GV, Manchester, UK).

To standardize isotopic data, values are reported in del notation with reference standards as in the equation below. The values are calibrated to Vienna Belemnite of the Pee Dee (VPDB) formation for $\delta^{13}C$, and the Vienna Standard Mean Ocean Water (VSMOW) for $\delta^{18}O$ and δD of water.

$$\delta^{y}X = \left(\frac{R_{sample}}{R_{standard}} - 1\right)$$

Intrinsic water-use efficiency (iWUE) is an isotopically derived measure of physiologically mediated gas exchange of water and CO_2 through stomata between leaf and air. This measure has been used to assess water stress, and productivity-efficiency tradeoffs in a variety of agronomic settings (Chaves et al., 2003; Farquhar, 1989; Farquhar et al., 1992). First isotopic discrimination ($\Delta^{13}C$) between the source (atmosphere) and plant tissue must be derived as below.

$$\Delta^{13}C = (\delta^{13}C_a - \delta^{13}C_p)/(1 + \frac{\delta^{13}C_p}{1000})$$

Then given previously determined (Farquhar, 1989) diffusive and biosynthetic fractionation factors, a, and b (4.4‰, and 27‰, respectively) are used with $\Delta^{13}C$ to calculate ci/ca, or the ratio of internal (ci), to atmospheric (ca) partial pressure of CO_2.

$$\Delta^{13}C = a + (b - a)\frac{c_i}{c_a}$$

Finally, according to Fick's law and a scaling factor of 1.6 for relative diffusivity rates of CO_2 and water through air, iWUE ($\frac{mmol\ C}{mol\ H_2O}$) can be calculated yielding a value for the relative amount of carbon assimilated by photosynthesis per water lost by transpiration.

$$iWUE = \frac{c_a\left(1 - \frac{c_i}{c_a}\right)}{1.6}$$

Yield and Yield Components - Orchard trees were harvested according to standard growing practices. Trees were mechanically shaken, and kernels were dried to 5 - 7% moisture content, processed, and weighed. Differences in yield were assessed based on both kernel size (grams/nut) and orchard-level productivity (lb/acre). Isotopic analyses were performed in kernel samples and correlated with data from leaf samples (described above). The relationship between yield data and climatic variability across sites leveraged resources from other synergistic projects by the Co-PIs and farmer advisors, including baselines of ET and soil water content, which were used to generate new Kc coefficients. These calculations were performed for excess, control, and deficit irrigation treatments replicated within and across sites. A summary of baseline ETo, ETc, cumulative ETc, new Kc coefficients, and yield production for each site and irrigation treatment is attached to this report. The amount of almond water demand (ETc) was calculated using the equation: ETc = ETo x Kc; where ETo represents water use by a reference crop (grass pasture), which can be found through a number of sources including the CIMIS system (http://www.cimis.water.ca.gov) and the crop coefficient (Kc) represents the ratio of water used by the crop used to calculate ETc determined based on site-specific bloom dates and ETo throughout the season.

Farquhar GD, O'Leary MH, Berry JA (1982) On the Relationship between Carbon Isotope Discrimination and the Intercellular Carbon Dioxide Concentration in Leaves. Australian journal of plant physiology, 9, 121–137.

Farquhar GD, Ehleringer JR, Hubick KT (1989) Carbon Isotope Discrimination and Photosynthesis. Annual Review of Plant Physiology and Plant Molecular Biology, 40, 503–537.

Vendramini PF, Sternberg LSL. A faster plant stem-water extraction method. Rapid Commun. Mass Spectrom., 2007;21: 164–168.

The overall scope of the project did not benefit commodities other than specialty crops.

The collaborative nature of this project greatly increased the scope of the proposed work and the impact of experimental results. The subcontract with Bachand & Associates allowed the transfer of knowledge directly to farmers across the state. Notably, the project started in October 2014, but previously established collaboration with farmers and extension specialists allowed staff to obtain data from irrigation trials initiated in 2013. The data collected for this project generated a four-year time series that demonstrates the feasibility of using deficit irrigation as a water-saving strategy, increasing "crop per drop" with no yield losses in Merced and Tehama orchards (but with statistically significant yield losses in Kern). The joint contribution of subcontractors and collaborators included integration of hydrologic data over time and across sites and preparation of outreach materials in the form of conference presentations and peer-reviewed articles.

Goals and Outcomes Achieved

All proposed activities were completed and some of the data have been published. Two key additional publications are currently being prepared discussing the data shown in attachments and below.

1- Soil Moisture across sites
Each orchard had distinct patterns of volumetric soil moisture with depth, independent of seasonal changes and treatment effects (Attachment 1 - Figure 2.1). The topmost layer of soil (0-100cm) contained similar levels of moisture between all three orchards throughout the growing season due to regular application of

irrigation, which occurred every 2-3 days during the driest part of the season. The middle soil layer (100-200cm) was wettest in Merced, ranging from 18.5 - 26.4cm, intermediate in Kern, which ranged from 15.0 - 22.7 cm, and driest in Tehama, which ranged from 9.6 - 14.8 cm. The greatest difference in soil moisture between orchards occurred in the deepest layer (200-300cm), with wettest values in Merced (26.4 - 30.5 cm), intermediate in Kern (10.0 - 14.7 cm), and driest in Tehama (3.1 - 7.1 cm). Almond tree root zone depth is assumed to be 0-60 cm, so the shallowest layer has the most important role in tree-water relations. However, there is evidence almond roots can go as deep as 200 cm, so deeper soil may serve as a secondary source of water (Ben-Asher et al. 1994). The results indicate Merced has a larger reservoir of soil water stored in deep layers compared to Tehama and Kern.

2- Depth of water uptake
Isotopic sourcing results indicate the statistical likelihood that stem water originated from each depth increment in the soil (Table 2.3, Figure 2.3). Among orchards, Kern had the highest likelihood of uptake from depth 1: 0-15 cm. The only exception was May T2 treatment, which displayed a mix of depth sources, primarily from depth 2 and depth 3 (15 – 45 cm). Merced was much more likely to uptake water from intermediate depths 4 and 5 (45 – 80 cm). Merced T3 in May and July had a combination of uptake from shallow and deep layers. Tehama in May had a strong likelihood of water sourced from depth 2 in all treatments. In July, Tehama uptake shifted to deeper layers in T2 (depth 7) and T3 (depth 6).
These results support the hypothesis that Merced buffers physiological tree water stress by accessing available water at deeper depths relative to Tehama and Kern (Fereres et al. 1981; Girona et al. 2005; Goldhamer et al. 2006). However, at the depth which water is absorbed in Merced (45 – 80 cm) moisture is still comparable between all orchards (Figure 2.1), which challenges the idea that moisture availability drives deeper root water uptake.

Within orchards, no strong pattern in treatment effect on depth of water uptake emerged. T1 treatments typically sourced water from depth layers in the shallower end of the depth range observed in each orchard. In Merced, T3 appeared to blend source water from multiple depths and in Tehama during July, T2 and T3 accessed water from deeper soil depths. The differences in depth of water uptake between May and July were not consistent across orchards.

3- Isotope profiles by depth
Isotopic profiles by depth reveal patterns in evaporation within the soil column. Limitations to depth of water uptake analysis are elucidated using the isotopic profiles by depth (Figure 2.4). Increased differentiation between isotopic signatures at each depth increment improves the accuracy of statistical sourcing. For example, Kern in July has an ideal profile from which to identify distinct source contributions. However, multiple profiles in Merced and Tehama are relatively homogeneous by depth, which could interfere with the accuracy of sourcing results. Additionally, in Merced (May and June), isotopic signatures increase from shallow to intermediate depth and decrease between intermediate and deep depths. When isotopic signatures are identical in shallow and deep layers, the sourcing results may reveal a blend in depth sources (eg. Merced T3 May and July) when water could have originated from the shallow depth only. Conversely, a blended combination of two or more source depths found in xylem water may be incorrectly identified by statistical software as only originating from a single depth (Ehleringer and Dawson 1992). Thus, sourcing results must be interpreted in conjunction with isotopic source data and system-specific knowledge about rooting depth and water use. Isotopic enrichment of shallow (<30cm) soil water due to evaporation is frequently observed in studies examining soil water isotopic profiles by depth (Ehleringer and Dawson 1992; Busch et al. 1992;

Gazis and Feng 2004). Enrichment in shallow layers is observed in several profiles and strongest in Kern (T1 and T2) in July. However, isotopic Figure 2.4. δ2H and δ18O isotopic signatures in soil water by depth for each orchard and treatment in May and July profiles in Merced and Tehama show minimal to no enrichment in shallow soil water relative to deeper soil water. Enriched signatures at intermediate depths, as observed in Merced, can result from pulses of enriched irrigation water infiltrating vertically into the soil column, through piston flow (Gazis and Feng 2004). Alternatively, if preferential flow and infiltration bypasses a considerable depth of soil, intermediate and deep soil layers could contain stationary soil water that has long residence time (Gazis and Feng 2004). In contrast, soil water near the surface is replaced frequently with periodic irrigation and an active root zone (Gazis and Feng 2004). Despite complications arising from heterogeneity in moisture availability and soil properties, isotopic soil moisture profiles reveal extent of evaporation and lend insight to soil hydrologic processes.

The data and publications generated by this project are expected to directly benefit almond, walnut, and pistachio growers in decades to come. The results validated the use of stable isotopes as reliable proxies for integrating the net effect of highly variable iWUE and SWP throughout the growing season, as scalable physiological indices that can be easily used to improve management and to save water while maintaining tree productivity.

In addition to the baseline data provided in previous reports and publications, the main research questions and methods led to the following key findings in the attached document (Attachment 2).

Additional findings that were not included in the original grant proposal can be found in attached document (Attachment 3).

The final products of this project include: one MSc thesis; four scientific peer-reviewed articles; two peer-reviewed manuscripts in preparation; and four conference presentations.

SEELY T. (2017) Physiological and yield response of almond orchards to deficit and surplus irrigation across a latitudinal gradient in California. UCD MSc Hydrology Thesis to be finalized in 2018. Committee members: Ken Shackle; Lucas Silva, Will Horwath.

JERSZURKI, SILVA, SHACKEL, et al. Impact of root growth and hydraulic conductance on canopy carbon-water relations of walnut trees (*Juglans regia* L.) under drought Scientia Horticulturae (In Press)

SPERLING, SILVA, et al. Temperature gradients assist carbohydrate allocation within trees
Nature Scientific Reports 2017; 7: 3265.

SILVA L.C.R. (2015) From air to land: Understanding water resources through plant-based multidisciplinary research. Volume 20, 7, 399–401

SILVA L.C.R., PEDROSO G., DOANE T.A., HORWATH, W. (2015) Beyond the cellulose: Oxygen isotope composition of plant lipids as a proxy for terrestrial water balance. Geochemical Perspective Letters 1, 33-42

SEELY T, SILVA LCR, SHACKHEL K (2016) Linking Plant Water Use to Field-Level Water Efficiency Under Surplus and Deficit Irrigation: A Case Study in Almond Orchards. SSSA Annual Meeting. Phoenix AZ.

SEELY T, SILVA LCR, SHACKHEL K (2016) Linking Plant Water-Use Efficiency and Depth of Water Uptake to Field--Level Productivity Under Surplus and Deficit Irrigation in Almond Orchards. American Geophysical Union Annual Meeting. San Francisco CA.

JERSZURKI D, SILVA LCR, et al (2016) Modeling an Alternative Reference Evapotranspiration Method under Different Climate Regimes. American Geophysical Union Annual Meeting. San Francisco CA.

MAXWELL T, SILVA LCR, et al (2016) Predictable oxygen isotope exchange of plant lipids improves our ability to understand hydrologic shifts and partition evapotranspiration across scales. American Geophysical Union Annual Meeting. San Francisco CA.

Beneficiaries

Specialty crop tree growers, crop modelers, and policy makers will benefit from this project.

In 2014, there were more than 6,000 almond growers and 100 processors/handlers in California who can potentially benefit from this project. The almond crop totaled 2.15 billion pounds valued at $6.4 billion.

Economic impacts will vary with the cost of almonds and water for irrigation at each location. As shown in the figures above, up to 40% increases in the “crop per drop” can be attained under deficit irrigation at cooler sites (Merced and Tehama). At the driest and warmest site (Kern), however, deficit irrigation led to a significant decline in productivity, such that yield declined in the same proportion as the water saved under deficit irrigation (i.e., no change in “crop per drop” indices).

Lessons Learned

Long-term partnerships between growers and researchers are crucial. Many of the concepts employed in this project have long been established by plant biologists in natural ecosystems and laboratory studies, but have yet to become part of the basic tree crop management ‘tool box.’ For example, here staff learned that individual kernels retain the isotopic signature of carbon and water exchanged in the canopy, effectively integrating the seasonal effect of stress response and stomatal regulation of iWUE of each tree. In other words, the analysis of leaves or kernels is more reliable than commonly used sensors that yield “noisy” datasets at finer temporal scales that are difficult to interpret. A few isotopic measurements of leaves within a plot is sufficient to predict and scale yield amount and iWUE to the orchard level. This approach could be used to improve management as well as to enforce certain irrigation levels that can ensure optimal water-savings while maintaining crop productivity (i.e., off-the-shelf kernel analyzed for stable isotopes can be used to back-calculate orchard iWUE and amount of water applied across the state and elsewhere). This result would not surprise a plant scientist working on, for example, isotopic-based climate reconstructions (e.g., tree rings) in which plant biomass is used to determine historical changes in water balance. However, the isotopic tool box is currently not used by the industry. This is one of many instances in which the project team felt that long-term projects involving scientist and growers could have a long-term positive impact on specialty crop sustainability and water savings in California.

Two unexpected events led to a major revision of the expenditure strategy:

1-The lab technician who was originally expected to work in the project, accepted a permanent position at UCD and was unavailable to receive funding to participate in the proposed activities. Graduate students replaced the lab tech, but this took additional time for adequate training to ensure data quality;

2-The subcontractors left their former company to start a new company. They effectively collaborated in the project but the transfer of funds was significantly delayed, which slowed down the progress in years 1 and 2.

Despite these unexpected events, all major project goals were accomplished within the proposed timeline.

Additional Information

A summary of baseline ETo, ETc, cumulative ETc, new Kc coefficients, and yield production for each site and irrigation treatment are presented in Tables 1 and 2 and Figures 1 and 2 of Attachment 4.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
41	Data-Driven Targeted Education to Increase the Adoption of Best Management Practices by Almond Growers	
Grant Recipient: SureHarvest	**Grant Agreement No.:** SCB14041	**Date Submitted:** December 2017
Recipient Contact: Joe Browde	**Telephone:** (707) 776-4943	**Email:** jbrowde@sureharvest.com

Project Summary

California almond production has achieved significant financial success yet continues to face challenges including increased farm input costs, enhanced demand for and fluctuating supplies of natural resources, concerns about water and air contamination and climate change, and the need to objectively demonstrate use of sustainable practices to almond manufacturers and buyers, regulators, and public policy makers. The California Almond Sustainability Program (CASP), a partnership between the Almond Board of California (ABC) and SureHarvest, addresses these challenges by demonstrating the industry's commitment to sustainable almond production and reinforcing California almonds as a "crop of choice, nut of choice." CASP includes the interrelated components of grower self-assessment of Best Management Practices (BMPs) and environmental performance metrics, interpretation and reporting of results, and application of results for strategic communications, targeted education, and continuous improvement. CASP participation was significant prior to the start of this project, with growers responsible for approximately 33 percent of the statewide almond acreage submitting BMP assessments for irrigation, nutrient, energy, air, and/or pest management. This vast participation enabled production of the 2014 Almond Sustainability Report which detailed BMP strengths and improvement opportunities based on over 95,000 assessed acres.

The overall goal of this project was to use the self-assessment data, established valuation methods, and 2014 Report findings to design and implement a targeted education campaign (workshops and online) to increase almond grower adoption of BMPs with low adoption rates but high environmental and grower economic benefits. The performance benchmarks detailed as high-value opportunities in the report were used as the baselines against which to gauge progress resulting from the execution of tasks in this project. This goal was to be achieved via three objectives: 1.) Apply assessment results and understandings of relationships between BMPs and environmental and grower economic value to prioritize grower educational needs (targeted education); 2.) Work with partners (ABC, University of California Cooperative Extension (UCCE), United States Department of Agriculture-Natural Resource Conservation Service (NRCS), private companies, individual almond growers and handlers, and other experts) to provide education via workshops and the CASP online system; and 3.) Measure subsequent progress in BMP adoption.

Challenges related to the California almond industry and environmental impacts intensified over the course of this project. High-profile concerns included (and remain) water use, nitrate contamination of groundwater, and dust created by harvest operations. These concerns intersected with the increased demand to objectively demonstrate the use of sustainable production practices to almond manufacturers, buyers, and consumers. This project was important and timely for two key reasons: 1.) The project addressed the need to more definitively link value to BMPs for almond growing and, thus, incentivize and increase adoption, and 2.) Increases in BMP adoption resulting from the project would help address the environmental and marketplace challenges. By accomplishing the goal of increasing almond grower adoption of higher-value (environmental and

economic) BMPs for irrigation, nutrient, energy, air, and pest management, the project would improve farm viability, environmental quality, and conserve energy, water, and other natural resources.

This project built upon two previous Specialty Crop Block Grant Program (SCBGP) projects. The 2009 SCBGP Project 12: *Almond Sustainability Initiative: Integrated Water and Nutrient Resource Management* and the 2010 SCBGP Project 28: *California Almond Sustainability Program (CASP): Integrating Resource Issues with BMP Implementation*. Funds from 2009 Project 12 were used to develop and implement materials and outreach activities for the first two self-assessment modules, Irrigation and Nutrient Management. Results included the formation of a CASP Leadership Team which oversaw the development of the Irrigation and Nutrient Management modules, and is composed of almond growers and handlers, ABC and SureHarvest staff, and representatives from universities, government, non-governmental organizations, private industries, and other external stakeholders. Other key results were the initiation and evolution of a grower outreach and workshop program for documenting and collecting assessment data, the composition and distribution of first customized grower reports comparing individual to statewide performance, and design and implementation of the online self-assessment and reporting system. The 2010 SCBGP Project 28 provided funds to produce modules and content for Pest Management, Ecosystem Management, Water Quality, and Soil Quality; and to initiate early phases of data-driven targeted education for pest management. Together, these two SCBGP projects were instrumental in securing assessment data from 575 growers for 95,496 acres, which constituted the baseline data used for the 2014 Almond Sustainability Report.

This project complemented past efforts by applying assessment data to customize a targeted educational initiative to increase and measure grower adoption of BMPs markedly benefiting the environment and grower economics. The demonstration of continuous improvement in the adoption of BMPs by California almond growers is central to CASP and ABC's mission.

Project Approach

The project goal was to use CASP self-assessment, established BMP valuation methods, and 2014 Almond Sustainability Report findings to design and implement a targeted education campaign (workshops and online) to increase almond grower adoption of BMPs with low adoption rates but high environmental and grower economic benefits. This goal was accomplished via three objectives: 1.) Apply assessment results and understandings between BMPs and environmental and economic value to prioritize grower educational needs (targeted education); 2.) Work with partners (ABC, UCCE, NRCS, private companies, individual almond growers and handlers, and other experts) to provide the targeted education via workshops and the CASP online self-assessment and reporting system; and 3.) Measure subsequent progress in BMP adoption. For the entire grant period, activities and progress made for tasks associated with these objectives and the work plan follow.

Task 1: Prioritize CASP BMPs for education by ranking each BMP by environmental and grower economic value and overlaying rankings with statewide grower self-assessment results.
This task was completed during the first project year. Based on a sustainability value analysis method developed by SureHarvest and used for the 2014 Almond Sustainability Report, the Project Manager and other SureHarvest staff ranked CASP BMPs according to environmental and grower economic value for six management areas – energy, air, water usage, water quality, nutrients, and pests. Educational priorities then were determined by overlaying value rankings with statewide self-assessment results through July 2013 to

identify BMPs with high value but low adoption rates (generally less than 50% use in orchards). The BMPs prioritized for education per management area are listed in Attachment 1.

Task 2: Recruit expert educators based on prioritized BMPs.
This task was also completed during the first project year. For each management area and for honey bee management (additional high-profile topic), the Project Manager and other SureHarvest staff recruited experts to help characterize and increase use of the prioritized BMPs via presentations at workshops and composition and distribution of educational materials. The committed group of experts included UC researchers and farm advisors, NRCS staff, personnel with private companies, and experienced and respected individual growers. See Attachment 2 for agendas, and associated expert educators, for many of the workshops conducted during the entire grant period.

Task 3: Secure existing and develop educational materials for grower education (workshops and online) based on prioritized BMPs.
Much effort was devoted to this task over the grant period. Achievements by the Project Manager, other SureHarvest staff, ABC staff, and the expert partners included the development of presentations and gathering of handouts associated with workshops about prioritized and other high-profile BMPs for energy, air, water, nutrients (nitrogen), pests, and bees (see Task 4 below).

Other key project accomplishments were the design and completion of education materials (pop-up guidance and user guides) for three CASP online, grower decision support tools developed during the project: 1.) Nitrogen budgeting decision support and reporting tool, 2.) Farm mapping and reporting tool, and 3.) Irrigation calculator and scheduling tool. These tools help growers more efficiently manage nitrogen and water resources and complete Irrigated Land Regulatory Program (ILRP) requirements for nitrogen management plans. By using the tools, growers implement many of the BMPs for nitrogen and irrigation management that add environmental and economic value via resource use efficiencies and cost savings. A widely distributed handout describing the CASP online system and use of these tools is at http://www.almonds.com/sites/default/files/content/attachments/casp_one-pager.pdf.

Grant funds also supported the development of educational videos, posters, trade publications, and industry newsletter articles. Three videos (Join the California Almond Sustainability Program, Nitrogen Budgeting, and Honey Bee BMPs) were developed for educating growers at workshops and online. Four posters characterizing CASP and its educational targets and achievements were presented at the annual Almond Conference held each December in Sacramento. Fourteen trade and industry newsletter articles have been published for highlighting the BMPs, the online decision-support tools, the grower workshops, ABC's associated Accelerated Innovation Management (AIM) initiative for improving irrigation efficiency, and grower grant opportunities relevant to this project (Attachment 3).

Task 4: Plan and facilitate 20 targeted education workshops for characterizing and demonstrating prioritized BMPs.
Conveying prioritized BMPs at targeted education events was key to this project. Over the course of the project, the Project Manager and other SureHarvest staff worked with ABC to plan and hold 45 workshops attended by 1,394 almond growers and handlers for characterizing the prioritized and other high-profile BMPs (Table 1 below). This included eight different series of replicated content totaling 30 workshops (see Attachment 2 for agendas) to ensure widespread dissemination of similar information to almond growers

across the Central Valley. Three series, one each in 2015, 2016, and 2017, focused on prioritized BMPs for water and nitrogen management. Likewise, three series, one each in 2015, 2016, and 2017, focused on BMPs for pest and/or honey bee management. The remaining two series, one each in 2015 and 2016, targeted BMPs for energy efficiency and air quality (especially harvest dust reduction). The balance of workshops predominantly occurred at the annual Almond Conference in Sacramento in 2014, 2015, and 2016.

To further outreach and provide content to growers not attending workshops, presentations from targeted education workshops, along with general program information, upcoming events, and relevant incentive funding opportunities, were posted on the ABC website at http://www.almonds.com/growers/sustainability.

Table 1. SCB14041 Targeted Education Workshops

Date	Location	Management Area(s)	*Priority BMP #s	# Growers & Handlers
12/9/14	Sacramento	Water	I61, I62	100
12/9/14	Sacramento	Pest	P36, P105, P151	100
12/10/14	Sacramento	Energy & Air	A35	50
12/10/14	Sacramento	Water	I61, I62	50
12/11/14	Sacramento	Pest	P36, P105, P151	50
2/26/15	Oroville	Water & Nitrogen	I61, I62, N6, N7a, N9g, N18	7
2/27/15	Woodland	Water & Nitrogen	I61, I62, N6, N7a, N9g, N18	7
3/5/15	Modesto	Water & Nitrogen	I61, I62, N6, N7a, N9g, N18	24
3/10/15	Merced	Water & Nitrogen	I61, I62, N6, N7a, N9g, N18	11
3/12/15	Visalia	Water & Nitrogen	I61, I62, N6, N7a, N9g, N18	20
3/13/15	Bakersfield	Water & Nitrogen	I61, I62, N6, N7a, N9g, N18	9
3/18/15	Bakersfield	Pest & Honey Bee	A6, A7, P36, P105	14
3/19/15	Visalia	Pest & Honey Bee	A6, A7, P36, P105	4
4/6/15	Oroville	Pest & Honey Bee	A6, A7, P36, P105	3
4/7/15	Woodland	Pest & Honey Bee	A6, A7, P36, P105	7
4/9/15	Modesto	Pest & Honey Bee	A6, A7, P36, P105	7
4/14/15	Merced	Pest & Honey Bee	A6, A7, P36, P105	4
4/23/15	Bakersfield	Energy & Air	A6, A20, A21, A34, E1, E14, E26, E35, N18	7
4/24/15	Visalia	Energy & Air	A6, A20, A21, A34, E1, E14, E26, E35, N18	2
5/1/15	Woodland	Energy & Air	A6, A20, A21, A34, E1, E14, E26, E35, N18	5
5/6/15	Merced	Energy & Air	A6, A20, A21, A34, E1, E14, E26, E35, N18	14
5/7/15	Modesto	Energy & Air	A6, A20, A21, A34, E1, E14, E26, E35, N18	8
7/29/15	Fresno	Nitrogen	N6, N7a, N9g, N18	90
12/9/15	Sacramento	Water	I61, I62	100
12/9/15	Sacramento	Water	I61, I62	100
12/9/15	Sacramento	Water, Energy, Air	I61, I62, A35, E26, E27	50
12/9/15	Sacramento	Water & Nitrogen	I61, I62, N6, N7a, N9g, N18	25
12/10/15	Sacramento	Water & Nitrogen	I61, I62, N6, N7a, N9g, N18	25

Date	Location	Management Area(s)	*Priority BMP #s	# Growers & Handlers
3/15/16	Tulare	Water & Nitrogen	I61, I62, N6, N7a, N9g, N18	12
3/16/16	Modesto	Water & Nitrogen	I61, I62, N6, N7a, N9g, N18	19
3/18/16	Chico	Water & Nitrogen	I61, I62, N6, N7a, N9g, N18	9
5/10/16	Arbuckle	Pest (Weeds)	P61, P143, P145, P151, P155, P163	17
5/11/16	Turlock	Pest (Weeds)	P61, P143, P145, P151, P155, P163	38
5/12/16	Bakersfield	Pest (Weeds)	P61, P143, P145, P151, P155, P163	25
7/7/16	Fresno	Air (Harvest Dust)	A14, A15, A16, A17, A18, A19, A20, A21	15
7/8/16	Arbuckle	Air (Harvest Dust)	A14, A15, A16, A17, A18, A19, A20, A21	13
12/7/16	Sacramento	Water	I61, I62	100
12/7/16	Sacramento	Water	I61, I62	100
12/8/16	Sacramento	Pest & Honey Bee	A6, A7, P36, P105	50
1/17/17	Livingston	Pollinator Bees	A6, A7, P36, P105	10
1/18/17	Woodland	Pollinator Bees	A6, A7, P36, P105	11
1/30/17	Fresno	Pollinator Bees	A6, A7, P36, P105	14
2/22/17	Modesto	Water & Nitrogen	I61, I62, N6, N7a, N9g, N18	23
3/2/17	Fresno	Water & Nitrogen	I61, I62, N6, N7a, N9g, N18	20
3/21/17	Williams	Water & Nitrogen	I61, I62, N6, N7a, N9g, N18	25
Total				**1,394**

Task 5: Build-out online educational content and links for prioritized BMPs.
The combination of targeted education workshops with user-friendly and -actionable enhancements to the CASP online system (educational and decision-support tools and links) were crucial for achieving the project goal of increased almond grower adoption of BMPs with low adoption rates but high environmental and economic value. For online enhancements, project funds were used to design and develop the irrigation calculator and scheduling tool, and to design and install educational pop-up guidance and user guides for all three decision-support tools: 1.) Nitrogen budgeting decision support and reporting tool, 2.) Farm mapping and reporting tool, and 3.) Irrigation calculator and scheduling tool. For additional, relevant information, the decision-support tools have links to relevant educational information on ABC, UC, and the California Department of Food and Agriculture web sites.

The irrigation tool (Figure 1 below) complements ABC's AIM initiative by helping growers adopt BMPs to increase irrigation efficiency, including those prioritized in this project. Completion of the tool's components, calculations, and user interface constituted a successful collaboration among the project manager and other SureHarvest staff, ABC staff, and UC irrigation specialists. Growers use the tool to establish and refine whole-season irrigation budgets by importing data for reference zone evapotranspiration (ETo) and rainfall from designated California Irrigation Management Information Management System (CIMIS) stations, importing weekly appropriate crop coefficients (Kc), and then calculating weekly crop evapotranspiration (ETc) with corresponding recommended run times. Growers further refine forecasted irrigation needs by entering irrigation system run times along with site-specific measures of distribution uniformity, rainfall, and soil moisture status.

Figure 1. Irrigation Calculator and Scheduling Tool

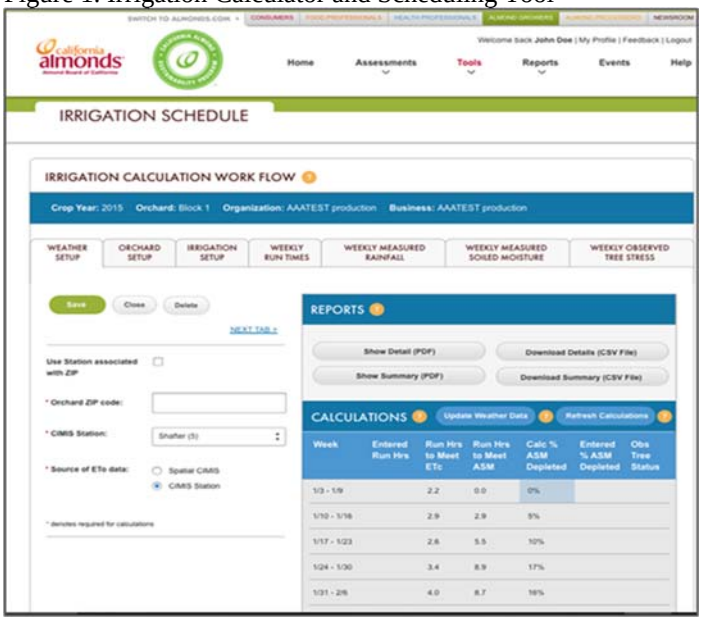
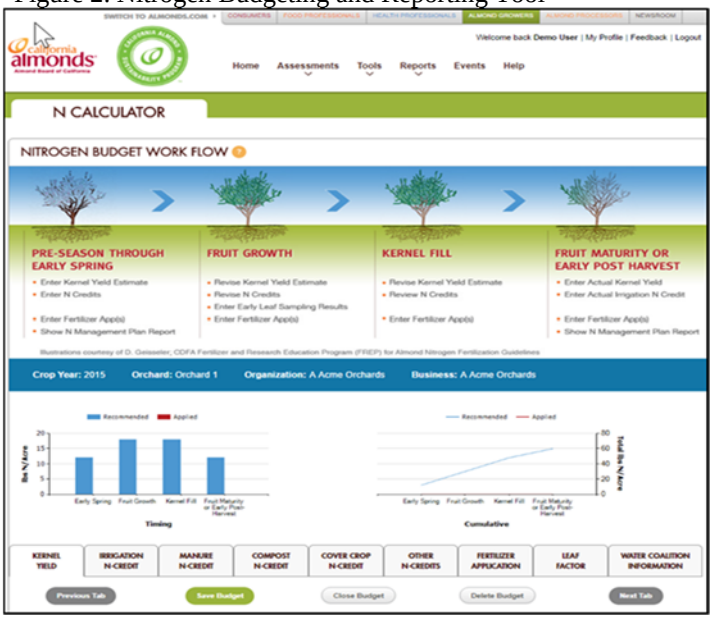


Figure 2. Nitrogen Budgeting and Reporting Tool



Use of the nitrogen (Figure 2 above) and farm mapping (Figure 3 below) tools helps growers optimize nitrogen use efficiency and meet ILRP requirements. The nitrogen tool enables growers to project nitrogen fertilizer needs by balancing nitrogen demand determined from yield estimates and early season leaf sampling with nitrogen credits from other sources. Growers also use this tool to populate, print, and save nitrogen management plans required by the ILRP. Growers use the farm mapping tool to electronically draw maps that include boundaries of fields, Assessor Parcel Numbers (APNs), and other features including wells and drainage discharge points. Completed maps are printed in a format consistent with ILRP requirements. By using these tools, growers implement numerous BMPs relevant to nitrogen management and water quality, and specifically achieve the prioritized BMP for nitrogen management plans.

Grower use of the nitrogen and irrigation tools is depicted in Figure 4 below. ABC and partners are committed to further advocating the benefits of these tools which should markedly increase future use.

Figure 3. Farm Mapping and Reporting Tool

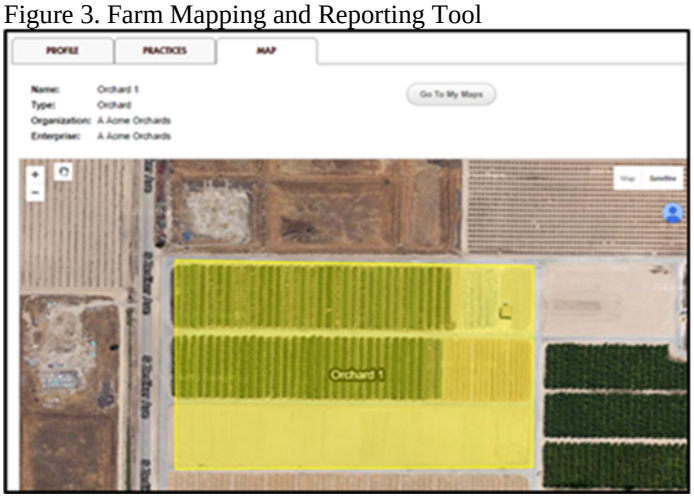
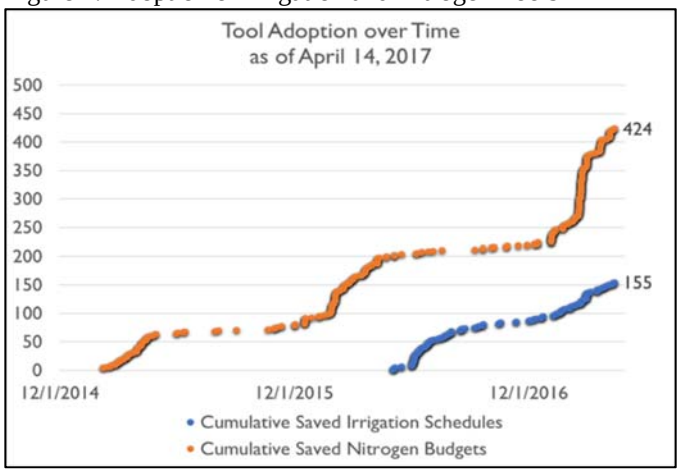


Figure 4. Adoption of Irrigation and Nitrogen Tools



Task 6: Measure and report changes in grower adoption of prioritized BMPs.
Quantifying progress in almond grower adoption of the prioritized BMPs was the key measurable outcome of success for the project. The prioritized BMPs were those CASP practices with high environmental and economic value but low adoption rates (% of orchards) after the first years of the program (2009-2013). These practices were characterized as high-value opportunities in the 2014 Almond Sustainability Report and are listed in Attachment 1. The grower adoption rates served as the baseline performance benchmarks against which to gauge future progress. Progress was first quantified in November 2016 to present interim results of targeted education efforts at the December 2016 Almond Conference. A complete statistical analysis was conducted in April 2017 to update the impacts of the targeted education activities at the end of this project. Because educational activities included focus on the mitigation of harvest dust, adoption rates for a select set of high-profile BMPs relevant to dust reduction also were analyzed.

Analysis of progress in adoption of prioritized BMPs entailed determining significant differences between assessment results for 2009-2013 (termed the 2014 Report interval) and assessment results over the project interval of 2014-2017 (termed the Post-Report interval). To qualify for testing for differences between intervals, results for each interval had to be deemed representative of the statewide industry. This was achieved by ensuring 95% confidence limits (CLs) of less than or equal to 10% based on the binomial distribution. Significant differences between intervals then were determined by normalizing the changes between intervals as Z statistics and testing for significance at a 95% level of confidence.

Attachment 4 displays the results of statistical analysis for the 17 prioritized BMPs, and four high-profile BMPs for harvest dust prevention. On the left side are columns of general descriptive information: BMP number, BMP and short name, and relevant management area(s). On the right side are columns of response statistics for each time interval: practice adoption (% Orchards), sample size (N), and 95% CL. The far-right column designates if adoption significantly increased or decreased between intervals.

For the 17 prioritized BMPs relevant to irrigation, nutrient, energy, air, and pest management, adoption significantly increased for 10 BMPs, remained unchanged for two BMPs, and significantly decreased for five BMPs. For the four high-profile BMPs for harvest dust mitigation, adoption significantly increased for two BMPs, remained unchanged for one BMP, and decreased for one BMP. In summary, adoption significantly increased for 12 of 21 (57%) of the BMPs targeted by the educational workshops and online tools supported with project funds. This demonstrates the success of the project in contributing to improvements in sustainable almond grower practices. Future educational and outreach effort outside the scope of this project should further increase use of all BMPs targeted here, especially those that showed no change or decreased in adoption.

Project activities targeted California almond growers, but achievements and results sharing have benefited and will continue to benefit and enhance the competitiveness of the entire California almond industry (growers and handlers). Tracking mechanisms used including contact information for workshop attendees, individual credentials associated with online activity, and how and with whom project activities and results continue to be shared ensure that solely the competiveness of the California almond industry is enhanced.

Key project partners included ABC, UCCE, NRCS, individual almond growers and handlers, regulatory agencies (e.g., regional water quality control boards), farm bureaus, water quality coalitions, and private industries (e.g., energy utilities and farm equipment manufacturers and retailers).

ABC staff contributed by helping organize, advertise, and make presentations at targeted education workshops; assisting with the design and development of relevant online software; and providing matching funds for workshops, targeted educational materials, and online system maintenance and development. UCCE specialists and farm advisors were invaluable in helping design and develop the online CASP nitrogen, mapping, and irrigation tools; and helping design, make presentations at, and provide educational handouts for targeted education workshops. All other partners have been instrumental in making presentations and distributing educational materials at targeted education workshops.

Goals and Outcomes Achieved

The project goal was to use CASP self-assessment, established BMP valuation methods, and 2014 Almond Sustainability Report findings to design and implement a targeted education campaign (workshops and online) to increase almond grower adoption of BMPs with low adoption rates but high environmental and grower economic benefits. This goal and associated measureable outcomes were achieved via three objectives: 1.) Apply assessment results and understandings between BMPs and environmental and economic value to prioritize grower educational needs (targeted education); 2.) Work with partners to provide the targeted education via workshops and the CASP online self-assessment and reporting system; and 3.) Measure subsequent progress in BMP adoption.

The first objective was achieved by using an established sustainability value analysis methodology to rank CASP BMPs based on environmental and economic value, and then overlaying rankings with statewide self-assessment results through July 2013 to identify BMPs with high value but low adoption rates. Through this process, 17 high-value BMPs related to irrigation, nitrogen, energy, air, and pest management were identified for targeted education (Attachment 1). As the project progressed, an additional four BMPs for harvest dust mitigation were identified and included for targeted education because of high-profile concerns with dust.

The second objective was achieved by recruiting relevant expert educators, securing and developing educational materials for grower education (workshops and online), holding workshops for characterizing and demonstrating the prioritized BMPs, and ensuring widespread dissemination of educational content through installation in the CASP online system. Achievements included 45 workshops attended by 1,394 almond growers and handlers that included presentations by the recruited team of UCCE, NRCS, ABC, respected peer growers, and other topic-specific experts. The educators made presentations, led demonstrations, and distributed educational handouts. Growers not attending workshops could access presentations and related materials at http://www.almonds.com/growers/sustainability. Online educational activities driving priority BMP adoption included the development of the irrigation calculator and scheduling tool, and the design and installation of educational pop-up guidance and user guides for this tool, the nitrogen budgeting decision support and reporting tool, and the farm mapping and reporting tool. Other educational activities promoting priority BMP adoption included three videos, four posters, and 14 trade and industry newsletter articles.

The third and final objective was achieved by determining significant differences between assessment results for 2009-2013 (termed the 2014 Report interval) and assessment results over the project interval of 2014-2017 (termed the Post-Report interval). Significant improvements were found in the adoption of 12 of the 21 BMPs (57%) targeted by the educational workshops and online tools. This demonstrates the success of the project in contributing to improvements in sustainable almond grower practices.

The measurement of significant improvements in the adoption of the 21 targeted BMPs was the key outcome measure for the project. Improvements in all 21 BMPs was the short-term target (over the project interval). Adoption has significantly increased for 12 of these BMPs, which is a marked achievement. In the long term, ABC and partners are committed to additional educational and outreach effort outside the scope of this project to increase use of all targeted BMPs.

Key goals (performance indicators) established for the reporting period were: 1.) 20 targeted education workshops attended by 400 almond growers, 2.) Series of targeted education materials for workshop attendees and for all California almond growers via online tools and information, and 3.) Significantly improved adoption rates for the 21 prioritized and high-profile BMPs. The goal for workshops was far exceeded with 45 workshops conducted and attended by 1,394 almond growers and handlers. The goal set for securing and developing education materials clearly was met through the expert presentations and materials distributed at workshops and ABC's website; and via the development of the nitrogen, irrigation, and farm mapping tools. Significant improvements in adoption for 12 of the 21 targeted BMPs was accomplished. This is a marked achievement despite not meeting the ambitious goal of improving the adoption for all targeted BMPs for the reporting period. Through additional education and outreach beyond the scope of this project, ABC and partners are committed to improving adoption for all the targeted BMPs.

Again, the measurement of significant improvements in the adoption of the 21 targeted BMPs was the key outcome measure for the project. By comparing grower self-assessment data collected before the project and at the end of the project, significant improvements in the adoption of 12 of the 21 targeted BMPs (57%) were determined. Although uses did not significantly increase for all targeted BMPs, this result represents a marked project achievement. ABC and partners are committed to additional educational and outreach effort outside the scope of this project to increase use of all targeted BMPs.

Key successful, quantifiable outcomes of the project are:

- A list of 17 priority BMPs for targeted education was developed based on environmental and grower economic value, and adoption rates measured by self-assessments prior to project start.
- In total, 45 workshops attended by 1,394 almond growers and handlers were held for characterizing the prioritized and other high-profile BMPs.
- A total of 30 of the 45 workshops constituted 8 different series of replicated content to ensure widespread dissemination of similar information to almond growers across the Central Valley.
- Online educational achievements for improving BMP adoption included the development of content for three grower decision-support tools: 1.) Nitrogen budgeting decision support and scheduling tool, 2.) Farm mapping and reporting tool, and 3.) Irrigation calculator and scheduling tool.
- Other educational accomplishments for promoting BMP adoption included three videos, four posters, and 14 trade and industry newsletter articles.
- Adoption significantly increased for 12 of the 21 prioritized and high-profile BMPs (57%) targeted by the workshops, online tools, and other project outreach. Increases in all targeted BMPs is expected through future education and outreach by ABC and partners.

Beneficiaries

Key beneficiaries include individual almond growers and handlers, the California Almond Industry, and ABC. Through the educational workshops and online tools, growers significantly increased their use of most of the

prioritized BMPs, which benefits their economic bottom line and enhances environmental protection. Continued effort by ABC and partners, outside the scope of this project, should further increase adoption. Almond handlers and ABC have benefited, and will continue to benefit, by sharing project results and BMP adoption status with commercial, regulatory, public policy, and consumer stakeholders. Having and sharing this information is crucial to ABC's "crop of choice, nut of choice" strategy and has important economic implications. Moreover, ABC has benefited by demonstrating and reinforcing their commitment to innovation and delivering value to growers and handlers. The people and environment across California have benefited, and will continue to benefit, from the improvements in natural resource conservation generated from project achievements and the continued execution of CASP activities.

All of California's estimated 6,000 almond growers and 100 handlers have been or will be beneficially affected by this project. This includes an expanded appreciation of the value of the BMPs advocated by the project, which has resulted in significantly increased adoption for 57% of the targeted BMPs to date. Because of these cost-effective and environmentally friendly on-the-ground improvements, almond growers will benefit economically and the environment will benefit from natural resource conservation and enhanced quality. Moreover, all California almond growers and handlers will benefit from the industry messaging and improvement in reputation management resulting from project achievements. Because of the issues that continue to confront the industry, it is crucial to advocate the commitment by growers and handlers to continuously improve their practices.

Lessons Learned

The lesson reinforced by this project is the importance of extensive, committed partnerships among agricultural industry, university and private researchers and extension staff, government personnel, and others for negotiating changes in grower behavior. The linking of value (economic and environmental) to prioritized BMPs provided tangible understandings of the benefits of using the advocated practices and decision-support tools. The combination of effective partnerships and innovative "what's in it for me" messaging produced the improvements targeted by the project.

There were no unexpected outcomes or results. A significant improvement in 57% of the targeted BMPs is a marked achievement. It is expected that ongoing effort outside the scope of this project will further increase adoption of all BMPs targeted by this project.

All goals and outcome measures were achieved.

Additional Information

Information referenced but not included in prior sections is in Attachments 1-4.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
42	Improvement of Grapevine Health Monitoring	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB14042	**Date Submitted:** December 2016
Recipient Contact: Adib Rowhani	**Telephone:** (530) 752-5401	**Email:** akrowhani@ucdavis.edu

Project Summary

In order to keep vineyards free of disease in California, imported grapevine stocks are monitored by the United States Department of Agriculture, Animal and Plant Health Inspection Service (APHIS) and the California Department of Food and Agriculture (CDFA) before release to the field. New accessions would undergo a lengthy bioassay certification process, using indicator plants. The project team proposed a technological improvement to this certification process, a genomics assay more sensitive and less expensive than the current standard. It would allow grape growers to avoid the current multi-year delays in putting new accessions into profitable production. The goal of the project was to facilitate a change in the APHIS and the CDFA regulatory standard for certification of imported grapevine varieties. The project team sought to provide to the regulatory decision makers the data that would substantiate the call for a new certification procedure.

Growers currently faced delays of at least two years in the release of candidate grapevine accessions from import quarantine to profitable production. That time was consumed in biological index testing for the presence of viral disease. This project was meant to show that High Through-put Sequencing ("HTS," formerly called Next Generation Sequencing, "NGS") analysis was better and cheaper at pathogen detection than the current bioassay. HTS was faster, and could reduce the certification time from years to weeks for vines that prove to be uninfected, and reduced delays to the onset of cleaning and propagative increase procedures by the same amount of time, for material that does prove to be infected. The savings of years of time should significantly improve the competitiveness of the growers.

The project did not build on a previously funded Specialty Crop Block Grant Program project.

Project Approach

Over the course of this grant, the project team gathered grapevine samples and made extracts from the same test plants, purified total nucleic acids (RNA and DNA) and/or double-stranded RNA (dsRNA), and prepared cDNA from total genomic RNA libraries. Those total genomic libraries contained the sequences of all the genomic sequences of the plants and the viral pathogens within them. The RNA and DNA sequences from those libraries were generated by commercial deep sequencing facilities. Bioinformatic techniques were used to catalog all the RNA sequences from each sample using dedicated computer programs, including the CLC Genomics Work Station. A list was generated of all the pathogen sequences from each sample through Basic Local Alignment Search Tool (BLAST) analysis and contig assembly. The project team evaluated cost- and time-saving approaches to use HTS to minimize the time and expense of grapevine certification. Outreach was conducted to the stakeholder community through discussions, publication of the results of the study and presentation at grape growers meetings.

Results were made available for use by the regulatory agencies in their consideration of a change to the certification process to include HTS. The project team demonstrated that HTS analysis was more rapid and reliable than the current bioassay process, and that it should be acceptable as the default diagnostic technique for routine application in grapevine certification.

The only commodity the project benefited was grapevine. The accounting department helped to track expenditures and ensure that funds were used to solely enhance the competitiveness of specialty crops.

This project was carried out without contributions from other project partners.

Goals and Outcomes Achieved

HTS was used to catalog the viral sequences from more than 50 test vines (see Tables 1 and 2). Those same vines were also assayed using the standard bioassay procedures. The project team evaluated cost- and time-saving approaches of HTS over the standard bioassay. It was demonstrated that HTS minimized the time and expense of grapevine certification compared to the bioassay process. Data was published for use by the regulatory agencies in their consideration of a change to the certification process. The findings were described to the stakeholder community through discussions, industry meetings, and by publication of the results of the study in trade journals. The primary findings were published as: Al Rwahnih et al 2015 Comparison of Next-Generation Sequencing Versus Biological Indexing for the Optimal Detection of Viral Pathogens in Grapevine; Phytopathology 105, p758-763. Further completion of the outreach performance goals entailed the descriptions of a previously unknown, possibly pathogenic virus in grapevine discovered in the course of this research, published as: Al Rwahnih, M., Alabi, O., Westrick, N. M., Golino, D., Rowhani, A. 2016. Description of a novel monopartite geminivirus and its defective subviral genome in grapevine. Phytopathology in press.

All project activities were completed over the course of the duration of the grant period.

All of the goals set out to reach in the goals statements described in the initial proposal were met.

The data on the final 56 samples from the analysis generated during the completion of this project are included below. This data demonstrated the improved pathogen detection afforded by HTS analysis, compared to the parallel results generated from the bioassay used in the standard certification process. The bioassay data is listed in Table 1, showing test results for biological indicator hosts CF (Cabernet franc), LN33 (rootstock), St G (St. George rootstock, detecting three pathogens), Kober 5BB (rootstock), and the herbaceous indicators; the HTS data for the same plants is listed separately in Table 2. This data provided a comparison between qualitative biological indexing results on the set of eight test plant sources (four field indicators and four herbaceous hosts including *Chenopodium quinoa*, *C. amaranticolor*, cucumber seedlings, and *Nicotiana clevelandii*) with a laboratory diagnostic panel (qualitative PCR results) versus the computer-generated HTS results.

Bioassay data was produced on four different grapevine cultivars and rootstocks and on a panel of herbaceous hosts (Herb). Indicators used were: a) *Vitis vinifera*, cv Cabernet franc (CF), b) hybrid rootstock LN33, c) *V. rupestris* cv St. George (St. G) and d) Kober 5BB. CF is an indicator for leafroll disease (LR) which is caused by four different viruses and their strains, associated with leafroll disease. LN33 detects corky bark disease (CB) caused by *Grapevine virus B* (GVB); St. G detects Rupestris stem pitting disease (RSP) caused by

Grapevine rupestris stem pitting associated virus (GRSPaV), Fleck disease (Fk) caused by *Grapevine fleck virus* (GFkV), and fanleaf degeneration disease (Nepo) caused by *Grapevine fanleaf virus* (GFLV). Kober 5BB detects Kober stem grooving disease (SG) caused by *Grapevine virus A* (GVA). Herbaceous hosts (Herb) includes *Chenopodium quinoa*, *C. amaranticolor*, cucumber seedlings, and *Nicotiana clevelandii* which detect number of different viruses in the genus *Nepovirus*. N/T represents those not tested.

Table 1. Bioassay data produced on four different grapevine cultivars and rootstocks and on a panel of herbaceous hosts (Herb).

Sample No.	Dis. Detected	CF	LN33	St. G RSP	St. G Fk	St. G Nepo	Kober 5BB	Herb.
1	CB, RSP, Nepo, SG	-	+	+	-	+	+	+
2	LR, RSP, Fk, SG	+	-	+	+	-	+	-
3	RSP, CB	-	+	+	-	-	-	-
4	LR, FB, RSP, SG	+	+	+	-	-	+	-
5	LR, RSP, SG	+	-	+	-	-	+	-
6	LR, SG, CB, RSP	+	+	+	-	-	+	-
7	LR, RSP	+	-	+	-	-	N/T	-
8	LR, RSP, Nepo	+	-	+	-	-	-	+
9	CB, RSP, Fk	-	+	+	+	-	N/T	-
10	LR, RSP, SG	+	-	+	-	-	+	-
11	LR, CB	+	+	-	-	-	N/T	-
12	RSP	-	-	+	-	-	-	-
13	LR, CB, RSP, Fk	+	+	+	+	-	-	-
14	LR, CB, RSP	+	+	+	-	-	-	-
15	LR, RSP	+	-	+	-	-	-	-
16	LR, CB, RSP	+	+	+	-	-	-	-
17	LR, CB, RSP, Fk, SG	+	+	+	+	-	+	-
18	LR, CB, Fk	+	+	-	+	-	-	-
19	LR, RSP	+	-	+	-	-	-	-
20	LR, RSP, Fk	+	-	+	+	-	-	-
21	LR, CB, RSP, Fk	+	+	+	+	-	N/T	-
22	LR, CB, RSP, Nepo	+	+	+	-	+	N/T	-
23	LR, Fk	+	-	N/T	+	-	N/T	-
24	LR, Fk	+	-	N/T	+	-	N/T	-
25	LR, CB, RSP	+	+	+	-	-	N/T	-
26	RSP	-	-	+	-	-	-	-
27	LR, RSP, Nepo, CB	+	+	+	-	+	N/T	+
30	LR, CB, RSP	+	+	+	-	-	N/T	-
32	Fk	-	-	-	+	-	N/T	-
33	LR, RSP, Fk	+	-	+	+	-	-	-
34	LR, RSP, Fk, Nepo	+	-	+	+	+	N/T	-
35	Fk, Nepo, RSP	-	-	+	+	+	N/T	-
36	LR, Fk, RSP	+	-	+	+	-	N/T	-
37	LR, CB, RSP, SG	+	+	+	-	+	N/T	-
38	-	-	-	-	-	-	N/T	-
42	-	-	-	N/T	-	-	N/T	-
43	-	-	-	N/T	-	-	N/T	-
44	-	-	-	N/T	-	-	N/T	-

Sample No.	Dis. Detected	CF	LN33	St. G RSP	St. G Fk	St. G Nepo	Kober 5BB	Herb.
45	LR	+	-	N/T	-	-	N/T	-
46	LR, CB	+	+	N/T	-	-	N/T	-
47	LR	+	-	-	-	-	N/T	-
48	LR	+	-	N/T	-	-	N/T	-
50	-	-	-	-	-	-	-	-
52	LR	+	-	N/T	-	-	N/T	-
53	LR	+	-	-	-	-	N/T	-
54	-	N/T	N/T	N/T	N/T	N/T	N/T	-
65	LR, Fk, Nepo	+	-	N/T	+	+	N/T	-
66	LR, Fk, Nepo	+	-	N/T	+	+	N/T	-
67	Nepo	-	-	N/T	-	+	N/T	+
83	-	-	-	-	-	-	-	-
84	-	-	-	-	-	-	-	-
85	-	-	-	-	-	-	-	-
86	-	-	-	-	-	-	N/T	-
87	-	-	-	-	-	-	N/T	-
88	-	-	-	-	-	-	N/T	-
89	LR	+	-	N/T	-	-	N/T	-

The data produced HTS from the same samples listed in Table 1 are shown in Table 2. Available RT-PCR data (PCR(+)) are also presented in this table. Abbreviations include: *Grapevine redglobe virus* (GRGV), *Grapevine syrah virus 1* (GSyV-1), *Grapevine asteroid mosaic virus* (GAMV), *Grapevine rupestris stem pitting associated virus* (GRSPaV), *Hop stunt viroid* (HSVd), *Grapevine leafroll associated virus* (GLRaV-1), *Grapevine vein feathering virus* (GVFV), *Grapevine fleck virus* (GFkV), *Grapevine virus F* (GVF), *Grapevine red blotch associated virus* (GRBaV), *Grapevine virus E* (GVE), *Tomato ringspot virus* (ToRSV), *Grapevine yellow speckle viroid* (GYSVd), *Grapevine reovirus* (GReV), *Grapevine deformation virus* (GDefV), *Arabis mosaic virus* (ArMV), *Grapevine faba virus* (GFabV) and the bacterial pathogen *Xylella fastediosa* (Xf)

Table 2. Data produced by high throughput sequencing (HTS) from the same samples listed in Table 1

Sample No.	Source plant PCR(+)	Viruses detected by HTS	Infections Missed by Bioassay/PCR	Infection Missed by HTS
1	GFLV, GRGV, GSyV-1, GAMV, GVB, GRSPaV	GFLV, GVB, GSyV-1, GVA, HSVd		
2	GLRaV-1, GVA, GRSPaV	GLRaV-1, GRSPaV, GVFV, GVA, GFkV, GVF		
3	GLRaV-2, GRSPaV	GLRaV-2, GRSPaV, GVB	GVB	
4	GLRaV-1, GLRaV-2, GLRaV-3, GVA, GVB, GRSPaV, GLRaV-5	GLRaV-5, GLRaV-2, GLRaV-1, GLRaV-3, GVB, GVA, GRSPaV		
5	GRBaV, GLRaV-2, GRSPaV	GLRaV-3, GRSPaV, GLRaV-2, GVA, GSyV-1, GLRaV-1, GLRaV-5, GRBaV		
6	GLRaV-2, GVA, GVB, GRSPaV	GLRaV-3, GLRaV-2, GVB, GRSPaV, GLRaV-1, GFLV, HSVd	GFLV	GVA
7	GRSPaV	GLRaV-3, GVB, GRSPaV, GVA, GLRaV-1, GVE	GVB	
8	ToRSV, GLRaV-3, GRSPaV	GLRaV-3, GRSPaV, ToRSV		
9	GRBaV, GLRaV-2, GLRaV-3, GVB, GRSPaV, GFkV	GLRaV-2, GRSPaV, GLRaV-3, GVB, GFkV, GRBaV		
10	GLRAV-2, GLRaV-3, GVA, GRSPaV	GLRaV-3, GLRaV-2, GRSPaV, GVA, GSyV-1		

Sample No.	Source plant PCR(+)	Viruses detected by HTS	Infections Missed by Bioassay/PCR	Infection Missed by HTS
11	GLRaV-2, GLRaV-3, GVB, GRSPaV	GRSPaV, GLRaV-3, GLRaV-2, GVB, GLRaV-7, GYSVd		
12	GRSPaV	GRSPaV,GLRaV-3,GLRaV-2,GVA	GLRaV-2, -3 and GVA	
13	GLRaV-3, GVA, GVB, GRSPaV	GLRaV-4, GLRaV-4Pr, GSyV-1, GRSPaV, GLRaV-3, GYSVd, HSVd, GVFV	GFkV	GVB
14	GLRaV-3, GVA, GVB, GRSPaV	GLRaV-3, GRSPaV, GVA, GLRaV-10, GLRaV-2, GLRaV-4, GSyV-1, GVB	GVA	
15	GLRaV-2, GLRaV-4, GRSPaV	GLRaV-4, GLRaV-3, GLRaV-2, GRSPaV, GLRaV-4, GVFV		
16	GLRaV-2, GVB, GRSPaV	GLRaV-2, GRSPaV, GRVFV, GVB, GLRaV-3, GVA	GVA	
17	GFLV, GSyV-1, GLRaV-2, GRLaV-3, GVB, GVA, GRSPaV	GLRaV-2, GLRaV-3, GRSPaV, GVA, GVB, GLRaV-4, GLRaV-10, GFLV, GLRaV-6, GSyV-1, GLRaV-5, GFkV	GFkV	
18	GRBaV, GLRaV-2, GVB, GRSPaV, GFkV	GLRaV-2, GRSPaV, GLRaV-3, GVB, GSyV-1, GFkV, GRBaV		
19	GLRaV-9, GRSPaV	GRSPaV, GLRaV-3, GLRaV-2, GVA, GLRaV-9,	GVA	
20	GLRaV-2, GLRaV-3, GVB, GRSPaV, GFkV	GLRaV-3, GRSPaV, GLRaV-2, GFkV, GVB, GReV	GReV a new novel virus discovered	
21	GLRaV 1,GLRaV-3,GRSPaV,GVA	GLRaV-4, GVA, GLRaV-5, GSyV-1, GLRaV-1, GLRaV-6, GLRaV-3, GRSPaV, GFkV, GVB		
22	GFkV, GFLV, GLRaV- 1, GLRaV 3, GRSPaV, GVA, GVD	GRSPaV, GLRaV-2, GFLV, GVA, GAMV, GVB, GLRaV-3, GLRaV-1, GFkV, GSyV-1, GDefV		
23	GFkV, GLRaV-1, GLRaV 3, GRSPaV, GVA	GLRaV-3, GRSPaV, GLRaV-2, GVA, GRBaV, GLRaV-1, GLRaV-5, GFkV, GLRaV-10, GSyV-1		
24	GFkV, GLRaV-1,-GRSPaV, GVA, GLRaV-3	GRSPaV, GVFV, GLRaV-1, GLRaV-3, GFkV, GVA, GPGV, GYSVd		
25	GLRaV-1, GLRaV 3, GRSPaV, GVA, GVB, GVD	GLRaV-6, GLRaV-3, GVA, GVF, GLRaV-1, GRSPaV, GVB		
26	GVFV	GRSPaV	GRSPaV	
27	GFkV, GFLV, GLRaV-1, GLRaV-3, GRSPaV, GVA	GLRaV-3, GLRaV-1, GVA, GRSPaV, GSyV-1, GDefV, GFLV, GFkV, ArMV		
30	GLRaV 1, GLRaV-2, GVA, GVB	GLRaV-1, GVF, GVA, GLRaV-10, GVB, GLRaV-3, GRSPaV, GSyV-1, GLRaV-2, GFkV	GFkV	
32	GFkV	GRSPaV, GFkV, GLRaV-10, GLRaV-2, GLRaV-3	GLRaV, GRSPaV	
33	GVB, GFkV, GLRaV-2	GRBaV, GRSPaV, GLRaV-7, GLRaV-6, GLRaV-4, GLRaV-2, GVF, GVE, GFkV, GVA, GVB, GSyV-1, GLRa-5, GLRaV-1	GVA	
34	GRSPaV, GFLV	GEEV, GFLV, GLRaV-3, GLRaV-2, GRBaV, GFkv, GLRaV-5, GLRaV-1, GLRaV-10, GVE, GSyV-1, GLRaV-2RG, GVF, GLRaV-4, GLRaV-6, GRSPaV,		
35	GFLV, GRSPaV	GRSPaV, GSyV-1, GFLV, GLRaV-3	GLRaV-3	
36	GLRaV-3, GRSPaV, GFkV, GLRaV-2	GLRaV-3, GRSPaV, GSyV-1, GLRaV-2, GFkV, GVB	GVB	
37	GLRaV-3, GRSPaV, GVA, GVB, GLRaV-2	GLRaV-3, GVA, GVB, GRSPaV, GLRaV-2, GSyV-1, GLRaV-10		
38	No virus detected	GYSVd		
42	GRSPaV	GRSPaV GLRaV-1	GLRaV-1	

Sample No.	Source plant PCR(+)	Viruses detected by HTS	Infections Missed by Bioassay/PCR	Infection Missed by HTS
43	GRSPaV	GRSPaV		
44	P-GRSPaV	GLRaV-3, GFkV, GSyV-1, GLRaV-4, GLRaV-7, GLRaV-10, GLRaV-6, GLRaV-1, GFLV, GRSPaV, GLRaV-5, GLRaV-2,	GFLV, GFkV	
45	GLRaV-3, GRSPaV, GVE	GLRaV-3, GRSPaV, GVE, GLRaV-1, GFkV	GFkV	
46	GLRaV-3, GRSPaV, GVE, GRBaV	GLRaV-3, GFkV, GRSPaV, GVE, GLRaV-5, GLRaV-1, GLRaV-2, GRBaV GLRaV-7,GVB	GFkV	
47	GLRaV-3, GRSPaV, GRBaV	GRSPaV, GLRaV-3, GLRaV-10, GFkV, GLRaV-1, GRBaV, GVF, GSyV-1, GLRaV-2, GLRaV-4, GLRaV-6, GLRaV-7	GRSPaV, GFkV	
48	GLRaV-3, GVA	GLRaV-3, GVE, GVA, GLRaV-1, GLRaV-2, GFLV, GFkV	GFkV, GFLV	
50	No virus detected	GLRaV-3	GLRaV-3	
52	GLRaV-3, GRSPaV, GVE	GLRaV-3, GRSPaV, GVE		
53	GLRaV-3, GVA	GLRaV-3, GVA, GSyV-1		
54	Xf	GLRaV-3, GRSPaV, GRBaV, GSyV-1, Xf		
65	GFkV, GLRaV-3, GRSPaV, GVE, GFabV	GVE, GRSPaV, GVFV, GLRaV-3, GFkV, GYSVd, HSVd, GFabV	GFabV a new novel geminivirus discovered	
66	GFkV, GLRaV-2, GLRaV-3, GFabV	GLRaV-2, GLRaV-3, GVFV GFkV, GYSVd, HSVd, GFabV	GFaBV a new novel geminivirus discovered	
67	GFLV	GFLV, GDefV, ArMV		
83	GPGV	GPGV, GYSVd-1		
84	GRSPaV	GSYV-1, GVFV, GRSPaV, HSVd, GYSVd-1		
85	No virus detected	HSVd		
86	GRBaV	GRBaV, GSyV-1, GYSVd		
87	GRBaV	GRBaV, GSYVd-1		
88	No virus detected	GSYVd		
89	GLRaV-2	GLRaV-2, GFLV		

The project sought to modify the protocols required by the governmental agencies that oversee the Certification of grapevines in California, for the benefit of the grape growing industry. The beneficial outcome of the project will become apparent when the certification protocols are officially modified, and the improved protocols are implemented.

Beneficiaries

The California grape growing industry stood to benefit in terms of time and cost savings from the revision of the certification standards as per the proposal. The revision of those standards is currently under consideration by the governmental oversight agencies.

Each of the more than 300 commercial vineyard operations in California would be affected to some extent by the revision of the certification process, as described by the findings from this research.

Lessons Learned

From this work, the project team gained an appreciation of the qualitative and quantitative superiority of the automated analytical process of virus detection, compared to the more classical diagnostic approach that is still in use.

The project team discovered a set of previously undescribed grapevine viral pathogens over the course of this research.

Additional Information

No additional information

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 43	**Project Title:** Disease Forecasting of Spinach and Lettuce Downy Mildew to Foster Best Management Practices	
Grant Recipient: United States Department of Agriculture, Agricultural Research Service	**Grant Agreement No.:** SCB14043	**Date Submitted:** December 2017
Recipient Contact: Steve Klosterman	**Telephone:** (831) 755-2845	**Email:** steve.klosterman@ars.usda.gov

Project Summary

Downy mildew diseases caused by *Peronospora effusa* on spinach and by *Bremia lactucae* on lettuce are the major disease constraints in California. Both diseases cause severe damage to the leaves, rendering the fresh product unmarketable. Though these diseases can be managed with the application of fungicides, it is costly to routinely apply fungicides to prevent establishment of downy mildew. In 2012, there were nearly 83,000 applications of 11 fungicides recommended for use in the management of downy mildew on lettuce and spinach in California. These applications translated to a cumulative total of 923,000 treated acres. The cost of a single fungicide application on lettuce is nearly $65 per acre, and a grower might use four applications per cropping season. Using these values, the aggregate cost for downy mildew control on both crops was approximately $60 million in California. In addition to the direct costs, routine fungicide applications can lead to fungicide resistance in the pathogen. Also, there is an increasing demand to limit chemical inputs due to their potentially negative environmental impacts. This may curtail product availability for effective management of these diseases, especially since the usage of only one or a few products may increase fungicide resistance in pathogen populations. In view of these concerns, the overall objective of the project is to deploy a downy mildew detection system in the field for the development of disease forecast models for both spinach and lettuce downy mildew based on which the frequency of fungicide applications can be reduced. An additional component of the project is to try to identify protein-protein interactions in the spinach downy mildew pathogen interaction, to identify the molecular basis of race for diagnostic and breeding purposes. This will be critical for breeding programs that aim to more quickly develop plant resistance to the different races of the pathogen.

The project remains timely because new races of downy mildew, for which there may be no host resistance, have been appearing at an increased pace. Of the 16 recognized races of spinach downy mildew, 12 appeared within the last 15 years and novel pathotypes have been similarly recovered in lettuce downy mildew. Therefore, it is difficult to match the pace of appearance of these new races of downy mildew with new resistant crop varieties. A reduction in at least one fungicide application across lettuce and spinach crops for the management of downy mildew in California could potentially save these industries approximately $15 million. Additionally, growers stand to benefit from improved disease management through better timed applications as well as fungicide resistance management. With increasing use of selected fungicides it is inevitable that the downy mildew population will develop resistance against some of these commonly used products, leaving the grower with fewer options for effective control. Of equal importance is the benefit accrued to growers as well as the public from the reduced usage of commonly used fungicides that have negative or unwanted environmental impacts. The role of seedborne downy mildew inoculum in transmitting the disease is also critically important to reducing spread of the pathogen; and this project demonstrated that nearly 20% of modern spinach seed lots are infested with downy mildew. The project will also generate

knowledge for further limiting the introduction of primary inoculum. Lettuce and spinach specialty crops in Arizona will also benefit since much of the United States' winter (November through early April) lettuce and spinach supply for California bagged salad companies is grown principally through a shift in production to Arizona, where downy mildews are also disease constraints. Identification of the environmental conditions that favor increased airborne downy mildew inoculum will have impacts in California and nationally on management decisions that concern related downy mildew diseases on other specialty crops.

This project did not build upon a previously funded Specialty Crop Block Grant Program (SCBGP) project.

Project Approach

Specific tasks included quantifying and cataloging the amounts of DNA of the downy mildew pathogens *Bremia lactucae* and *Peronospora effusa* obtained from spore traps in the field over time. Staff contacted growers about placing spore traps in additional fields in the Salinas Valley, and collected downy mildew-infected leaf samples from spinach and lettuce in fields for use in assay testing. Staff maintained spore traps, and collected samples from spore traps as applicable, and extracted DNA from these samples, and used these samples to conduct molecular marker testing for downy mildew detection of both spinach and lettuce pathogens. Staff worked on developing a model to determine optimal conditions favoring downy mildew using 1) spore concentration, and 2) weather data. Staff completed the monitoring downy mildew pathogen near three grower fields in Salinas, in 2016, in relation to spore trap calculations of pathogen DNA present. Staff advised a collaborator on the project to spray the field with fungicide based upon the level of airborne downy mildew detected. Staff compared the results of disease control obtained with regular calendar based fungicide sprays. In the current period, where three different lettuce crops were evaluated, staff were able to reduce spray application by 1.7 applications on average, for three crops evaluated. This is a significant accomplishment since staff originally set out to determine if this was possible. A manuscript describing these results is in preparation. Staff initiated work on the yeast two-hybrid assays for identifying interacting proteins of the spinach downy mildew pathogen and spinach, but have not identified interacting proteins yet. The Project Director (PD) also invited industry members in a workshop format to examine spinach downy mildew symptoms in fields in Salinas, and to also demonstrate the spore trap usage.

Below are six publications that have emanated from this grant. Staff are preparing two additional manuscripts for publication on lettuce and spinach disease predictions based on spore trapping results.

Publications:

Choudhury, R. A., Koike, S. T., Fox, A. D., Anchieta, A., Subbarao, K. V., Klosterman, S. J., McRoberts, N. Spatiotemporal patterns in the airborne dispersal of spinach downy mildew. 2017. Phytopathology 107:50-58.

Choudhury, R.A., Garrett, K. A., Klosterman, S. J., Subbarao, K. V., McRoberts, N. A framework for optimizing phytosanitary thresholds in seed systems. 2017. Phytopathology 107:1-10

Klosterman, S.J. 2016. Spinach downy mildew – Threat, prevention and control. Progressive Crop Consultant 1:12-15.

Kunjeti, S. G., Anchieta, A., Martin, F. N., Choi, Y.-J., Thines, M., Michelmore, R. W., Koike, S. T., Tsuchida, C., Mahaffee, W., Subbarao, K. V., Klosterman, S. J. 2016. Detection and quantification of *Bremia lactucae* by spore trapping and quantitative PCR. Phytopathology 106:1426-1437

Kunjeti, S. G., Anchieta, A., Subbarao, K. V., Koike, S. T., Klosterman, S. J. 2016. Plasmolysis and vital staining reveal viable oospores of *Peronospora effusa* in spinach seed lots. Plant Disease 100:59-65.

Choudhury, R. A., Koike, S. T., Fox, A. D., Anchieta, A., Subbarao, K. V., Klosterman, S. J., McRoberts, N. 2016. Season-long dynamics of spinach downy mildew determined by spore trapping and disease incidence. Phytopathology 106:1311-1318.

In addition to the documented publications above, the PD, Co-PDs, and Postdoctoral Researcher (PR) on the project disseminated project results in 12 oral presentations. These presentations included six oral presentations to the California Leafy Greens Research Program in Pismo Beach, Coalinga, and Salinas, California. The PD presented research results to nearly 200 growers and pest control advisors at the annual Plant Disease Seminar (November 2015), hosted by another Co-PD on this project. One presentation by the PD was also made to the California Seed Association (September 2016) attended by California spinach and lettuce growers and also another presentation was delivered by the PD on spore trapping and airborne downy mildew quantification at the International Spinach Conference held in Yuma, Arizona in February 2015. A broad audience was reached at oral presentations on downy mildews given at national meetings in 2015 in Pasadena, California and 2016 in Tampa, Florida. Each of these presentations acknowledged support from the SCBGP. Staff disseminated project results in August 2017 at an invited technical presentation at the American Phytopathological Society meeting in San Antonio, Texas.

The SCBGP funds were used to solely enhance the competitiveness of specialty crops of spinach and lettuce.

There has been significant contributions by all of the project Co-PDs throughout the project. One Co-PD provided detailed weather data to accompany the spore trap data obtained in the Salinas Valley. One Co-PD sprayed fungicides on plots within commercial fields on a calendar spray basis about every 10 days and also as advised based upon the spore trap result. Another Co-PD was involved in co-supervising the PR in development and deployment of the sensitive *Bremia lactucae* molecular assay previously developed by the PR in this project. Three Co-PDs analyzed data, along with the PD and PR.

Goals and Outcomes Achieved

Progress toward achieving the goal to quantify the levels of the lettuce and spinach downy mildew pathogens in the environment were monitored by the quantities of inoculum detected and whether the assay is specific for the detection of one or both pathogens. Staff were able to detect the equivalent of a single spore of the lettuce downy mildew pathogen. For the goal to correlate downy mildew-conducive weather conditions for both spinach and lettuce downy mildew with spore loads, weather data were collected daily during experiments and analyzed to monitor conditions in relation to disease occurrences. In support of both of those goals, data on downy mildew pathogen quantities was collected from at least two spore traps in the Salinas Valley at regular 48 or 72 hour intervals over a 10 month period, and repeated for two consecutive years, in 2015 and 2016, and again in 2017 for lettuce and spinach downy mildew detection and quantification. For the long term expected measurable outcome from this project which concerns the adaptation by growers of best management practices for downy mildew, a survey was conducted. The survey was conducted at the outset of

the project. The participants were asked to rate questions on a 1 to 10 scale, in addition to yes/no format and multiple choice. Staff were not able to administer the later survey for the project because they could not implement the disease model soon enough. Thus growers could not determine if implementation of the findings reduced fungicide applications and the likelihood of growers and Pest Control Advisers (PCAs) using a forecast. Similarly, staff could not survey if there were reductions in fungicide application and by how many. The population surveyed included growers and PCAs most likely to implement best management practices for downy mildew. The ideal audience is in Salinas each year during the plant disease seminar held by the Co-PD.

A long term measurable outcome of this project is the adaptation by growers of best management practices for downy mildew for lettuce and spinach at a field and a regional scale. A performance measure for this outcome included the numbers of growers that have adapted the knowledge obtained from the project and the number of fungicide applications reduced. Because staff have not produced a disease risk model for growers to follow and its posting online, staff could not make a final assessment of a savings in fungicide applications for spinach or lettuce. However, in research from this project, in a manuscript near completion for publication, staff describe the savings of 1.7 fungicide applications over three different lettuce crops.

The word has spread about the spinach downy mildew pathogen continuously being imported to California on infested spinach seed. Thus, growers are requesting clean seed or treated seed from those that produce seed outside of the state. As indicated in the original outcome measures, the findings of the project reached interested specialty crop stakeholders through online publications. The PD and Co-PDs produced eight publications including two online industry reports (please see Additional Information section). One of the trade journal articles from this project was published in a journal viewed over 6,000 times by agricultural professionals in California.

Goal: Staff prepared and conducted grower/PCA surveys; assess results by scoring on the 1-10 value scale and yes/no answers.
Accomplishment: Completed for the 2014 year but not the remaining years of the project.

Goal: Establish low medium high disease risk classifications for lettuce and spinach downy mildew.
Accomplishment: Staff contacted growers about placing spore traps in additional fields in the Salinas Valley and collected downy mildew-infected leaf samples from spinach and lettuce in fields for use in assay testing; maintained a dozen spore traps, and collected hundreds of samples from spore traps, and extracted DNA for downy mildew detection; catalog and store DNA for future testing. Staff quantified airborne inoculum for both spinach and lettuce downy mildew pathogens over time in and round commercial fields and test plots, and verified correct target sequences from each of the downy mildew pathogens. Staff assessed disease incidence in the field in relation to spore traps placed in and around spinach and lettuce fields. Staff collected weather data including temperature, relative humidity, wind speed and direction, rain, and leaf wetness and analyzed this in relation to inoculum load, but found this difficult to associate clear weather patterns with mildew load observed thus far (however, additional lags need to be accounted for as discussed elsewhere). Staff determined advisements for lettuce downy mildew based on airborne spore load, but these were not shared online with specialty crop growers through a webpage.

Goal: Conduct molecular marker testing for downy mildew detection of both spinach and lettuce pathogens simultaneously.

Accomplishment: Detection of both spinach and lettuce pathogens simultaneously in the same assay proved difficult to achieve as the there was a drop off in efficiencies of detection reactions when used together for simultaneous detection. However, staff routinely detected either pathogen and quantified them independently using methods established and developed in this project.

Goal: Examine protein-protein interaction to identify additional race specific detection markers for spinach downy mildew.
Accomplishment: Staff purchased the kit for examining protein-protein interaction and began to prepare the appropriate vectors, but have not used these experimentally to identify interactors for race specific marker development.

Goal: Monitor number of views of the online downy mildew advisory site.
Accomplishment: This goal to set up and monitor online downy mildew advisory site was not accomplished because the disease model is not yet in place at the end of the project.

Among the survey data, growers and PCAs were asked if they were aware of efforts to develop downy mildew disease forecasting for spinach and lettuce to which 100% of the respondents reported Yes. They were further asked "Do you think that a downy mildew disease forecast system would be useful? Please rate on a 1-10 scale with 10 being highly useful and 1 as not useful." The average response to this question was 8.8, indicating the overall importance of project goals. The growers or PCAs were also asked "On average, how many annual fungicide applications are used per crop for either spinach or lettuce for control of downy mildew?" Ten of the respondents indicated that the number of fungicide applications was greater than or equal to three applications. Among the eight growers responding to the survey, six of the eight indicated that they grow > 1000 acres of spinach and lettuce annually and a single respondent indicated < 200 acres. Three of these growers produced spinach and lettuce crops in both coastal and southern desert areas in California, while one of the growers grew both spinach and lettuce in the San Joaquin Valley. Only two of the growers responding had production limited to central coastal California. Surprisingly, among all of the growers and PCAs surveyed, they indicated that on average >4 different fungicide chemistries are applied annually. Staff originally intended later surveys to assess the savings in fungicide applications from the growers and PCAs, but because they could not release the disease risk model in time, they could not conduct these additional surveys during the project period.

Progress toward achieving the goal to quantify the levels of the lettuce and spinach downy mildew pathogens in the environment were monitored by the quantities of inoculum detected and whether the assay is specific for the detection of one or both pathogens. Staff were able to detect the equivalent of a single spore of the lettuce downy mildew pathogen. For the goal to correlate downy mildew-conducive weather conditions for both spinach and lettuce downy mildew with spore loads, weather data were collected daily during experiments and analyzed to monitor conditions in relation to disease occurrences. In support of both of those goals, data on downy mildew pathogen quantities was collected from at least two spore traps in the Salinas Valley at regular 48 or 72 hour intervals over a ten month period, and repeated for two consecutive years, in 2015 and 2016, and again in 2017 for lettuce and spinach downy mildew detection and quantification.

Staff aimed to determine the amounts of downy mildew inoculum associated with disease levels with the goal to quantify the levels of the pathogens present in environment. The performance measures are based on numeric values associated with the amount of inoculum detected. Spinach downy mildew quantification from

spore traps using a DNA-based assay indicate average pathogen DNA levels equivalent to less than 10 spores in the environment when there are no diseased plants nearby. Thus, 10 spore equivalents was the initial benchmark, to generate target low, moderate, or high risk advisements. The amount of disease will be measured by scouting fields and determining percent diseased plants in select fields. Additionally, a major indicator of successful outcomes of this project includes the number of publications that describes the work. There are two research reports to the industry and there are six quality publications that have resulted from this project.

Beneficiaries

Lettuce and spinach growers across California benefited from the knowledge that both of these pathogens were detectable nearly year-around in air samples obtained.

Knowledge from the project was disseminated to various groups of PCAs and growers interested in the control of downy mildew diseases of spinach and lettuce, and these were the principal beneficiaries of the work, thus far. Besides the presentations to the grower groups, article metrics suggest a more broad audience. The 2016 article by the PD in Progressive Crop Consultant, which is advertised as the leading magazine for California Ag professionals, reached over 6,332 subscribers in print throughout the state every month (http://www.progressivecrop.com/advertise).

At this point, however, the economic benefits of the project will be longer term as the modeling from spore load and weather parameters is further developed. Projected savings from the monitoring of spore load already include about $15 million savings from the reduction of at least one fungicide application per lettuce crop.

Lessons Learned

Staff encountered difficulty in correlating weather patterns with the levels of detectable pathogen to aid in a forecasting model. This difficulty stems from multiple factors, including primarily determining the most optimal conditions for pathogen dispersal to work into the disease model. Also, staff must take lag time into consideration, as the pathogens may land on the plant leaves and manifest in symptoms seven to 10 days later. Because the model is not yet in place, staff canceled posting of disease risk categories online for 2017 and preparation of additional surveys.

Staff also have not posted disease risk numbers on the internet. This will take longer than anticipated. This is due to the finding in the research of the variability in pathogen detection between sampling sites in the Salinas Valley, contingent on the proximity (to the traps) and wind direction. This is why the recent publication is also important to clarify that the assay for spinach downy mildew detection and quantification and advisement of disease risk is anticipated to work better on localized scale, on the level of one or a few tightly clustered ranches. In other words, staff have a clear understanding now that they cannot place spore traps at one location in the Salinas Valley, to provide disease risk reports for the entire valley. The risk assessment must come from a more localized sampling on a ranch scale.

Staff had continued difficulty trying to multiplex, or combine the assays, for detection of the spinach and lettuce downy mildew pathogens, simultaneously. Nevertheless, staff are still able to detect both pathogens from a single spore trap using two separate assays, one for each downy mildew pathogen. Also, in in this

reporting period, staff were able to effectively use the assay for *Bremia lactucae*, to reduce the amount of fungicide spray applications by 1.7 applications, on average, over three different crops.

Staff continue exploring different time frames for weather analysis in relation to actual pathogen detection even past the project expiration date, as they anticipate a lag between weather parameters and the actual effect on the pathogen population. It is complex with changing wind patterns which staff also monitor. Also staff planned the additional field plot experiments at the USDA station in Salinas for spinach downy mildew risk level assessment based on spore trapping. In this final reporting period, staff established field plots of spinach at the USDA station, Salinas, but have yet to evaluate the weather results in relationship to spore trap detection. This will hopefully assist in the finalization of a disease risk model in the near future.

One unexpected result included the finding of downy mildew pathogens of spinach and lettuce in airborne sampling year-around. However, there was significantly more airborne DNA detection of both pathogens during the growing season, April to October, when examined in periods in the years 2014 - 2016. Nevertheless, this means the growers of spinach and lettuce are always under disease threat, at least some level. Another unexpected find was that on two occasions, some susceptible fields were not infected with downy mildew, and thus there appears to be a threshold level where infection does occur when coupled with disease conducive environmental conditions.

The finding of viable oospores in modern spinach seed lots was also not anticipated, and is anticipated to have a big impact in cleaning up the problem of the spread of spinach downy mildew to California, if the problem on spinach seed is addressed. In fact, this line of research has opened the door to new research on seed treatments to eliminate or reduce viability of the oospores coming into California on spinach seeds.

As mentioned above, the growers of spinach and lettuce are always under disease threat, at least at some level, because the airborne downy mildew pathogens are nearly always present in air samples in the Salinas Valley. One of the chief lessons learned is that staff need to establish optimal periods of infection based on weather variables for implementation of a model, rather than relying on pathogen quantification. An additional area that requires more attention is the threshold level at which infections occur in susceptible crops. This extends from the complexity of patterns in dispersal of the downy mildew pathogens in the Salinas Valley for the purposes of disease forecasting. Also, these pathogens fluctuate in airborne detectable levels, and both are typically present in the Valley, even in the winter months. Quantification of these pathogens to advise disease risk based on real time knowledge of spore load would only be applicable on a local scale, encompassing one or several local ranches, rather than valley wide disease forecasting based on spore load.

Additional Information

Trade journal citing this project:
http://www.progressivecrop.com/images/pdf/May-June_PCC_2016_Web.pdf

Two industry reports citing this project:
http://calgreens.org/wp-content/uploads/2016/06/Spinach-and-Lettuce-Downy-Mildew-Klosterman-McRoberts-and-Subbarao.pdf

http://calgreens.org/wp-content/uploads/2015/09/Klosterman-and-McRoberts-Detection-and-quantification-of-spinach-downy-mildew.pdf

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
44	Developing Lettuce Cultivars with Resistance to Bacterial Leaf Spot and Tospoviruses	
Grant Recipient: United States Department of Agriculture, Agriculture Research Service	**Grant Agreement No.:** SCB14044	**Date Submitted:** December 2017
Recipient Contact: Ivan Simko	**Telephone:** (831) 755-2862	**Email:** Ivan.Simko@ars.usda.gov

Project Summary

Lettuce is a valuable California crop, but the diseases bacterial leaf spot (BLS) caused by *Xanthomonas campestris pv. vitians* (*Xcv*) and two related Tospoviruses, Tomato spotted wilt virus (TSWV) and Impatiens necrotic spot virus (INSV), reduce profits. No known lettuce cultivars or accessions are TSWV and INSV resistant. A gene for *Xcv* resistance is known but is defeated by resistance-breaking *Xcv* strains. This project deals with identification and characterization of lettuce accessions with resistance to TSWV, INSV, and resistance-breaking *Xcv* strains. Part of the project involves development of greenhouse methods for testing TSWV and INSV resistance, determining the inheritance of resistance, and determining the diversity and prevalence of resistance-breaking *Xcv* strains in California. New genes, breeding lines, and scientific information are being released to private seed companies and the lettuce industry. This project is increasing the number and utility of resistance varieties, thereby reducing crop losses.

Although a gene for *Xcv* resistance is known (*Xanthomonas* resistance 1 gene, *Xr1*), it is defeated by resistance-breaking *Xcv* strains present in California. However, it is not known to what extent these strains are present. This research gives a snap shot of the diversity of the strains causing disease in California and helps to develop additional sources of resistance to this pathogen namely that from Reine des Glaces (RdG). This work facilitates breeding by private seed companies. Tospoviruses are highly destructive and transmitted by thrips insects. Essentially nothing is known about testing lettuce for tospovirus resistance or the existence of resistance in lettuce, although preliminary results indicated the presence of resistance gene(s) in wild *Lactuca* species and unadapted lettuce. The United States Department of Agriculture, Agriculture Research Service (USDA, ARS) developed a greenhouse method to assess resistance to INSV and TSWV and identify lettuce with resistance to INSV and TSWV in field and greenhouse experiments. Crosses with resistance sources were made to initiate introgression of INSV and TSWV resistance into lettuce. New genes, breeding lines, resistant accessions, useful *Xcv* and virus strains (as permitted), and scientific information has been released to private seed companies and the lettuce industry.

This project builds upon 2010 Specialty Crop Block Grant Program Project 8: "*Accelerated development of pest resistant baby leaf lettuce cultivars*," identified the gene *Xr1* conferring resistance to *Xcv* due to a hypersensitive response. Incompatible strains causing the HR on *Xr1* germplasm were the first race of *Xcv* to be identified. These strains came from three of five genetically distinct groups. It was unknown whether the two remaining genetically distinct groups belonged to the same or different races. This project expanded those findings by identifying resistance to two additional races of the pathogen and additional genetic diversity.

Project Approach

The research team collected *Xcv* samples from diseased lettuce throughout California from the start of the grant through 2016. In 2015 the drought conditions in California resulted in little to no bacterial leaf spot on lettuce and no samples were obtained either through grower submission or scouting. However, 77 isolates were collected from 10 locations in 2014 and 2017. In 2016, eight isolates were isolated from one location (Lettuce26) were not members of *Xanthomonas campestris* and were not further researched. The research team's work demonstrated that strains of *Xcv* can be divided into three races that correspond to resistance on three different genotypes of cultivated and wild lettuce. Multilocus sequence followed by plant testing demonstrated that all strains from 2014-2017 were pathogenic on lettuce and belonged to one of the five sequence types or races previously identified. *Lactuca serriola* and other accessions were identified to which type A and type C strains of *Xcv* were resistant. Thus, a major result of this work is that three races were identified of *Xcv* and resistant germplasm resistant to these accessions.

The research team phenotyped the population of 160 recombinant inbred lines (RIL) developed from a cross between *cvs*. Batavia Reine des Glaces and Eruption (RdG x EPN). Plants of this population were grown in a greenhouse and inoculated with three different strains of *Xcv*. The experiment was repeated nine times, with three replications per experiment, and three plants from each RIL and parents per replicate. Molecular linkage map was developed using single nucleotide markers (SNPs) detected using the genotyping by sequencing (GBS) approach. The molecular linkage map spanned all chromosomes (nine linkage groups) of lettuce and provided a valuable tool for identifying and locating resistance gene alleles originating from cv. RdG.

A novel, greenhouse-based approach has been developed to screen lettuce cultivars for resistance to Tospoviruses. One hundred and fifty accessions of cultivated lettuce and other *Lactuca* species were tested for the resistance using this approach. In addition, 775 accessions were tested in field trials. Results from these tests allowed the research team to identify accessions with a partial resistance. Seventy-five crosses were made between the most resistant accessions to develop material that combines resistance genes from multiple sources, and between resistant and susceptible accessions to study the inheritance of partial resistance. Over 3,000 F_1 seeds were produced from these crosses.

The overall scope of the project did not benefit commodities other than specialty crops. All technicians paid through this account worked only on this project. All consumables and instruments that were purchased using this account were placed in the laboratories that work with lettuce only.

The collaborator at Penn State University and the original principal investigator isolated and screened 77 strains from symptomatic lettuce from 2014-2017. The collaborator identified three races of Xcv and germplasm resistant to the two races for which resistant germplasm had not yet been available. The collaborator screened germplasm for resistance to various strains for additional goals led by other members of the team.

Goals and Outcomes Achieved

Xcv characterization*:*

- 77 additional strains were screened and determined that only two sequence types present in California defeat *Xr1*.

- Over 500 accessions were screened to identify an accession on which type C strains interacted to produce an HR. This resulted in the definition of the third race of *Xcv*. Thus, germplasm with resistance to all known strains has been identified.

Mapping resistance genes to *Xcv:*
- Screened the mapping population of 160 RILs for the resistance to three strains of the pathogen in nine replicated trials.
- Genotyped the mapping population with GBS markers and constructed the molecular linkage map of lettuce.
- Mapped quantitative trait loci (QTL) for resistance to *Xcv*.

Breeding lines with *Xar1* gene:
- Made crosses to introgress *Xar1* gene into red-leaf type of lettuce.
- Tested performance and resistance in multiple greenhouse and field trials.

Resistance to tospoviruses*:*
- Tested over 10,000 plants for the resistance to tospoviruses in greenhouse conditions.
- Tested over 70,000 plants for the resistance to tospoviruses in field.
- Made 75 crosses to introgress genes for partial resistance.
- Produced over 3,000 seeds of F_1

Actual accomplishments with the goals established:
Goal 1: Study pathogenicity of *Xcv*; Performance Measure: The number of characterized *Xcv* strains and lettuce accessions; Benchmark: One California strain that defeats *Xr1* is known, ten *L. serriola* accession are purportedly resistant to BS3127; Target for June 2017: Determine if additional isolates defeating *Xr1* exist in California and identify accession resistance to these isolates and to BS3127, thus making them useful parents to breed new *Xcv* resistant cultivars.
- All benchmarks have been met. Isolates were characterized and described.

Goal 2: Breed and release red leaf lettuce with the *Xr1* gene; Performance Measure: The number of resistant families released and external requests for these families; Benchmark: Cultivars like this do not exist; Target for June 2017: Develop one red leaf family with *Xcv* resistance.
- All benchmarks have been met. Two families with resistance to *Xcv* were developed and released.

Goal 3: Determine the inheritance of resistance in RdG; Performance Measure: Data will be collected and analyzed to determine the inheritance of res; Benchmark: Nothing is known about resistance in RdG; Target for June 2017: Have new knowledge about inheritance of *Xcv* resistance.
- All benchmarks have been met. Genes were mapped for the resistance to *Xcv* that originate from cv. RdG. The major gene is located in the resistance gene hotspot on chromosome 2.

Goal 4: Identify lettuce accessions with resistance to INSV and TSWV; Performance Measure: The number of tested accessions; Benchmark: There is no published information about lettuce resistance to INSV and TSWV; Target for June 2017: Determine resistance and susceptibility in 150 accessions in replicated trials.

- All benchmarks have been met. 150 accessions were screened for the resistance to tospoviruses in a greenhouse. An additional 775 were tested for resistance in field.

Goal 5: Introgress genes for resistance to INSV and TSWV from wild species and unadapted lettuce to cultivated lettuce; Performance Measure: Number of crosses and number of produced seeds; Benchmark: Commercial cultivars with resistance to INSV and TSWV do not exist in California production; Target for June 2017: Make 10 crosses with resistant accessions, and produce seeds from each cross.

- All benchmarks have been met. Over 75 crosses were made and produced over 3,000 seeds.

Goal 6: Communicate scientific information about *Xcv* diversity and lettuce resistance to INSV, TSWV, and *Xcv* in peer-reviewed articles, conferences, and online at the CLGRP website; Performance Measure: Number of publications, presentations, and website views of project information; Benchmark: There are no publications or websites reporting the information developed in this proposal; Target for June 2017: Complete one manuscript for a peer-reviewed journal, two presentations at scientific conferences, and have project findings uploaded to the CLGRP website and monitor the number of website views.

- All of the benchmarks have been met. Manuscripts describing research results were published, or submitted to scientific journals. Seven oral or poster presentations were prepared from this research and presented at conferences or meetings.

Completed outcome achieved:

- Goal 1: 77 strains from symptomatic lettuce were tested for their compatibility with *Xr1*resistance gene
- Goal 2: Two families of red-leaf type lettuce with resistance gene were developed
- Goal 3: Nine tests with three *Xcv* strains were performed on 160 RILs, plus two parents, plus five control accessions.
- Goal 4: 150 accessions were tested in 47 greenhouse tests for the resistance to Tospoviruses (over 10,000 plants). 775 accessions were tested in six field trials for the resistance to Topoviruses (over 70,000 plants)
- Goal 5: 75 crosses were made and over 3,000 seeds of F_1 generation were produced
- Goal 6: Three papers were published, one manuscript was submitted (accepted, pending minor changes), and another manuscript is under preparation. Seven presentations were made on scientific conferences. Three reports with research results were uploaded to websites. See additional information.

Major successful outcomes:

- It was demonstrated that thus far only three races of *Xcv* exist in California and resistant germplasm has been identified to combat each of the three races.
- Two new families of red-leaf lettuce with resistance to *Xcv* were developed.
- QTL for resistance to *Xcv* originating from cv. RdG were identified and placed on the molecular linkage map of lettuce.
- 3,000 seeds of F_1 generation were produced that could be used to develop lettuce cultivars with improved resistance to Tospoviruses.
- Two published papers, one submitted manuscript, and one manuscript in preparation.
- Seven presentations at conferences and meeting.

Beneficiaries

Tangible outcomes and results of this project will benefit lettuce seed and breeding companies, growers, processors, and eventually also consumers. Seed and breeding companies can use released breeding lines and published information to develop lettuce cultivars with improved resistance to *Xcv* and tospoviruses. Growers will be able to grow more resistant cultivars, thus limiting needs for chemical treatments, while processors will be able to use material with blemishes caused by *Xcv* and tospoviruses.

In Monterey County of California, that encompasses the Salinas Valley – the main lettuce producing area of the U.S., lettuce is grown on approximately 80,000 acres. All lettuce is susceptible to both *Xvc* and Tospoviruses. All growers in this region could benefit from more resistant cultivars of lettuce. At least 15 lettuce seed and breeding companies and 5-7 processing companies may also directly benefit from more resistant lettuce cultivars. Approximately $1.5 billion worth of lettuce is produced annually in Monterey County alone. If the overall level of infection is similar to the one observed in field trials, about 5% of the crop may not be harvestable due to Tospoviruses, and 0.5% due to *Xcv*. This indicates that ~ $82.5 million worth of lettuce could be saved annually by employing more resistant cultivars.

Lessons Learned

Due to hiring restrictions that affect most of the federal government agencies, it is problematic to hire on time all qualified personnel. It may take 6-10 months to hire a skilled technician or post-doc. This puts an enormous strain on the remaining personnel, because the project planned for 30 months (2.5 years) has enough qualified personnel during only 20 months (2/3 of the project duration).

An unexpected outcome that was an effect of implementing this project was no accession of cultivated lettuce, or closely related species is completely resistant to Tospoviruses. Therefore, breeders need to focus on developing cultivars that combine genes for partial resistance originating from multiple accessions.

Additional Information

Papers published:

Bull, C.T., Gebben, S.J., Goldman, P.H., Trent, M.A., and Hayes, R.J. 2015. Host genotype and hypersensitive reaction influence population levels of *Xanthomonas campestris* pv. *vitians* in lettuce. Phytopathology 105:316-324.

Koike, S.K., and Bull, C.T. 2017. Bacterial Leafspot. in: Compendium of Lettuce Diseases. Subbarao, K.V., Davis, R.M., Gilbertson, R.L., and Raid, R.N., eds. APS Press. ISBN

Manuscript submitted: Simko, I., Richardson, C.E., and Wintermantel, W.M.: Variation within *Lactuca* spp. for resistance to *Impatiens necrotic spot virus.* (accepted to Plant Disease, pending minor edits)

Manuscript in preparation: Bull et al., Description of three races of *Xanthomonas hortorum* pv. *vitians* pv.

Presentations at conferences and society meetings:

Bull, C.T., Trent, M.A., and Hayes, R.J. 2016. Three races of *Xanthomonas campestris* pv. *vitians* causing bacterial leaf spot on lettuce identified. American Phytopathological Society annual meeting, July 30 - August 3, 2016, Tampa, FL P-437.

Ramos, G. J., Rubio, I., Wright, A., Hayes, R.J., and Bull, C.T. 2015 Sensitivity of various genotypes of *Xanthomonas campestris* pv. *vitians* to bacteriophages isolated from soil and water in lettuce production fields. Phytopathology 105(S4):116. 2015 American Phytopathological Society annual meeting, Pasadena, CA.

Ramos, G., Rubio, I., Wright, A., Hayes, R.J., and Bull, C.T. 2015. Sensitivity of various genotypes of *Xanthomonas campestris* pv. *vitians* to bacteriophage from soil and water in lettuce production fields. SACNAS National Conference, October 29-31, 2015, National Harbor, MD 20745.

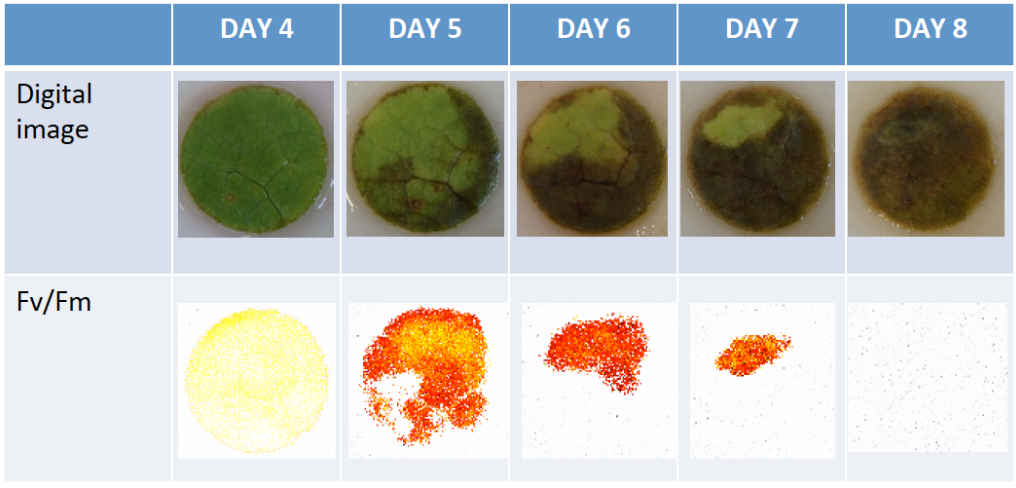
Four presentations at the California Leafy Greens Research Program (CLGRP) board meetings in Salinas, October 2015; Coalinga, March 2016; Salinas, October, 2016; and Shell Beach, March 2017. All presentations have the same group of authors and the title. Simko, I., Mou, B., and McCreight: Lettuce breeding.

A summary of research results can be downloaded from the CLGRP website:
http://calgreens.org/wp-content/uploads/2016/06/Lettuce-Breeding-USDA-ARS-Simko-Mou-and-McCreight.pdf

http://calgreens.org/wp-content/uploads/2015/09/Wintermantel-and-Simko-Lettuce-germplasm-screening-for-Tospovirus.pdf

http://calgreens.org/wp-content/uploads/2014/07/Wintermantel-and-Simko-Development-of-methods-for-maintenance-of-lettuce-infecting-tospoviruses-effective-germplasm-screening-and-identification-of-sources-of-resistance.pdf

TRANSECT instrument was used to determine decay on lettuce leaves infected with the pathogen. Chlorophyll fluorescence approach used by TRANSECT allows quantification of the decay progress due to gradual decrease in the efficiency of photosynthesis. The figure below shows quantification of a gradual decay process.



CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 45	**Project Title:** Development of High Throughput Seriological Assays for the Routine Detection of Grapevine Red Blotch Virus	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCBG14045	**Date Submitted:** December 2017
Recipient Contact: Dr. Neil McRoberts	**Telephone:** (530) 752-3248	**Email:** nmcroberts@ucdavis.edu

Project Summary

The Grapevine Red Blotch associated Virus (GRBaV) emerged as a new disease problem in red wine grape varieties in the last five years. The formal identification and description of the disease led to a period in which growers and wine makers were uncertain of the impact of the virus on grape and wine quality and there was no laboratory diagnostic test available to confirm its presence. While the certification program worked with the University of California, Davis (UCD), Foundation Plant Services and the grape nursery industry to develop a diagnostic test for the virus and went through the process of including it formally in the certification regulations a need was identified for a rapid, low-cost, in-field diagnostic for the virus.

The discovery of red blotch virus caused a very large uncertainty in the wine grape industry as to the effect of the virus on grape quality. With little information to work on, many winemakers began to take a precautionary approach and ask for grapes to come from blocks that were free from red blotch. While a Polymerase Chain Reaction (PCR)-based lab test for red blotch quickly became available, it is relatively expensive, slow and cumbersome to use on a large number of samples. A rapid test that could be used in the field by growers and pest control advisers would greatly reduce the level of uncertainty in the industry about the prevalence and impact of the virus. At the time the project was proposed red blotch was the number one issue in the California wine grape sector.

The project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Activities that were completed in order to achieve the performance goals and measurable outcomes identified in the approved project proposal were as follows:

- Tag GRBaV proteins with fluorescent protein markers: The virus proteins were expressed and tagged with fluorescent markers of different colors.
- Carry out localization studies of GRBaV proteins in grape and other host plant cells: All virus proteins were traced to their localizations in infected host cells and a complete scheme of localizations was developed.
- Develop infection model for GRBaV in host cells: Project staff know from the previous two activities where each virus protein localizes in the infected host cells. Project staff are in the process of comparing the localizations with known functions of analogous proteins in Gemini viruses to develop a model for red blotch virus.
- Diffusion of knowledge about GRBaV biology to stakeholders: This activity has been completed through several presentations by the project team to grower and industry meetings. Outreach from the program is

on-going so although project staff have transferred the project findings to the industry, staff will continue to diffuse information on the biology and epidemiology of red blotch in other, related projects.

- Diffusion of knowledge to scientific community: The results from the project have been presented at scientific meetings and provided results to the wider group of grape virologists in the US working on this disease. Project staff are in the process of preparing refereed papers on the completed work which will be submitted for publication.
- Final assessment of total results, and the quantification of progress made, and future directions for research and/or outreach efforts: Compared with knowledge before the project started, project staff have achieved a 100% increase in what is known about where the virus proteins interact with the host cells. One of the proteins, C3, has been found to associate with the host cell nucleus in a way that has not previously been observed. It appears to localize, sometimes, in cytoplasmic vesicles that are located adjacent to the nucleus but have also been observed in experiments to move through the cytoplasm away from the nucleus. The significance of these observations and the role of the vesicles in the infection of host cells is unknown at this time.

The overall scope of the project did not benefit commodities other than specialty crops.

Principle Investigator (PI): The PI managed the project and in collaboration with a fellow professor from UCD (Co-PI) and a project scientist (collaborator) made decisions on the direction of the project, activities, and timelines. The PI was responsible for the majority of the outreach to stakeholders.

Co-Principle Investigator (Co-PI): The Co-PI was responsible for the direction of much of the specific laboratory work, selecting approaches and specific methodology in conjunction with the collaborator.

Project Scientist (collaborator): The collaborator did much of the hands-on technical work of the project, with support from graduate students in the Co-PI's lab. The collaborator was responsible for specific technical details needed to achieve the activities in the work plan, and for implementing the approaches agreed with the Co-PI.

Goals and Outcomes Achieved

The following activities were completed in order to achieve the following measureable outcomes identified in the approved project proposal:

(1) Develop an antibody to the red blotch virus coat protein
    - Project staff were able to develop antibodies that successfully bound to the virus coat protein expressed by bacterial vectors, but project staff were not able to achieve reliable binding of the protein from infected host tissue, so it was not possible to develop a practical field test for the virus.

(2) Develop infectious clones of one or more isolates of the red blotch virus
    - Project staff successfully developed two different infectious clones from isolates of the red blotch virus collected in different locations in California. Each infectious clone belonged to one of the two known clades of the virus. It is not known at this time what the biological significance of the existence of the two clades is, or even if the existence of different clades has any significance at all.

(3) Determine if red blotch virus can infect herbaceous hosts and develop an herbaceous host model system for experimentation if it seems one can be developed
    - Project staff were able to show that herbaceous hosts can be infected by the red blotch virus and achieved high virus titre in infected common bean in some experiments, but the level of infection

achieved across different experiments has not so far proved to be reliable enough to use as a model system to study the sub-cellular biology of the virus.

(4) Carry out localization studies of virus proteins in infected host cells

- This was the major goal of the project after it was revised. Project staff were completely successful determining the localizations for all the virus proteins.

No outcomes measures of the project can be considered long term.

The initial goal of this project was to develop highly specific highly specific antibody-based detection assays for GRBaV, a new virus that causes leaf reddening and reduced sugars production. The partial characterization of this virus suggested that it was a geminivirus, a type of virus characterized by having twinned quasi-icosahedral virions encapsidating a circular single-stranded DNA genome. However, the GRBaV has turned out not to be a typical geminivirus, and relatively little is known of the nature of the proteins encoded by the viral genome. As indicated below, this has made it difficult to apply traditional methods for diagnostics.

Development of an Antibody to Detect GRBaV

To develop an antibody for detection of GRBaV, project staff initially obtained isolates of the virus from two locations: Davis, California and St. Helena, California. Leaf tissues with typical symptoms of red blotch were obtained and PCR with primers were developed and used to confirm infection with GRBaV. As indicated below, two isolates of the virus were obtained and used in this study.

Next, project staff performed an *in silico* analysis of the genome of GRBaV. This analysis indicated that the genetic structure of the virus was similar to, but also substantially divergent from genetic structure and sequences of known geminiviruses. Based on this analysis and other performed by others, the most logical candidate for the capsid protein is the V1 open reading frame. Subsequent expression and subcellular localization experiments with the V1 supported the hypothesis that the V1 protein was the most likely candidate to be the viral capsid protein. Project staff also developed methods to extract nucleic acids and proteins from grapevine tissues with and without GRBaV infection for subsequent testing of antibodies and other methods of detection and we also cloned the six putative genes of GRBaV for protein expression. Project staff successfully expressed the *E. coli*-expressed V1 (putative capsid protein), and this was used as a control for the GRBaV monoclonal antibodies.

Project staff provided the V1 sequence to a company, which then analyzed the amino acid sequence and identified seven peptides from antigenic regions of the V1 protein that we candidates for generating monoclonal antibodies. The company then generated seven monoclonal antibodies and also provided the corresponding peptides that were used to generate these antibodies. The first step was then to test the monoclonal antibodies against the V1 protein expressed in *E. coli*. Of the seven antibodies, three reacted with the *E. coli*-expressed V1 protein. However, when these three antibodies were used in Western blot analyses with GRBaV-infected grapes, project staff failed to detect a protein of the size expected for the V1. This experiment was repeated multiple times with the same results. Unfortunately, these results indicated that it was unlikely that these antibodies would provide a sensitive method for detecting GRBaV in infected grapevines.

In order to identify additional controls for GRBaV detection, project staff identified a vineyard in St. Helena, California with red blotch disease where samples with red blotch symptoms could be selected. Here project staff collected leaves from varieties with red- and white fruits, and showed that with the PCR method the

project staff could readily detect the virus in the red varieties with typical red blotch symptoms and not in most of the white varieties that did not show symptoms. Unfortunately, project staff failed to detect GRBaV infection in leaves of these materials with the GRBaV monoclonal antibodies. These results supported the fact that grapevines with typical symptoms of red blotch were positive for the virus by PCR, whereas most of those without symptoms were negative. In addition, these results supported the concept that the PCR test was probably the most effective for detection of GRBaV. The project's inability to generate monoclonal antibodies that could sensitively and reliably detect GRBaV turned out to be similar to results by other researchers, suggesting that yet to be determined factors make this virus difficult to detect by traditional antibody based methods.

One of the project's goals was to educate and inform stakeholders in the grapevine industry about the GRBaV detection assay in order to promote its adoption into common use. Nurseries and grape growers would benefit from this detection tool for assessing the disease status of their vineyards. The project anticipated that at least 85 percent of propagation material in California would come from a nursery that used the GRBaV detection assay. Unfortunately, this target was removed from the original project proposal because project staff were unable to generate a high throughput assay for the virus due to the peculiarity of its structure and the behavior of GRBaV in its grape host. Since the development of the GRBaV detection assay was crucial to the project's progress, the initial project goals had to be adjusted to include outcomes that could be met using data accumulated during initial experiments.

Development of Infectious Clones

As part of the development of tools for this project, staff developed infectious clones of the two isolates for GRBaV, an isolate from Davis (isolate 337) and an isolate from St. Helena (isolate 214). Isolated 214 has since been detected in the Napa Valley as well as in Davis. The complete nucleotide sequences of these two isolates were determined and it was found to be ~9% divergent, and represent the two recognized sub-groups of GRBaV. To generate infectious clones, project staff first worked with isolate 337 and used a standard method with geminiviruses that involves generating a dimeric form of the viral genome. This involved generating with viral genome with the rolling circle (RCA) method and then cloning the dimeric form from among the multimeric forms normally generated with this methods. The dimeric clone of 337 was then sub-cloned into the *Agrobacterium tumefaciens* binary vector (pCAMBIA 1300) and the resulting recombinant plasmids were transformed into *A. tumefacien*s to generate a red blotch agroinculation systems. Grape plants (cultivar Cabernet Sauvignon) were agroinoculated in the younger buds and new leaves and new growth tested after 4 weeks of growth (note that the plants did not show symptoms at this time). Petioles of newly emerging leaves tested positive for GaRBV DNA by PCR with primers designed to detect the coat protein. This indicates that the clones are infectious. Consistent with this result, the grapevine seedlings developed typical symptoms of red blotch about one year after inoculation. These results confirmed the infectivity of the clones of the GRBaV isolate 337 and fulfilled Koch's Postulates for the virus in grapevines.

Can we Identify an Herbaceous Host for GRBaV?

Identification of an herbaceous host for GRBaV would be a very useful tool for studying the genetics of GRBaV, for purifying the virions of the virus and possibly for generating diagnostic tools. Using the agroinoculation system with GRBaV isolate 337 was then used to agroinoculate herbaceous plants also with GaRBV. The following hosts were inoculated: *Nicotiana benthamiana, N. glutinosa*, common bean, and *Chenopodium quinoa*. Four weeks after agroinoculation, total genomic DNA was extracted from newly emerged leaves and tested by viral DNA by PCR and rolling circle amplification. Project staff detected

GRBaV DNA in leaves of some agroinoculated *Nicotiana benthamiana*, *N. glutinosa*, common bean plants by PCR, but not by RCA. This suggests that the viral titer may be very low. Consistent with this result, the majority of agroinoculated plants that were PCR-positive for GaRBV DNA were symptomless, except for dwarfing or reduction of growth in *N. benthamiana*, and some yellowing in beans and *N. glutinosa*. However, project staff are not sure if these symptoms are due to infection by the virus or not. Thus, at this point, it is not certain that GRBaV is infecting these herbaceous hosts. Additional experiments are needed to determine this, but it seem likely that these are not good hosts for GRBaV infection.

Cloning of GaRBV Genes for Protein Expression

Another approach to understanding the nature of the GRBaV and generating useful tools for studying the virus is to clone and express the genes of the virus. To this end, the sequence of isolate 337 was used to identify the six putative genes of the virus, to clone these genes and to express the proteins in *E. coli*. This included the putative GaRBV capsid protein (CP)/V1 gene as well as the other genes: V2, V3, C1, C2 and C3 (Figure 1 – See Attachment). All six genes were amplified and cloned into the intermediary vector pGEM. Sequence analysis confirmed that each gene had been cloned and was in-frame. Then, all six genes were sub-cloned in the protein expression vector pRSET for protein expression in *E. coli*. All six GRBaV genes were then inserted into the pRSET protein expression vector and expressed in *E. coli*. Proteins of the expected size were obtained for most of the proteins. This included the CP gene, which was the expected size ~29 kDa protein. These expressed proteins will be used in future experiments to generate another source of antibodies and in microinjection studies to further assess protein function.

Generation of fusion proteins of the GRBaV proteins with the green fluorescent protein (GFP). Project staff took each of the individual GRBaV genes (V1, V2, V3, C1, C2 and C3) and fused them, in frame, the fluorescent markers GFP (green), RFP (red) and CFP (blue). All of the proteins have now been tagged with GFP at the N- and C-termini (12 constructs), with the objective of determining the individual subcellular location of each protein and then to compare the pattern of localization of the N- and C- terminal tagged proteins to see if they have the same subcellular location (Figure 2 – See Attachment). Figures 3 through 8 show a series of localization studies for the viral proteins (See Attachment). The specific details in each case are given in the figure legends.

Here, it should be mentioned that one of the proteins, C3, has been difficult to express, possibly due to instability. Table 1 shows the results to date the subcellular location of the GFP-tagged proteins (so far both the N- and C-terminal labelled proteins have a similar subcellular localization). Multiple proteins target to the cell nucleus, including V1, V2, V3, C1 and C2; whereas only V1 also localized to the nucleolus. The V2 appears to target the cell periphery as well as the nucleus; and V3 was targeted to the nucleus and cajal bodies. This suggests multiple proteins are involved in replication, transcription and, possibly, virion formation in the nucleus. Interestingly, the lack of proteins localizing to the cell periphery or the nucleus may be consistent with a phloem-limited lifestyle. To look at protein-protein interactions, project staff co-infiltrated proteins of different colors to look for possible interactions. Here, different proteins with different markers were co-infiltrated in order to see if there is a change in the localization of one of the proteins or if they co-localize (if which case the merged color will be different than that of either of the individual colors). This information is important because it provides insight into gene function and possible aspects of viral biology, e.g., is the virus likely to be limited to the phloem or not and what proteins may be involved in the replication or encapsidation of the virus.

Gene	Subcellular localization
V1	Nucleus and nucleus
V2	Nucleus and cell periphery
V3	Nucleus and cajal bodies
C1	Nucleus
C2	Nucleus
C3	Cell periphery
35-S control	Nucleus, cell periphery and cytoplasm

Table 1. Subcellular localization of GFP-labelled proteins of the *Grapevine red blotch virus* (GRBaV).

The results of these analyses revealed that GRBV V1 localized to the nucleus and nucleolus, consistent with being the putative capsid protein; GRBV V2 is a DNA binding protein, which may mediate nuclear export of virions or viral DNA; and GRBV V3 interacts with cajal-like bodies in the nucleus, possibly reflecting the reprogramming of the cell cycle and altered gene expression. Protein-protein interaction studies among the virion-sense proteins labelled with GFP forms that fluoresce at different wavelengths indicated an interaction between the V1 and V2 proteins. GRBV C1 and GRBV C2 are putative replication proteins that are likely involved in viral replication in the nucleus. GRBV C3 is a putative movement protein, which localized to the cell periphery and plasmodesmata (PD)-like structures, consistent with a role in movement or suppression of gene silencing. The majority of the GRBV proteins were targeted to the nucleus, which is fully consistent with the presence of nuclear localization signals in these proteins and replication of a DNA virus in the nucleus. Preliminary studies revealed DNA binding properties for C1 and V2. In future studies, additional functional analyses (DNA binding, PD interaction, silencing suppression) and co-localization of fluorescently-tagged viral proteins with markers of known subcellular structures will be conducted.

The major successful outcome for the project is the comprehensive documentation of the localization of the virus proteins in host cells. These results are recorded in the table in the preceding subsection of the report.

Beneficiaries

The Beneficiaries of this project include:

- California wine grape growers
- California grape nursery producers
- CDFA nursery certification program
- Grape virologists, extension scientists and plant pathologists

California has an estimate 5,900 wine grape growers and in the order of 20 significant nursery operations who service the wine grape industry by producing certified planning stock. All of these will benefit from the knowledge generated in this project. The wine industry generates in the order of $57 billion of economic activity within California alone and an estimate 23.6 million tourists attracted to California each year to wine-related tourist activity. The associated economic value of tourism activity is estimated at $7.2 billion alone. All of this economic activity is based on the perceived premier status of the quality of California wines. This quality is threatened by viruses such as red blotch. The precise economic value of this individual project is hard to estimate, but it contributes to safeguarding the aforementioned economic value.

Lessons Learned

The project was speculative given how little was known about the red blotch virus when the project first started the work. At that time the indications were that the virus was probably a previously undocumented member of the Gemini viruses. Had this been the case, the proposed research plan would have had a reasonable chance of success. Project staff now know that, if GRBaV is a member of the Geminiviridae at all, it is certainly atypical and the failure of the project to generate a high throughput assay for the virus is not a result of the lack of technical capability of the project team, but a result of the peculiarity of the structure and behavior GRBaV in its grape host. Project staff perhaps continued with the work on trying to generate a serological assay longer than they should have, but they wanted to try all available options before giving up.

It was not completely unexpected that it would be difficult to establish a serological assay for the redblotch virus, but previous success with other similar viruses led staff to be initially optimistic about the objective. It was unexpected how difficult it has proved to detect the virus coat protein in infected plants, when the antibodies bind with the protein when it is expressed in bacterial vectors. The reasons for the lack of reaction from infected plant material remain unclear but may be related to low virus titre in grape vines and localization of the virus in the infected tissue; factors which in combination may restrict the sensitivity of the assay.

Because all of the goals in the initial version of the proposal depended on the success of the first goal, project staff ended up in the situation where no progress could be made. With some projects, this critical dependence is unavoidable. Project staff didn't identify early enough that they were in a situation where no progress was being made and should've started to plan alternative and additional activities in order to successfully complete the project. The general lesson to be learned is that the decision to stop (or reduce) a failing line of work probably always needs to be made before it feels like the right decision.

Additional Information

See Attachment.

USDA Project No.:	Project Title:	
46	Melon Powdery Mildew Race Variation in California	
Grant Recipient: United States Department of Agriculture, Agricultural Research Service	**Grant Agreement No.:** SCB14046	**Date Submitted:** December 2017
Recipient Contact: James D. McCreight	**Telephone:** (831) 755-2864	**Email:** jim.mccreight@ars.usda.gov

Project Summary

Cucurbit powdery mildew (CPM), incited by the airborne, obligate parasitic fungus *Podosphaera xanthii*, is a chronic and major disease problem of cantaloupe and honeydew (*Cucumis melo L.*; melon) production worldwide. Early infection can kill plants or reduce fruit yield; late infection reduces fruit quality. Two races of *P. xanthii* were known in California until 2003 when a new race, S, was observed in Imperial Valley (Figure 1). Race 3.5 and 5 are now known in the California Central Valley. Race variation compromises genetic host plant resistance to CPM in melon. It takes time and resources to transfer genes for resistance to the races into elite cultivars. This project sought to characterize *P. xanthii* race variation on melon in California, and identify and characterize unique sources of resistance to the most prevalent and virulent races.



Figure 1. Left: first commercial melon field infected with race S (left) near Holtville, California, and Right: close-up of CPM-infected melon leaves field. (Photos provided by J.D. McCreight)

Note: CPM can be caused by two predominant fungal species, *Podosphaera xanthii*, as introduced above, and *Golovinomyces cichoracearum* (synonymous with *Golovinomyces orontii*), which has not been verified on melon in the United States, but is known on melon in Europe. This project was focused on *P. xanthii.*

There had been a great increase in the number of powdery mildew races on melon worldwide, including the important melon production areas of California (Figures 2 and 3). The challenge to those working with CPM, especially those interested in host plant resistance to the pathogen whether from the breeding standpoint or cultivar (variety) selection, was to understand how races described on melon in various parts of the world related to each other in light of: i) different race designations/nomenclature, and ii) different/incomplete sets of differential melon race differentials/genotypes.

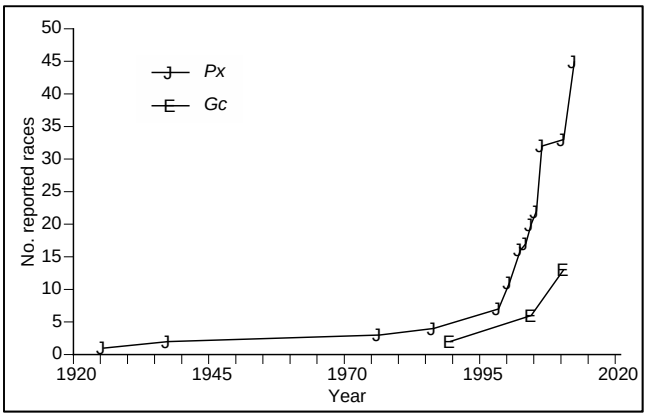
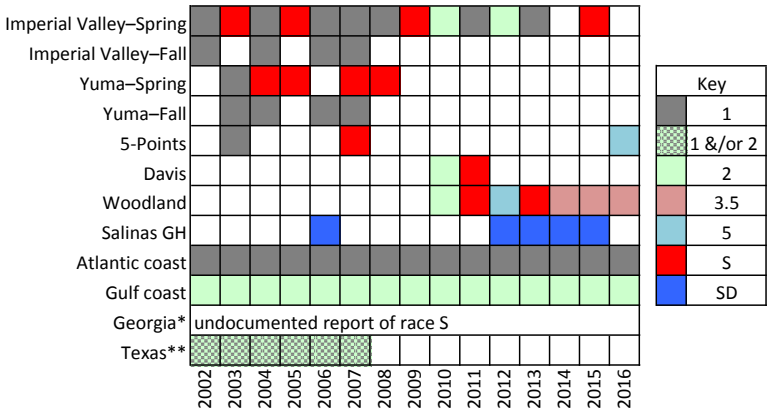


Figure 2. Change in the numbers of races of *Podosphaera xanthii* (*Px*) and *Golovinomyces cichoracearum* (*Gc*) on melon (*C. melo*) from 1925 through the 2012 (McCreight et al., 2012).



*McGrath, M. 2010. www.extension.org/pages/30604/managing-cucurbit-powdery-mildew-organically. Accessed on March 24, 2017.
**Crosby, K.M., J.L. Jifon, and D.I. Leskovar. 2008. HortScience 43:1904–1906.

Figure 3. Summary of melon CPM races by year in California, Arizona and other areas of the United States. California and Arizona based on published and unpublished data; Atlantic and Gulf coast information from personal communication with S. Kousik (USDA-ARS, Charleston, South Carolina). (Chart provided by J.D. McCreight)

A systematic approach to CPM race denomination and designation was, therefore, proposed in 2008 (Lebeda et al., 2008), refined, and presented to the CPM community at an international meeting in Warsaw, Poland in 2016 (Lebeda et al., 2016a). The complete proposal was subsequently published for the international CPM community with a revised set of CPM differential lines suitable for use with *Podosphaera xanthii* and the other major CPM pathogen, *Golovinomyces cichoracearum* (Figure 4). A core group of seed company representatives at the Warsaw meeting agreed to move forward with implementation of the proposed system and initiated arrangements for increasing seeds of the CPM race differentials, including development of molecular markers with which to characterize the lines in order to assure their identity/integrity, and designation of a repository for their distribution.

In the meantime, the European CPM community, including crop variety regulatory agencies, funded a project (Harmores) to characterize CPM race variation in southern Europe (France, Italy, Spain) and north Africa

(Morocco) and to establish uniform testing protocols based on reactions of excised leaf discs from the differentials that were inoculated and incubated in axenic culture under strict and uniform light and temperature conditions. The European project involved GEVES (Groupe d'Etude et de contrôle des Variétés Et des Semences), several international seed companies working through the International Seed Federation (ISF) Pathology Working Group (sub-Working Group for CPM on Melon), and the Collaboration for Plant Pathogen Strain Identification (CPPSI), based at the University of California, Davis. The initial data gathering phase of the European project finished and the group, at the time of this report, was preparing the analysis and recommendations for future research leading to the development of a reduced set of CPM race differentials that would be more amenable to routine testing for European variety regulatory functions and breeding programs designed to transfer resistance to the new races into adapted genetic backgrounds and, ultimately, elite commercial cultivars. The Principal Investigator served in an *ad hoc* advisory capacity to the current GEVES–ISF–CPPSI project.

Table 2 Proposed CPM race differential genotypes (Cucumis melo L.) by group number

Differential genotype			Origin	
Group.No	Cultigen/Accession	Other designation(s)[a]	Source	Country
1.1	Iran H	–	INRA	Iran
1.2	Védrantais	M 319	INRA	France
1.3	PI 179901	Teti	USDA	India
1.4	PI 234607	Sweet Melon	USDA	South Africa
1.5	AR HBJ	AR Hale's Best Jumbo	USDA	USA
1.6	PMR 45	M 321	USDA	USA
1.7	PMR 6	Ames 26810	USDA	USA
2.1	WMR 29	M 322	USDA	USA
2.2	Edisto 47	NSL 34600	Clemson Univ.	USA
2.3	PI 414723	LJ 90234	USDA	India
2.4	PMR 5	Ames 26809	USDA	USA
2.5	PI 124112	Koelz 2564	USDA	India
2.6	MR-1	Ames 8578	USDA	USA
2.7	PI 124111	Koelz 2563	USDA	India
3.1	PI 313970	90625 VIR 5682 PI 315410	USDA	India
3.2	Noy Yizre´el	–	Bar Ilan Univ.	Israel
3.3	PI 236355	–	USDA	England
3.4	Negro	–	Univ. Zaragoza	Spain
3.5	Amarillo	–	Univ. Zaragoza	Spain
3.6	Nantais Oblong	M 320	INRA	France
3.7	Ames 31282	PI 134198	USDA	China

Differential genotypes of C. melo listed are maintained by Dept. Botany, Palacký University, Olomouc (Czech Republic), and by ARS, USDA, Salinas, California (USA)

M 319 – 322 original designation by M. Pitrat, INRA, Montfavet, France; provided to A. Lebeda in 1997, INRA L'Institut National de la Recherche Agronomique, Montfavet (France), USDA United States Department of Agriculture, Agricultural Research Service; info. on USDA accessions available on the website of the National Genetic Resources Program, Germplasm Resource Information Network (GRIN), http://www.ars-grin.gov/npgs/acc/acc_queries.html

[a]Name or additional accession number in the germplasm database or in working collection

Figure 4. Set of 21 proposed CPM race differentials for use in describing CPM race variation and breeding of melon for resistance to CPM (Lebeda et al., 2016b).

This project was proposed to provide similar information about CPM races on melon in California, which in 2016 produced 43% and 100% of the United States cantaloupe and honeydew production, respectively. This

project also sought to identify and characterize unique sources of resistance to the most prevalent and virulent races.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Powdery mildew isolates were collected from the major melon production areas of California in 2015, 2016 and 2017. The project team initially reached-out to pest control advisors (PCA) and the University of California Cooperative Extension Farm Advisors in Imperial, Coachella, Palo Verde, and San Joaquin Valleys and requested their assistance in providing isolates of CPM from commercial fields or providing locations for sample collection. The postdoc hired on the project presented the project objectives and goals to a PCA group in Imperial Valley that included members in Coachella and Palo Verde Valleys. Based on the dearth of responses from the PCA and farm advisors in the first year of the project, one would conclude that CPM was not a significant problem that year. This also seemed to be true in the subsequent two years of the project. This was, in retrospect, not entirely surprising, as occurrence and severity of CPM could be spatially and temporally variable. CPM isolates (samples) were obtained from seed companies in the Woodland-Davis area, the University of California Research and Extension Centers (REC) in Imperial Valley (Desert REC and Westside REC), and from the United States Department of Agriculture, Agricultural Research Service, research station in Salinas, California.

CPM isolates were separately increased in laboratory cultures for testing on melon powdery mildew race differential lines (cultivars, breeding lines and exotic foreign germplasm). Single spore isolates (one to three each) of each isolate were produced in sterile culture as a means to sample variation for pathogenicity within each isolate. Single spores of each isolate were transferred with the aid of a microscope in order to establish individual colonies (Figure 5); one to three sub-isolates of each isolate were established and maintained separately.

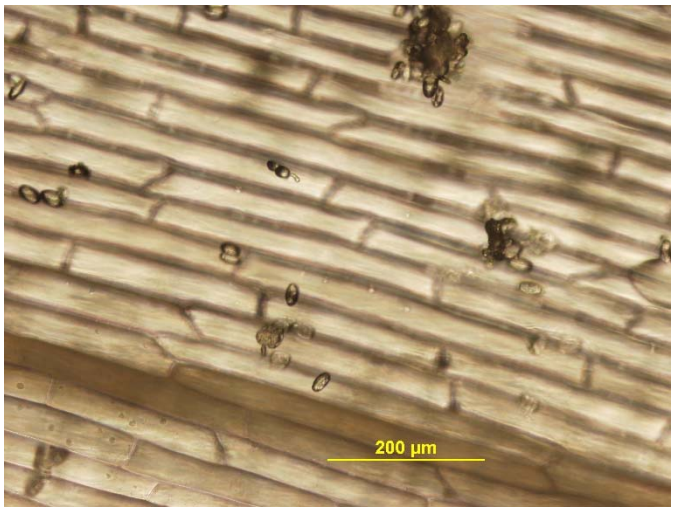


Figure 5. Spores of *Podosphaera xanthii* germinated on onion epidermis. Colonies that develop from such single spores can be transferred *en masse* to CPM-free host and allowed to grow in axenic culture. (Photo: J.D. McCreight)

Thus, unselected (original field or greenhouse) isolate and single spore sub-isolates (strains) were obtained for characterization of their race identity using a set of 11 commonly used CPM race differentials (see

Attachment 1). The isolates and their single spore strains were increased and placed in cryogenic storage (vapor phase liquid nitrogen tanks at minus 150 to minus 186ºC) for long-term storage at University of California, Riverside.

Thirteen isolates from 17 field and greenhouse collections were successfully cultured and placed in cryogenic storage. The number of strains established from each isolate ranged from one (eight isolates) to three (two isolates). Eight of the 13 isolates were characterized on 11 commonly used CPM race differentials during the project period. A total of 30 isolates and their strains were developed by the project team; 25 were characterized for their disease reaction on the 10 CPM race differentials.

Despite the extensive experience of the Co-Principal Investigator in working with powdery mildews, the amount of effort to establish axenic cultures free of mycoparasites (fungi that parasitize CPM), produce single spore strains, and characterize their disease reactions on the race differentials was greater than anticipated. The relative dearth of field isolates permitted the development of protocols for establishment of the isolates, production of inoculum in axenic culture, disease reaction assays on whole plants in a greenhouse, and preparation of spores for cryogenic storage. As a result, most of the resources were directed to the establishment of the isolates, generation of strains for each isolate, and disease reaction assays on the set of 11 melon CPM race differentials.

A new website, potentially the first for any powdery mildew species, was developed to provide access to the information about melon CPM, including the history of the main races, links to PDF copies of the scientific manuscripts, and axenic methods for their maintenance and mass production of inoculum, and long-term storage: http://powderymildew.ucr.edu.

Project results were disseminated on an ongoing basis:

- Fall Desert Crops Workshop: Melon Host Plant Resistance to Powdery Mildew and CYSDV in El Centro, California on October 29, 2015 (approximately 40 attendees).
- California Melon Research Board annual meeting entitled, “Powdery Mildew Race Variation in California” in San Diego, California on January 6, 2016 (approximately 80 attendees).
- Cucurbitaceae 2016, XIth Eucarpia Meeting on Genetica and Breeding of Cucurbitaceae, “Initiative for International Cooperation of Researchers and Breeders Related to Determination and Denomination of Cucurbit Powdery Mildew Races” on July 24-28th, 2016 in Warsaw, Poland (approximately 163 attendees) and ensuing discussion session (approximately 13 participants).
- Collaboration for Plant Pathogen Strain Identification (CPPSI) international conference call on March 16, 2017 (approximately 10 participants).
- International Seed Federation Working Group Disease Resistance Terminology (IFS WG DRT)/ CPPSI international conference call on July 7, 2017 (approximately 13 participants).
- Fall Desert Crops Workshop: Melon Powdery Mildew Race Variation in California in Holtville, California on December 7, 2017 (approximately 50 attendees).

The Principal Investigator increased seeds of the melon powdery mildew race differentials, collected several isolates from greenhouse and field, and arranged for at least one isolate from a seed company test site. The Principal Investigator also conferred with the Co-Principal Investigator on experimental design, spore production, testing on differential hosts, data analyses, and web design. The Co- Principal Investigator

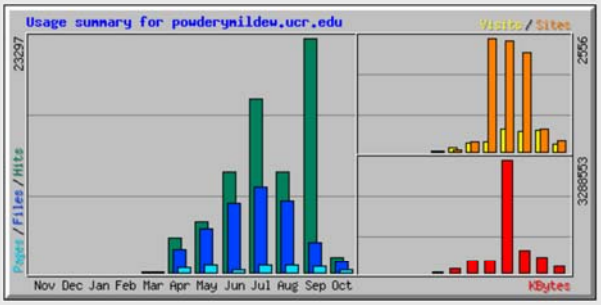
received the isolates, supervised a postdoctoral scientist to carry-out their initial increase and single spore procedures, and refined methods for increasing spores and their long term storage in vapor phase liquid nitrogen. The Co-Principal Investigator also oversaw the testing of isolates on race differentials, and led development of the project website.

Goals and Outcomes Achieved

The project team completed the increase of 30 CPM isolates and their strains and placed them in cryogenic storage. The number of isolates obtained was less than anticipated, and though there was not a specific target number of isolates, one might conservatively estimate 30 isolates (five collection areas x three years x two isolates per area per year) that could have resulted in 30 strains, for a total of 60 isolates and strains. The project team characterized 25 of the isolates and their strains on the melon CPM race differentials; that number likely would not have been greater even if 60 isolates and strains were produced due to facility and personnel limitations. The website was designed and launched to the general public. The site will be maintained for five years by the University of California, Riverside, at which time additional funding source or an alternative host server will be identified. The website was expected to be a resource for CPM researchers with access to the World Wide Web. The project team collected data on the number of hits etcetera received by the website (Figure 6). The most current site hit data available at: http://powderymildew.ucr.edu/stats/. The 30 isolates and strains in cryogenic storage will be made available, upon request, to CPM researchers and seed company personnel for use, provided submission of appropriate permits, e.g., United States Department of Agriculture, Animal and Plant Inspection Service (APHIS) Permit to Move Live Plant Pests, Noxious Weeds, and Soil.

Usage Statistics for powderymildew.ucr.edu

Summary by Month
Generated 12-Oct-2017 00:17 PDT



Summary by Month

Month	Daily Avg				Monthly Totals					
	Hits	Files	Pages	Visits	Sites	KBytes	Visits	Pages	Files	Hits
Oct 2017	142	102	24	16	250	173342	177	270	1122	1566
Sep 2017	776	102	22	15	496	447808	478	678	3077	23297
Aug 2017	323	230	22	15	2228	670450	468	694	7157	10033
Jul 2017	555	274	25	16	2486	3288553	500	798	8508	17219
Jun 2017	335	229	10	7	2556	335822	215	329	6889	10059
May 2017	164	140	25	6	209	353485	207	790	4370	5111
Apr 2017	118	80	16	2	44	106094	82	489	2404	3553
Mar 2017	2	1	1	1	21	13	22	22	21	44
Totals						5375567	2149	4070	33548	70882

Figure 6. Early Powdery mildew website hit data through October 12, 2017.

The project team collected 13 isolates of CPM from field and greenhouses where melons were grown in California, established them in cryogenic storage for long-term research use and to serve as a reference in

future comparative studies. Disease reaction data for 25 of the isolates and strains in whole plant test serve top characterized this collection. Additional details of the disease reaction assays will be added to the website in order to provide a more complete description of each isolate and its respective strain(s).

Establishment of a collection of field isolates and up to three single spore sub-strains using sterile laboratory techniques, and procedures for their increase and long-term storage in vapor phase liquid nitrogen tanks at minus 150 to minus 186 ºC. This included confirmation of viability and pathogenicity after vapor phase liquid nitrogen storage. Data collected from controlled inoculation greenhouse tests of field isolates and their respective single spore strains revealed small variation for pathogenicity (race differences) within individual field isolates.

Beneficiaries

Melon breeding companies, melon growers and shippers, and scientists working on melon powdery mildew benefitted from the completion of this project.

Exact numbers were not available for each of the groups listed above; following were estimates only.

- Breeding companies: minimum of 15 (most international, many that do business in California).
- Growers: 175 (J.D. Allen, California Melon Research Board)
- Shippers: 45 (J.D. Allen, California Melon Research Board)
- Public scientists working on cucurbit powdery mildew: 15 (United States)

Lessons Learned

Fewer powdery mildew field isolates were received than anticipated. The negative result of this was fewer samples for research on race variation. This however, allowed the team to focus on the development of improved procedures for handling field isolates and their single spore strains, and refinement of procedures to increase inoculum for testing isolates and strains on race differentials. It also allowed the team to focus on the development of a reliable protocol for vapor phase liquid nitrogen, the “gold standard” for long-term cryogenic preservation of genetic materials.

A large set of 21 cucurbit powdery mildew race differentials was increased but pared to 11 for practical reasons due to the large number of powdery mildew-free plants required to characterize the isolates and their single spore sub-strains. Disease reaction data based on the 11 differentials will serve to provide baseline data for subsequent testing on the full set of twenty-one differentials.

Additional Information

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CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 47	**Project Title:** Biology and Control of *Euwallacea* sp., the Vector of Fusarium Dieback Disease in California Avocado and Nursery Tree Production	
Grant Recipient: The Regents of University of California, Riverside	**Grant Agreement No.:** SCB14047	**Date Submitted:** December 2017
Recipient Contact: Timothy Paine	**Telephone:** (951) 827-5835	**Email:** timothy.paine@ucr.edu

Project Summary

A species of ambrosia beetle (*Coleoptera: Curculionidae: Scolytinae*), closely related to the Southeast Asian species, *Euwallacea fornicatus*, was first identified in Southern California in 2004. After an initial lag in expansion, it has recently expanded its geographic range to include Los Angeles, Orange, Riverside, and San Diego counties. Critically, for the avocado industry, this same species has also been introduced in Israel and is killing a large number of trees in that nation. The beetle is associated with a fungal complex including a *Fusarium* species that has caused extensive tree mortality. In California, it has expanded its host range to include attacking more than 200 tree species, including avocados, common landscape trees, native forest trees, and weedy invasive species. The large source populations of beetles are poised to move across urban environments into adjacent commercial avocado production areas. Avocado producers will need management tools to reduce populations of insects within their groves and protect their trees. The objective of the project was to develop effective management of the insect/fungus complex. It is necessary to provide short term tools for the industry to protect their trees. The range of options may include direct control using contact or systemic insecticides to prevent infestation or to kill infesting beetles to limit spread. It is also necessary to develop effective sanitation of infested wood to prevent emergence. This could include chipping or solarization. These approaches needed to be tested for efficacy. The longer term solutions will involve understanding more about the life history and ecology of the pest complex in California. This will require understanding more about the environmental requirements, the reproductive biology, the susceptibility and suitability of commercial and woody nursery stock hosts, the attraction of host materials to the insects, and the influence of host condition on beetle success.

A preliminary version of this project is supported by the California Avocado Commission (CAC). The CAC recognized the threat posed to their industry by the beetle/fungus complex and acted quickly to limit damage rather than react to a later crisis. Unfortunately, their ability to continue funding for the next two years of the research is limited by a short crop. They remain intensely interested in the research and have been very aggressive in educating their members of the threat and the progress made in combating it. The results that are generated by this research will be transferred directly to the industry through extension efforts for implementation. If there is a need for refinement of the proposed research in the future, CAC funding environment should be improved. In addition, the California Association of Nurseries and Garden Centers, representing another concerned specialty crop industry at risk from the beetle, recognized the critical nature of the problem and provided a small amount of seed support.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

I. Insecticide trials

A. Pesticide and fungicide trial:

The objective of this study was to test the effectiveness of insecticides, fungicides, and insecticide–fungicide combinations for controlling *Euwallacea* sp. The project staff chose one systemic insecticide, one contact insecticide, three triazole fungicides, and one bacterial fungicide applied individually and in combinations. To test the effectiveness of the pesticide treatments, project staff treated mature, infested sycamore trees, and monitored for increasing attacks over time. They selected heavily infested mature sycamore trees on the campus of University of California, Irvine. This ensured an abundance of beetles and a way to quickly assess differences in pesticide effectiveness. The project staff initially had 10 treatments; an 11th treatment was added one month after the others were initiated. Treatments 2-7 evaluated individual pesticides, treatments 8-11 evaluated pesticide combinations. There were initially 11 trees for each treatment, but some trees were lost during the course of six months monitoring due to tree removal.

1. Untreated control
2. Bifenthrin (contact)
3. Emamectin benzoate (systemic)
4. Tebuconazole (triazole fungicide)
5. Propiconazole (triazole fungicide)
6. Metconazole (triazole fungicide)
7. *Bacillus subtilis* (bacterial fungicide)
8. Emamectin benzoate + Propiconazole
9. Emamectin benzoate + Tebuconazole
10. Bifenthrin + Tebuconazole
11. Emamectin benzoate + Bifenthrin + Metconazole

Prior to treatment, all Polyphagous Shot Hole Borer (PSHB) holes on the main trunk in an area approximately three feet from the ground to six feet were counted. Treatments were applied in June 2015. Attacks on the main trunk were counted again at one month, three months and six months post-treatment, through December 2015. The project staff found that pesticide combinations were generally more effective than single pesticide treatments. The combination of a systemic insecticide (emamectin benzoate), a contact insecticide (bifenthrin), and a fungicide (metconazole) provided some level of control for these heavily infested trees. The biological fungicide *Bacillus subtilis* provided short-term control. There was no difference in the performance of the three triazole fungicides (propiconazole, tebuconazole, and metconazole). Although no pesticide combination provided substantial control over time, pesticide treatments may be more effective when trees are treated during early stages of attack by this ambrosia beetle.

The previous trial at University of California, Irvine used very heavily infested trees. These pesticide trials focused on the long-term effectiveness of the top performing pesticides on more lightly infested trees. This is a critical area of information for park managers, industry professionals, and other agencies.

B. Systemic insecticides alone:

The project staff compared two different systemic insecticides, imidacloprid (Merit) and emamectin benzoate (TREE-äge), which have not previously been compared during the same trial, and untreated controls.

Ten trees for each treatment were selected in park areas of a gated community in Newport Beach, California in September 2016. Prior to treatment, all PSHB holes on the main trunk in an area approximately three feet from the ground to six feet were counted. Initial attacks present on trees were very light at 4.8 ± 1.2 attacks/m^2 (mean ± s.e.). Treatments were applied on October 17, 2016. Attacks on the main trunk were counted again every one or two months, with the count interval depending on weather and beetle activity, and the increase in attacks was calculated for each tree. There were no significant differences in attack rates among the treatments. Beetle activity has been very low at this site. This may be due to the cold, wet winter. Beetle activity remained low through spring and early summer. There were signs of beetle activity picking up in July, 2017. The trees were removed by the housing association at the end of July 2017, for reasons unrelated to PSHB, so no further monitoring was possible at this site.

C. Systemic insecticides in combination with a contact insecticide and fungicide:
This trial focused on a combination of three agents (a systemic insecticide, a trunk spray insecticide, and a trunk spray fungicide), which was found to be the most effective treatment in trials conducted on the campus at University of California, Irvine. The project staff used two different systemic insecticides in this combination, imidacloprid and emamectin benzoate. Bifenthrin, the most effective contact insecticide from laboratory trial was included as a positive control. The biorational microbial fungicide *Bacillus subtilis,* which was previously found to be effective short term, was also included as a treatment.

There was five treatments with 10 trees each, for a total of 50 trees:
1. Bifenthrin (Onyx), metconazole (Tourney), and emamectin benzoate
2. Bifenthrin, metconazole, and imidacloprid
3. Bifenthrin alone (most effective single pesticide during laboratory trials)
4. *Bacillus subtilis*, a microbial fungicide (Cease)
5. Untreated controls

Ten trees for each treatment were selected at Mason Regional Park in Irvine, California in September 2016. Prior to treatment, all PSHB holes on the main trunk in an area approximately three feet from the ground to six feet were counted. Initial attacks present on trees were light at 36.5 ± 6.7 attacks/m^2 (mean ± s.e.). Treatments were applied on September 14, 2016. Attacks on the main trunk were counted again every month, and the increase in attacks was calculated for each tree. There are no significant differences in attack rates among the treatments. Beetle activity has been low at this site. This may be due to the cold, wet winter. Beetle activity remained very low through June 2017 (nine months post treatment) and there were no significant differences among treatments for the first nine months. At month 10 (July 2017), project staff observed signs of fresh beetle activity. Trees treated with the combination of imidacloprid, bifenthrin and metconazole had significantly lower attacks than trees treated with bifenthrin alone. The project staff expect beetle activity will continue to increase at this site in the next few months. The project staff will continue monitoring at this site.

D. Pesticide summary:
PSHB is difficult to control with pesticides. This is often the case with ambrosia beetles because of their cryptic habits. Since they feed on symbiotic fungi rather than wood, their ingestion of wood by is limited. The beetles spend little time on the tree surface. Females mate with siblings in maternal galleries before they leave their natal tree. All these factors may limit the beetle's interaction with pesticides. However, the impact of PSHB on trees in southern California is severe enough that pesticide options for management are needed. Options for biological control agents are also being explored, but will take several years to develop. To date,

the best options for beetle control with pesticides will use a combination of systemic and contact insecticides with a fungicide.

II. Avocado Cultivar Comparisons
A. Laboratory trials:
The project staff conducted two types of trials: mixed cultivar choice trials, and single cultivar no choice trials. For all trials, un-infested host material was infested with PSHB using cut logs from an infested tree as a beetle source. After a period of exposure, the source logs were removed, and the beetle activity was tracked for several more weeks, to allow time for beetles to lay eggs and larva to complete development. Beetle activity was recorded as holes with fresh sawdust accumulation, or fresh exudate. At the end of the experiment, branches were frozen, and then the bark was stripped to facilitate counting of all the beetle entry holes. The branches were split, and gallery holes were counted to evaluate beetle activity inside the branch.

Two mixed cultivar choice trials were conducted, where one branch from each cultivar was placed together in a bucket and branches were exposed attack by PSHB from infested source logs for two weeks. After two weeks, the source logs were removed, and beetle activity was tracked for several more weeks. To compare between replicate buckets, project staff calculated attacks for each cultivar as the percentage of total attacks for that bucket.

The first mixed cultivar trial compared nine avocado cultivars with five replicate buckets. Although there were no significant differences, Zutano tended to have the highest attack rates. Hass, Gem and Zutano had higher ratios for galleries per total surface attacks, indicating there were more galleries formed for every beetle attack for these cultivars. Fuerte had a low gallery/attack ratio, indicating this cultivar may be more resistant to beetle activity.

The second mixed cultivar trial compared eight avocado cultivars with 10 replicate buckets. There were no significant differences in attacks at two weeks, but total attacks at the end of the trial were significantly higher for Nabal and UC 1 (a University of California cultivar) compared to Fuerte. The ratio of galleries per total surface attacks was once again lowest for Fuerte.

For no choice trials, several branches from a single cultivar were placed together in a bucket, exposed to PSHB, monitored and processed as for the mixed cultivar trials. Since overall attack rates could vary from bucket to bucket depending on the source log and time of year, project staff used the ratio of galleries/surface attacks to compare among cultivars for the no choice trials. The ratio of galleries per attacks was significantly higher for Zutano than for all other cultivars except Lamb Hass.

B. Field Trial:
Avocado trees (average stem diameter 18 mm) were planted at CalPoly Pomona in April 2014 and exposed to beetles using infested box elder logs wrapped next to each tree trunk with burlap. This activitiy was paid for with other funding sources. Source logs were left in place for six weeks. Cultivars included Ettinger, Hass, Lamb Hass, Pinkerton and Zutano with 12 trees for each cultivar. At the end of the infestation period Ettinger, Pinkerton and Zutano were more heavily attacked than Hass. At the end of the trial (105 days) attacks on Pinkerton were significantly higher than all other cultivars. Gallery density and the ratio of galleries per total attacks were significantly higher for Zutano than for Lamb Hass and Hass. The ratio of galleries per attacks showed similar patterns as was found in the bucket trials.

C. Field Survey:
PSHB infestations in Orange County have expanded to include University of California's South Coast Field Station in Irvine, California. The project staff surveyed mixed cultivar avocado groves at the field station where PSHB had been observed. Trees were surveyed from November 2016 to February 2017, while weather was cool, and PSHB was not actively establishing new galleries. For each tree surveyed, project staff counted all attacks visible from ground level to approximately six feet, on trunks and primary branches. The project staff surveyed a total of 16 cultivars, but only eight cultivars were present in sufficient quantity to allow statistical comparisons. Hass was more frequently attacked than most other cultivars (GEM, Harvest, Reed, Thomas, Lamb Hass and Fuerte). Hass was surveyed on three different rootstocks. There were no differences in attack rates associated with rootstock variety. Attack rates were very low in the avocado groves, and no disease symptoms were observed on the trees. However, differences in attack rates as beetle populations establish in avocado growing regions and increase may lead to differences in disease symptoms and impacts on production in years to come. The project staff plan to continue monitoring avocado at the field station.

D. Avocado Summary:
Zutano was often the most heavily attacked cultivar in both field and laboratory trials. It typically had high rates of attack and a high ratio of gallery formation compared to the number of surface attacks. Fuerte had the lowest ratio of galleries per attacks in both choice trials. The low ratio indicated that there was less gallery formed for every beetle attacking the branch. Based on the laboratory trials, in addition to Fuerte, other cultivars that may be more resistant to beetle attack and gallery formation include Gwen and Bacon. Hass and Lamb Hass cultivars were more variable in the response observed.

III. Temperature and Development:
The developmental rate of PSHB was tested under six different temperatures in controlled laboratory conditions. Single adult females were placed in a tube containing semi-artificial media and reared at 15, 18, 20, 25, 30, or 32 ℃ in a climate controlled temperature chamber. Subsets of tubes were dissected at regular intervals in order to track the development of the beetle and her offspring. Using the Briere model to analyze the data, the minimum, maximum, and optimum temperatures were determined to be 15.00, 33.08, and 27.58℃, respectively. It is important to note that these temperature limits were only for the range development could occur and are not temperatures that were necessarily lethal for adult beetles. Adult beetles were able to survive for extended periods of time at 15 ℃ and would likely be able to survive until the temperature increased.

The climate modeling programs MaxEnt and CLIMEX were used in order to predict PSHB's potential invasive range in California. MaxEnt used presence-only data gathered from the Eskalen lab (Eskalen et al, http://eskalenlab.ucr.edu/distribution.html) and collection information obtained by Stouthamer et al (2017) in order to predict the range of PSHB. CLIMEX utilized the development data gained from the previously conducted rearing experiments. Both models recovered and showed high levels of climate suitability in PSHB's native range which supports the accuracy of the model's predictions. The two models had general agreement on the predicted range of PSHB in California. Both predict the possibility of PSHB expanding its range all the way to northern California through the central valley.

IV. Climex and vegetation models to predict potential areas of spread:
Climex results depicting which areas of California contained a climate that was suitable for the development of PSHB were combined with multiple vegetation datasets to determine whether areas with suitable climate

also contained hosts that would allow for beetle development. Datasets from multiple plant communities were compiled from the United States Department of Agriculture (USDA) Forest Service Region five Resource Management (www.fs.usda.gov/main/r5) Vegetation Mapping and Classification resources. The range of potentially suitable plant communities was compared with the climatic range of PSHB. Based on the results it appeared that most suitable plant communities bordered the areas with potentially suitable climates, except in southern California where there was direct overlap. This was likely due to the presence of urbanized areas within the areas the plant community's border. Due to the usage of multiple host trees in urban forests, urban areas could also be at risk and allow the spread of PSHB into the neighboring native plant communities. Strictly based on the plant communities the beetle is more of a threat in southern California where multiple plant communities directly overlap with the weather stations that predict suitable climate allowing for numerous hosts to choose from. The California distribution of 14 reproductive hosts from the Geosciences and Environmental Change Science Center (USGS) (https://esp.cr.usgs.gov/data/little/) were compared to the climatic range of PSHB as well. The overlap indicated that any region that was climatically suitable would also have suitable hosts for colonization as well. For all weather stations with positive Ecoclimatic Indices, they shared at least one reproductive host for PSHB to spread to and in almost all cases more than one reproductive host. If PSHB were to spread to any of these areas with suitable climate they would likely be able to establish due to the presence of reproductive hosts. These estimates are conservative as not all reproductive hosts were able to be mapped and many reproductive hosts are planted in urban landscapes which could not be mapped. Due to these findings it is definitely a possibility that PSHB could spread through the central valley all the way to northern California.

V. Water stress studies:
Three different studies were undertaken to examine the effect of irrigation on a trees likelihood to be attacked by PSHB. At the University of California, Irvine, sycamore trees were evaluated after a portion of the tree population had their irrigation halted. At the Huntington Botanical Gardens two studies were performed, one on currently existing stands of liquidambar trees and another on potted box elder trees.

Thirty-nine trees were evaluated at the University of California, Irvine, with 20 of them irrigated and the other 19 with irrigation ceased. Trees had the number of attacks along the circumference of the main trunk and the health of the crown visually assessed over the course of one year. The number of initial attacks, diameter of the tree at breast height, and level of crown senescence were recorded during multiple surveys over the course of the study. Logistic regression was used to assess the effect of irrigation on attack rate and tree health with $\alpha = 0.05$. It was found that irrigation only played a role in crown health (Wald's $\chi^2 = 10.84$, $p=0.001$), but not attack rate (Wald's $\chi^2=1.64$, $p=0.20$).

Three stands of liquidambar with either consistent, inconsistent, and no irrigation were evaluated to determine if the three levels of irrigation had different attack rates. Like the University of California, Irvine, the number of attacks on the main trunk and the visual assessment of crown health were recorded during three surveys. A Kruskal-Wallis one-way ANOVA was conducted, with significance set at $\alpha = 0.05$, to determine if irrigation had an effect on the number of attacks per tree. It was found that irrigation did not affect the number of attacks per tree (Kruskal-Wallis df =2, $\chi^2=0.4483$ P=0.7992).

Sixty-four trees were planted in pots at the Huntington Botanical Gardens in San Marino and subjected to four different watering regimes: 4.2, 3.0, 1.8, 0.8 gallons per week. After one year, the trees were each infested with 16 PSHB. The trees were cut down and checked for signs of entry by the PSHB four months

later. Each watering regime showed low levels of attack. A Chi-square test was run in SAS to determine if the probability of a beetle attacking one irrigation treatment was greater than the others ($\alpha = 0.05$) and it was found that there was no significant difference in the probability of one level of irrigation being attacked over the other ($p>0.15$).

This indicates that for these trees the beetle did not exhibit a strong preference in water stress levels of the tree it attacked. Unlike in some wood-boring insect species, water stress does not make a tree more susceptible or prone to be attacked. The beetle does not seem to be seeking out well watered trees for its fungal symbionts either. For irrigated trees this means that management does not need to alter irrigation practices as watering does not affect the probability that a tree will be attacked. For beetle preference it may be more affected by tree size or trees are selected randomly.

VI. Host Preference:
The project staff have been examining host preference in two ways. First, collecting branches from trees that have been attacked by the beetle in the infestation zone. Branches are then examined to determine surface attack rates, and then split to examine gallery density.

A. Field observations:
For field collected logs, project staff have examined branch samples from 36 species. Both documented reproductive hosts and tree species that have not been found to be reproductive hosts for PSHB had a wide range of attack rates and a wide range of gallery formation. The ratio of galleries was calculated to surface attacks. A high ratio indicates that once the beetle has attacked the tree, it is actively forming galleries. A low ratio would indicate less gallery formation once the beetle attacks. Overall there was little correlation between attack rates and gallery formation. Even among listed reproductive hosts, some species with very high attack densities (e.g. *Brachychiton populneus*) had a very low ratio.

B. Laboratory trials:
The project staff have collected freshly pruned branches from healthy trees outside the infestation zone, these branch samples were cut in 12-15 inch segments and placed in a five gallon buckets with beetle infested branches for two weeks. Logs were then tracked for 10-11 weeks to allow beetle larva to complete growth and emerge. Logs were then frozen and split to examine gallery formation. This provided a comparison of beetle activity with a similar time for attacks, gallery formation and beetle development for all tree species examined.

For clean host logs infested in colony buckets, project staff have examined 147 branch samples representing 22 species, both known hosts for PSHB, and non-host tree species. Similarly to field collected branches, both documented reproductive hosts and non-host species a wide range of attack rates and a wide range for the ratio of galleries to surface attacks.

C. Host preference summary:
It is clear that PSHB may attack a much wider range of tree species than have been documented to support the beetle's reproduction, and sometimes those trees may be very heavily attacked with extensive gallery formation. It is likely that in some circumstances, such as high population densities in a given area, PSHB may heavily attack and form galleries in a non-suitable host. Very little is known about host finding and beetle

performance on different hosts under field conditions. Much more research is needed to understand the host finding, host choice and beetle performance on different hosts.

VII. Wood Age:
It is known that beetles can persist for months in the wood of cut branches and felled trees. Beetles not only survive in cut wood, they can continue to expand galleries and lay eggs, and larvae can complete development. One sanitation concern that arises, is that beetles may be able to infest wood piles as well as living trees, especially when infested wood is stored near other wood. The project staff have used bucket trials to examine beetle attacks and gallery formation for cut branches as a function of time since the branches were pruned.

All branches were pruned from Pinkerton avocado trees in Riverside California. Branches were cut and air dried for 11, 6, 3, 2, or 1 weeks, or freshly pruned at the beginning of the experiment. For choice trials, one branch of each wood age was placed in a bucket for a total of six branches, along with a piece of infested log as a source of beetles. For no-choice trials, one branch was placed in each bucket with a beetle source. Beetle attacks were monitored for 10 weeks. After 10 weeks, all logs were frozen, and will be examined for gallery formation.

For choice tests, beetle attacks were significantly higher for freshly pruned wood compared to all other wood age classes at 3, 4 and 10 weeks after the trial was initiated. After 10 weeks, beetle attacks on branches that had been aged for one week were higher than for all alder age classes. For no-choice tests, beetle attacks were significantly higher for freshly pruned branches, but only at the end of the trial at 10 weeks observation.

The project staff examined branches for gallery formation. The project staff have looked at a small proportion of branches from the choice trials. (3 of 12 buckets). Thus far, gallery formation was significantly higher for freshly pruned branches compared to all other wood age classes. Results showed that beetles had a strong preference for freshly pruned wood, and that beetle attacks in wood piles or downed wood in natural habitats was unlikely.

VIII. Work in progress:
In March 2017, project staff had trees planted at the University of California, Riverside Agricultural Experiment Station. These nursery-stock trees (84 box elder, over 200 Japanese maple) were used for testing pesticide combinations, biopesticdes with protective gel surfacants, and irrigation trials. The project staff also planted 62 avocado with five different cultivars (Bacon, Fuerte, Hass, Lamb Hass and Zutano). Avocado were used for monitoring long-term tree growth and disease symptoms among the different cultivars for infested and un-infested trees.

Beetle activity at field sites has been increasing as of July 2017. In the future, the project staff will test three biological agents (*Bascillus subtilis*, a fungus and a nematode) with and without a gel barrier surfactant. The surfactant that will be used is Barricade Fire Gel. This is a non-toxic gel coating approved by the Forest Service for use in wildland areas. The plan is to test cut branches infested with PSHB, to examine if adding a surfactant protects the biological agent from desiccation and increases the longevity of biorational control agents such as B. subtilis. This may potentially provide an environmentally friendly option for managing PSHB in sensitive areas, such a riparian habitats.

This project did not enhance the competitiveness of non-specialty crops. The cropping systems that benefited from the research conducted and supported by Specialty Crop Block Grant Program funds were the avocado and nursery crops industries in California.

Project staff had a collaboration from Advisors with University of California, Cooperative Extension who helped conduct the research and facilitate the outreach efforts.

Goals and Outcomes Achieved

The project staff have completed the goal of establishing the potential geographic range of the beetle. Also developed methods to assess risk (e.g., impact of water stress) and control of infestations (e.g., combinations of insecticides and fungicides, solarization, and sanitation through chipping). The project staff have assessed the level of current understanding of the audiences for presentations about the nature of the problem in the affected industries. During the reporting period, there were approximately 30 presentations to organizations including industry professionals, city government officials, and public outreach, and also assisted in developing materials for dissemination through University of California Cooperative Extension. Assessments of the knowledge of research-based recommendations prior to and after presentations to industry and general public audiences has indicated that 80% of the attendees have gained an understanding that they did not have previously. Specifically, the baseline at the beginning of the project was zero for all three of the project goals:

Goal 1: Increase the number of growers using recommended best practices for prophylactic treatment of trees and sanitation of infested material from dying trees. Performance Measure: Performance would be quantified by comparing responses to surveys regarding recommended best practices presented to audiences of industry representatives and professional pest control audiences at the beginning of the study and at the end of the study. Benchmark: Best practices have not been established therefore the benchmark is zero percent. Target: An adoption rate of 40 percent after two years would be considered a success.

Goal 2: Increase end-user knowledge of areas at risk of infestation and seasonal activity of the beetle in different parts of California. Performance Measure: Performance would be quantified by comparing responses to surveys regarding life history presented to audiences of industry representatives and professional pest control audiences at the beginning of the study and at the end of the study. Benchmark: Thermal thresholds and development rates have not been determined therefore the benchmark is zero percent. Target: An adoption rate of 40 percent after two years would be considered a success.

Goal 3: Increase grower understanding of risk ratings of potential hosts, including avocado varieties and containerized nursery trees, and best cultural practices to reduce tree susceptibility. Performance Measure: Performance would be quantified by comparing responses to surveys regarding best practices presented to audiences of industry representatives and professional pest control audiences at the beginning of the study and at the end of the study. Benchmark: Host susceptibility and host response to stress evaluations are not complete therefore the benchmark is zero percent. Target: An adoption rate of 40 percent after two years would be considered a success.

At the end of the project, the success rate was measured by changes in the audience responses to sets of oral assessment questions asked before and after invited presentations given at meetings organized through UC Cooperative Extension, the wholesale nursery industry, and the avocado industry; 80% of the surveyed individuals had understood and adopted best practices for prophylactic treatment of trees and sanitation of

infested material from dying trees (Goal 1), understood the risk of infestation and seasonal activity of the beetle in different parts of California (Goal 2), and understood the risk of infestation to specific potential host tree species or cultivars (Goal 3). The 80% rate of understanding at the end of the project, from a level of 0% the beginning of the project exceeded the target goal criteria for project success.

During the project period, three manuscripts were submitted for publication, two are now published, and one is in press.

Beneficiaries

The beneficiaries of the project accomplishments were the California avocado and nursery crop industries. Although not an agricultural industry, managers of California natural resources and the general public may also have benefited. Riparian forests throughout the state are composed of species that are highly susceptible to beetle attack. The increased understanding of the biology and management of the beetle disease complex may enhance management efforts in these natural areas.

California's 4,900 avocado growers (California Avocado Commission) produce 88% of the nation's avocados on 52,200 acres of bearing trees and the crop ranked 19th in California commodity value in 2011 at $460.6 million. California also leads the nation in the production of nursery crops. Nursery production was ranked fifth in California commodity value in 2011 at $2.683 billion. Although difficult to partition the value of tree production from that total, the more than 200 attacked tree species constitute a large, high value segment of the nursery industry. The research benefited producers and consumers of avocados and susceptible nursery crops through determining the probability and impact of this invasive insect disease complex and by developing tools to detect, eradicate, and control the pests. The beetle fungus association can kill susceptible trees in a short period of time or, through repeated attacks, may cause a progressive decline in the vigor of the tree resulting in declining rates of production. Infested nursery stock trees are not marketable. In addition, because of an overall reduction in the beetle population, a residual benefit of the research will lower infestation rates of susceptible trees in landscapes. This may preserve the value of those trees as suitable for planting and maintaining which, in turn, protects their value as a production commodity for the nursery industry. Assuming a conservative loss of five percent in reduced harvest due to tree mortality and lowered tree vigor or to unmarketable containerized trees, the potential losses could be $134 million to nurseries and $23 million to the avocado industry. Treatment approaches developed in the proposed research that protect trees from infestation or that reduce the size of the insect population have the potential to greatly limit those losses and enhance the competitiveness of a wide range of California's specialty crops. The management approaches will also benefit production areas in other states if the beetle expands the geographic range.

Lessons Learned

The research involved field plots using living plant material and relied on actively flying beetles. The project staff learned that it was critical to have established good cooperative relationships with public agencies and private pest management companies to be able to find locations that met the requirements for replication and access. It was also noted that it was critical to have an effective public information program in place prior to initiation of field trials to avoid misunderstandings and to garner public support.

Although the focus of the research was to provide benefit to California specialty crops, project staff needed to develop some level of risk of infestation from beetles emerging from other sources. Preliminary analysis of a recently external completed project suggested that killed host material was only suitable for infestation by the

beetles for a very short period of time (days to weeks). This unexpected result had significant implications for risk management.

Additional Information

Attachment 1: Prioritizing Management Efforts Guidelines.

Manuscripts can be found:

Eatough Jones M., Kabashima J., Eskalen A., Dimson M., Mayorquin J.S., Carrillo J.D., Hanlon C.C., Paine T.D. 2017. Evaluations of Insecticides and Fungicides for Reducing Attack Rates of a new invasive ambrosia beetle (*Euwallacea* Sp., Coleoptera: Curculionidae: Scolytinae) in Infested Landscape Trees in California. Journal of Economic Entomology 110: 1611–1618. https://doi.org/10.1093/jee/tox163

Eatough Jones M., Paine T.D. 2017. Differences among avocado cultivars in susceptibility to polyphagous shot hole borer (*Euwallacea* spec.). Entomologia Experimentalis et Applicata 163: 296-304. http://onlinelibrary.wiley.com/doi/10.1111/eea.12577/epdf

Eatough Jones M., Paine T.D. 2015. Effect of Chipping and Solarization on Emergence and Boring Activity of a Recently Introduced Ambrosia Beetle (*Euwallacea* sp., Coleoptera: Curculionidae: Scolytinae) in Southern California. Journal of Economic Entomology, 108(4):1852-1559. http://www.bioone.org/doi/full/10.1093/jee/tov169

USDA Project No.:	Project Title:	
48	Improved Detection Methods for *Tuta absoluta*, a Potential New Pest of Tomatoes	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB14048	**Date Submitted:** December 2017
Recipient Contact: Kris Godfrey	**Telephone:** (530) 754-2104	**Email:** kegodfrey@ucdavis.edu

Project Summary

Tuta absoluta (*T. absoluta*) is a key pest of tomatoes and is spreading rapidly through tomato growing regions of the world despite strict plant pest regulations designed to stop its spread. *T. absoluta* larvae and damage resembles that of other tomato pests found in California, such as the tomato pinworm, and positive identification of adults currently requires dissecting the genitalia of male moths. This project sequenced the genome of *T. absoluta* and used this new resource to develop a molecular diagnostic using deoxyribonucleic acid (DNA) based genotyping technology. This molecular detection tool can be used with all life stages of *T. absoluta*, not just adult moths, and to distinguish them from related tomato-feeding species that are already in California. Even a single insect can be used for DNA genotyping and the procedure allows for large numbers of insects to be screened in a short period of time. Educational programs for *T. absoluta* were developed for tomato growers in an attempt to improve early detection of this pest should it enter California. The ability of *T. absoluta* to use solanaceous weeds found near California tomato fields was also evaluated to determine the overwintering potential of this insect in California.

T. absoluta is a gelechiid moth that has caused between 80 to 100 percent crop loss in tomatoes in recently invaded areas. A native of South America, *T. absoluta* is spreading northward through Central America and is currently found in Panama and Costa Rica. *T. absoluta* has the potential for introduction into California in tomato transplants, tomato stems, and fruit. This insect was accidentally introduced into Spain in 2008 and despite rigorous enforcement of regulations, it spread throughout Europe in just three years. *T. absoluta* has up to 10 generations per year and attacks all parts of the tomato plant. *T. absoluta*, in all of its life stages, is morphologically similar to other pests of tomatoes in California, and positive identification is difficult even for taxonomic experts. Growers could easily think that they have an infestation of tomato pinworm when, in fact, they have *T. absoluta*. This could result in *T. absoluta* establishing and spreading through California well before the first detection. There is a need for robust and rapid molecular methods of identification of all life stages of *T. absoluta*. Such a test will decrease time required for positive identification by regulators, increasing the probability for a successful response to prevent its establishment, contain its spread, and reduce length of expensive and disruptive quarantine holds for nurserymen, growers, packers, and processors. Grower and pest control adviser (PCA) education about *T. absoluta* further increases the probability of its early detection reducing the likelihood of establishment and spread as well as its associated economic and environmental costs for pest response. Determining if *T. absoluta* can overwinter on solanaceous weeds in California is needed to develop an integrated pest management (IPM) approach that includes reducing pest densities through alternate host removal and the number of insecticide applications. Judicious use of insecticides provides economic and environmental benefits for growers and society.

This project did not build upon a previously funded Specialty Crop Block Grant Program (SCBGP) project.

Project Approach

The Principal Investigator (PI) attempted to obtain permits from the United States Department of Agriculture (USDA) to import *T. absoluta* from a laboratory colony in Spain to initiate a colony in the University of California-Davis, Contained Research Facility (CRF; Biosafety Level 3-Plant), but the permit was denied. The PI and Co-PIs then contacted cooperators in Spain, Costa Rica, and Brazil to assist in collecting preserved specimens of *T. absoluta* from throughout Spain (1 location), Costa Rica (1 location), and South America (12 locations, 8 countries) for use in molecular studies. The Spanish cooperator also agreed to conduct studies on alternate host plants and life history. The PI obtained a USDA permit to import tomato pinworm from anywhere in the United States, and initiated and maintained a colony at the CRF sent by cooperators in Florida. The PI also obtained a California Department of Food and Agriculture (CDFA) permit to obtain and initiate a colony of potato tuberworm from California sources. With the cooperation of the University of California Cooperative Extension (UCCE)-Kern County Farm Advisor, a colony of potato tuberworm was initiated and maintained at the CRF. The tomato pinworm and potato tuberworm are close relatives of *T. absoluta*, and the insects were used in the design and testing of the molecular diagnostic tool.

To obtain genomic information to design accurate molecular diagnostic tools, project staff first sequenced the Tuta genome using the Illumina HiSeq platform. DNA extraction was performed on the Spanish population using the Cetyl trimethylammonium bromide (CTAB) protocol to obtain high molecular weight DNA. 10X genomics microfluidics was used for library preparation to obtain long-range positional information necessary for genome assembly. De novo assembly was performed on the 10x linked-reads using Supernova 1.15. The total assembly size is 422 Mb from 638.8 million reads. The contig and scaffold N50s are 18.09 Kb and 82.45 Kb respectively, with 8,647 long (>10 Kb) scaffolds. In addition, since the genomes of tomato pinworm and potato tuberworm are not available, project staff proceeded to sequence these genomes at lower coverage to enable comparative genomic analysis and design of molecular diagnostics to differentiate these three species. Subsequently, *T. absoluta* samples from South America and Costa Rica were sequenced at lower genomic coverage to evaluate genetic diversity and for the development of a collection of single nucleotide polymorphism (SNP) genotyping diagnostics that can be widely used for *T. absoluta* from different continents. SNP genotyping was performed using Sequenom MassARRAY iPLEX platform after DNA of individual insect was extracted using the Qiagen BioSprint 96 DNA Blood kit and instrument and was quantified using Qubit fluorometric quantitation. Populations of *T. absoluta* from distinct geographical regions, tomato pinworm, and potato tuberworm were used to validate the molecular detection tool.

Studies on the host suitability and life history attributes of *T. absoluta* were conducted by the project's cooperator in Spain using seeds provided by the PI. The seeds included 500 seeds of "Qualit 23" tomato, a common tomato grown in California; 500 seeds of Patio Princess tomato; 28.9 gm of Jimson weed seeds collected in Tulare County; 4.5 gm of black nightshade seeds collected in Yolo County; 50 seeds of hairy nightshade; and 17.5 gm of tomatillo seeds. The tomato, hairy nightshade, and tomatillo seeds were purchased from commercial seed companies. After obtaining the necessary phytosanitary certifications from the United States and Spain, the seeds were sent to the Spanish cooperator to grow plants and conduct the studies. The results of the host suitability studies showed that *T. absoluta* adults would oviposit on all of the host plants tested. However, any larvae hatching from eggs placed on Jimson weed or tomatillo did not survive more than 24-48 hours. On the other hosts, *T. absoluta* completed development from egg to adult. Tomato, black nightshade and hairy nightshade are suitable hosts for *T. absoluta* development and Jimson weed and tomatillo are not. On the suitable host plants, a mean of 3.75 – 4.58 adults developed from eggs on tomato, a

mean of 5.0 adults developed from eggs on hairy nightshade, and a mean of 2.5 adults developed from eggs on black nightshade. The analysis of the results from the life history studies are currently underway.

The training class on the use of the molecular tool for the regulators will be offered in the spring of 2018. The project will consider the training class on the molecular identification tools successful if 50% of those taking the class can answer at least 75% of the questions on the quiz that will be given at the end of the class. Educational materials for Master Gardeners, homeowners, growers, and PCAs have been developed. A Master Gardener and homeowner publication, entitled "South American Tomato Leafminer, *Tuta absoluta*: A Serious Threat to California" is available as hard copies at county UCCE offices or may be downloaded from the UC-IPM's web page at http://www2.ipm.ucanr.edu/Invasive-and-Exotic-Pests/. A National Pest Alert was also written and can be downloaded at http://www.ncipmc.org/action/alerts/tuta.php. The University of California, Agriculture and Natural Resources (UC-ANR) grower publication, entitled, "*Tuta absoluta*, the South American Tomato Leafminer", has been accepted for publication and will be available for free download at www.anrcatalog.ucanr.edu in the spring of 2018. The online course for those interested in learning about *T. absoluta* is available at the UC-ANR Online Learning Management System (http://class.ucanr.edu) and those who may need continuing education credits can receive one hour of credit for this course. The online course has been available since July 2017. As of November 30, 2017 there have been 64 people who have viewed the online course; 60 people have completed the online course; 53 people attempted the final exam where 46 of those people actually completed and passed the exam; and 44 of the 46 people who passed the exam have printed completion certificates. The PI and Co-PIs are in the process of advertising this course more widely to all those associated with California tomato production and processing, and other tomato growers in the world. Examining the questions to determine appropriateness and making changes as needed will continue into the next year. The survey of California tomato growers and PCAs has just begun and will be completed by the end of next year. During the course of this project, eight oral presentations were made to growers and general audiences as well as two radio interviews.

This project did not benefit commodities other than specialty crops. All project activities focused on tomatoes.

The PI wrote the first draft of all the educational materials and coordinated the editing, and production of all materials; collected and coordinated the shipment of seed to the Spanish cooperator; worked with the Spanish cooperator to develop the protocols used for host testing and life history studies; maintained the tomato pinworm and potato tuberworm colonies and provided insects for the molecular biology studies; and actively participated in outreach activities.

One of the Co-PIs contacted cooperators in Spain and Brazil and coordinated obtaining preserved specimens from cooperators in Brazil, Costa Rica, and Spain, as well as hosting the Spanish cooperator in his lab; edited multiple drafts of the educational materials; narrated the online educational course; and coordinated and actively participated in outreach activities, including advertising our efforts to others in the world dealing with *T. absoluta*.

The other Co-PI conducted all of procedures necessary for genomic library preparation and quality control; performed genome assembly and annotation; conducted bioinformatic and comparative genomic analysis necessary to develop the molecular diagnostics; validated the detection tool using iPLEX SNP genotyping assays; and actively participated in outreach activities.

The Spanish cooperator visited California (using non-SCBGP funds); actively participated in outreach activities; provided preserved materials for the molecular studies; and conducted the host plant and life history studies. The Florida cooperators provided tomato pinworms to start the colony that was maintained at the CRF. The UCCE-Kern County Farm Advisor provided potato tuberworms to start the colony maintained at the CRF.

Goals and Outcomes Achieved

The activities completed to achieve the Expected Measureable Outcomes include the development and validation of a molecular diagnostic test to distinguish *T. absoluta* (all life stages) from other native gelechiids found in California tomatoes. This test is expected to have an accuracy of over 95%, after validation with 12 geographical populations of *T. absoluta*, one population of tomato pinworm, and one population of potato tuberworm. With the help of the project's Spanish cooperator, project staff have measured four life history attributes for 50 male:female pairs of *T. absoluta* on host plants on which it will develop. Project staff have attempted to measure the life history attributes on two cultivars of tomato, three solanaceous weed species and two cultivars of tomatillo, a suspected host plant. Analysis of the data is pending, and upon completion, it will be shared with the scientific community, grower community, and the general public. Three publications (UC-ANR grower publication; a Master Gardener and homeowner publication; and a National Pest Alert) have been written and two have been disseminated to various audiences. The UC-ANR publication will be published in the spring of 2018. The online educational course is available for anyone to access and take the training. The Department of Pesticide Regulation (DPR) continuing education credits were requested and approved for this course. The research team has given eight talks during the course of the grant, and two radio interviews. Another talk is scheduled for tomato growers in Modesto in January 2018. A survey of growers as to their knowledge of this pest is drafted and will be implemented during winter extension meetings next year.

Originally the project wanted to quantify the number of publication downloads throughout the project lifetime. Unfortunately the website that hosts the publication doesn't make that possible, but instead the project was able count the number of times the publications was viewed. The Master Gardner publication located on the CRF website (http://crf.ucdavis.edu) has been viewed 121 times over the duration of the project. The project's assessment also included quantifying the number of times the online training course and publications were accessed every two months. Since the training launched in July 2017, there was only data from 5 months available. In July and August 2017 the course was accessed by 22 people, in September and October 2017 the course was accessed by 24 people, and in November 2017 the course was accessed by 14 people. The number of times the publications were accessed could not be quantified every two months because of the programming used to create and maintain the website. Project staff decided to determine if the training program was successful by providing the growers and PCAs with a survey to demonstrate their knowledge of *T. absoluta*. These surveys will begin in spring of 2018 when most of the grower meetings for tomato production are held. The survey will also be distributed at the Modesto meeting in January 2018 where project staff will be discussing the threat of *T. absoluta*. The project anticipates that 50% of the growers and PCAs attending the grower meetings will respond to the surveys, which will result in a successful training program.

The only long-term outcome measure in this project is associated with the online educational course. The PI will continue to monitor the course and make changes as necessary to the questions in the quiz. The PI will also continue to pay the annual fee for the DPR continuing education credits with other funds.

The researchers completed most of the goals outlined in the project. The research team has developed and validated a molecular tool for identification of any life stage of *T. absoluta*. The team also wrote and published the educational materials, plus a National Pest Alert available online from the National IPM Centers, to educate tomato growers and the general public about *T. absoluta*. Multiple talks and radio interviews were also given in an attempt to educate tomato growers and the general public about *T. absoluta*. The evaluation of the online education and the survey of growers concerning their knowledge of this pest will occur after the completion of the grant period. The Spanish cooperator completed the host testing and life history attributes testing for two cultivars of tomatoes, three solanaceous weed species, and two cultivars of tomatillo. The results are currently being analyzed and will be shared with appropriate audiences when completed.

Project staff have generated baseline data on the genomes of multiple populations of *T. absoluta* from South and Central America and Europe as well as genomes of tomato pinworm and potato tuberworm. This data did not exist before this project. Project staff have also provided educational materials that are readily available to all Californians, not just those in the tomato industry. These materials are continuing to be used after the end of this project without the need for additional funding. This project has also generated baseline data for *T. absoluta* life history attributes on both host and non-host plants that are common in California. These studies have demonstrated that some of the solanaceous weeds found in California are not hosts of *T. absoluta*. This information is important in developing integrated pest management programs for *T. absoluta* should it arrive in California.

The project has provided three publications on *T. absoluta* and an online educational course. For the outreach talks, a total of 300 people were in attendance at all of the talks. The Co-PIs interacted and networked with Tuta researchers from around the world at the International Congress of Entomology meeting in 2016. The project's Spanish cooperator has provided data that shows that Jimson weed (from California) and tomatillos are not hosts of *T. absoluta*. The Spanish cooperator has also provided information on the number of *T. absoluta* insects that can develop on each of the host plants (young plants), the fecundity or number of eggs laid on each plant; the survival rate of male and female *T. absoluta* moths on each host plant; and the time required for development from egg to adult on the known host plants. The information provided by the cooperator is needed when making decisions about where detection activities should occur, what sort of monitoring for detection may be necessary, and making decisions about which tactics will be most useful for integrated pest management programs.

Project staff have generated genome resources of 13 geographical populations of *T. absoluta* from South and Central America (9 countries) and Europe (Spain) as well as genomes of tomato pinworm and potato tuberworm. These resources did not exist before this project and will be shared with the research community and will enable the development of more species-specific control strategies to control *T. absoluta*.

Beneficiaries

Several groups will benefit from the completion of this project. California tomato growers, commercial, organic, and home gardeners, will benefit from the educational materials that are developed, and can provide assistance to detecting the first invasions of this insect into California. In addition, all tomato growers worldwide can view the educational materials that were developed in this project, and use the appropriate information for their situation. Researchers tasked with developing integrated pest management programs for

T. absoluta can use the information generated in this project. Regulatory agencies may also benefit from the molecular diagnostic tool when attempting to identify suspect insects from tomatoes.

Commercial (conventional and organic) tomatoes in California cover about 326,400 acres and are worth an estimated $1.7 billion at harvest (2015, CDFA Resource Directory). California tomato growers currently spend about $20 per acre on insecticidal control of insect pests (2017, UC-ANR, Agricultural Issues Center Costs and Returns Report). When *T. absoluta* invades California, the cost of tomato production will increase dramatically due to the need for additional insecticide applications, costs associated with new regulations designed to mitigate the invasion by *T. absoluta*, and possible temporary loss of both domestic and export markets. To estimate the economic impact of invasion of *T. absoluta* into California, the economic impacts from Spain after invasion by *T. absoluta* can be examined. Tomato growers in Spain saw costs increase by as much as 400% or more because of increased insecticide applications, additional labor needed at planting and harvest to meet regulatory requirements, as well as a temporary loss of markets due to quarantines. Some areas also saw 80-100% crop damage (Desneux, N., Wajberg, E., Wyckhuys, K., Burgio, G., Arpaia, S., Narvaez-Vasquez, C., Gonzalez-Cabrera, J., Ruescas, D., Tabone, E., Frandon, J., Pizzol, J., Poncet, C., Cabello, T., and Urbaneja, A. 2010. Biological invasion of European tomato crops by *Tuta absoluta*: ecology, geographic expansion and prospects for biological control. J. Pest Sci. 83: 197-215). By educating California tomato growers and homeowners, the project is increasing the probability of detecting *T. absoluta* very soon after initial invasion. Rapid initiation of management and mitigation tactics should reduce the overall economic impact of this pest in California as well as any impact on domestic and export markets. As enumerated above, web users are visiting the on-line educational course and are taking the final exam and getting continuing education credits. USDA and state regulators may use the molecular diagnostic tests in some of their screening of lepidopterous insects associated with tomatoes, both in the field and with imported tomatoes and nursery plants.

Lessons Learned

In this project, the researchers learned that the agencies giving permits to import invasive pests do not believe that a Biosafety Level 3-Plant facility can contain *T. absoluta*, so no import permit was received. Luckily, the researchers on this project were able to find a cooperator in Spain to assist with the studies that required having live *T. absoluta*. In the future, the researchers will make sure that contingencies are in place before requesting funding or permission to import an invasive insect, so that the research can be conducted without delay. Also, there were delays in genome sequencing services. The researchers had to perform sequencing at a private facility to accomplish the project in a timely manner. On the positive side, UC-ANR personnel were extremely helpful in getting the education materials available for public use. Multiple groups within UC-ANR Communications and Statewide IPM Program assisted in getting the materials developed and published. The researchers reaffirmed longstanding relationships with UCCE Advisors, and collaborations with them assisted in obtaining potato tuberworm pupae to initiate the colony, and invitations to make presentations during grower meetings. The comments received so far from growers, PCAs, and others involved in tomato production have been extremely positive and suggest that the outreach efforts are having their intended effect in terms of education. The researchers have also started to network with *T. absoluta* researchers worldwide. This networking will provide information and contacts that will be helpful in designing integrated pest management programs for *T. absoluta* should it arrive in California.

The first unexpected outcome of this project was to learn that the taxonomy of some of the gelechiid relatives of *T. absoluta* is poorly understood and that diagnostics based on larvae was virtually impossible even for

specialists. This fact highlights the urgent need for molecular biology based taxonomic tools for some of these gelechiids, in this instance for those that feed on solanaceous weeds. Successful management of these insects relies on proper identification because the different species may have different physiological properties or behaviors that impact the efficacy of the management tactic selected. Another unexpected outcome is that Jimson weed (seeds for the study were collected in California) is not a host of *T. absoluta*. The scientific literature says that a weed with the same scientific name as Jimson weed, but collected in Europe, is a host for *T. absoluta.* This suggests that the plant that is called Jimson weed may in fact not be one species, but a species complex comprised of several species.

One goal that was not achieved during the project was hosting a workshop to teach anyone who is interested in learning how to use the molecular tool to identify *T. absoluta*. If there is interest from the taxonomic community, project staff will be offering this workshop in the spring of 2018. The workshop will be held on the University of California, Davis campus and will cover the following topics: design and procedures used to create the molecular tool; demonstration of proper collection and preservation of specimens; demonstration of DNA extraction from each specimen; information on using a single nucleotide genotyping (SNP) assay on an iPLEX platform; and assistance in optimizing the SNP assay in their own labs.

Additional Information

No Additional Information.

USDA Project No.:	Project Title:	
49	The Bagrada Bug Invades the Salinas Valley - the Salad Bowl of the World	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB14049	**Date Submitted:** December 2017
Recipient Contact: Frank Zalom (prev. Larry Godfrey)	**Telephone:** (530) 752-3687	**Email:** fgzalom@ucdavis.edu

Project Summary

The bagrada bug, *Bagrada hilaris*, is an invasive stink bug pest that was first found in the United States June 2008 in Los Angeles County. It is a major pest of cruciferous crops, including broccoli, cauliflower, cabbage, kale, turnip, and radish. These crops are an important component of the vegetable industry. Both adult and nymph bagrada bugs damage plants with their feeding, which create large stippled/wilted areas on leaves. Seedlings and plants can be completely devastated or suffer from distorted growth. California discovered this pest, and now other states and countries have concerns about receiving this pest via commodity trade. Cruciferous crops are valued at approximately $1 billion in California, and in the Salinas Valley cruciferous crops are grown on approximately 85,000 acres and are valued at $485 million.

The purpose of this project has been to expand knowledge of bagrada bug biology, ecology, and damage in the Salinas Valley. This is in efforts to improve pest management in the region and to transfer this knowledge to the grower community and vegetable industry. Previous research was conducted on this pest in the desert vegetable production areas of southern California and Arizona. The bagrada bug was first found in the Salinas Valley in 2013, a number of years after it was introduced into California's Imperial Valley, Arizona, and Mexico. While many important aspects on this pest's biology and management were investigated in those regions, it was unknown how much of this information could be transferred to the Salinas Valley. Salinas Valley is different from the desert in terms of production practices, climate, and landscape which could affect the damage potential, biology, and management of this pest.

This project was extremely timely because it allowed project personnel the opportunity to research bagrada bug conditions in the Salinas Valley and to benefit the specialty crop industry. Commodity board funding was not available for cruciferous crops, which made this project key for research for the bagrada bug. A major component of the project research was outreach, especially with members of California specialty crop growers and pest control personnel. The project team was able to conduct pest management research, and subsequently provide information at extension meetings each year and in newsletters and blogs.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

As part of this project's effort to understand the relationship between bagrada bugs and non-crop hosts, bagrada bug populations were surveyed on non-crop hosts at sites that covered the length of the Salinas Valley. The project team surveyed adult and nymph populations on non-crop hosts each month for nearly two years, which covered two periods of bagrada bug population peaks. Each sampling site was dominated by a known host of bagrada bug. The primary focus was on sites that contained shortpod mustard or perennial pepperweed, but also included several sites that also had perennial wall-rocket growing. Nine sample

locations were chosen and surveyed at the beginning of the study. During the second year of the survey, eight additional sites were surveyed, increasing the coverage of the project survey. It was found that populations varied substantially from site to site.

The project team was able to document large yearly changes in the overall size of bagrada populations at the landscape level. In 2016, populations of bagrada bug on non-crop hosts were substantially lower at the project team's survey sites. At some sites where bagrada bug had been found in 2015, the project team was unable to find any in 2016 or found only a handful of individuals and/or very light plant damage. Populations peaked in August or September and rapidly tailed off after that. This coincided with the drying down of the cruciferous hosts and then cooling of temperatures. Other weed species were surveyed for bagrada bugs, however indications of bagrada bug feeding on species other than shortpod mustard, perennial pepperweed, or perennial wall-rocket were not found.

To complement the field surveys, laboratory choice assays were completed to determine the feeding preference of bagrada bugs among various weed hosts. This included plants in the mustard family (Brassicaceae) which are considered to be potential hosts of bagrada bugs, as well as two plants (ripgut brome and little mallow). Bagrada bugs were added to a choice arena containing the plants and were observed over the course of several days to determine feeding preference. At the tested phenology stage of the weeds, wild radish (*Raphanus raphanistrum*) was most preferred, followed by shepherd's purse, and shortpod mustard. In pairwise comparisons, the bagrada bugs preferred bolting shortpod mustard over young broccoli plants, but showed no preference between non-bolting perennial pepperweed and the broccoli.

To better understand how non-crop hosts affect bagrada bug populations, a field study that examined how plant host (crop and non-crop) affects bagrada bug development and adult size was performed. Naturally growing weeds (shortpod mustard, wild radish, and little malva), potted weeds (perennial pepperweed), and potted crop hosts (broccoli and cauliflower) were used. The project team examined the differences between shortpod mustard leaves and pods on insect development and adult size. It was found that plant host affected the bagrada bug development time, with these effects generally matching preference (shortest development time, largest insects on wild radish, longest development time and smallest insects on broccoli and cauliflower). The bagrada bug did not successfully develop on little malva.

The project team examined the oviposition preference of bagrada bug among different crops to better understand the biology of the bagrada bug. In a laboratory experiment, the project team compared the number of eggs laid in the soil under a number of different cruciferous crops (broccoli, cauliflower, radish, turnip, and arugula), a cruciferous plant used as an insectary plant (sweet alyssum), a presumed non-host (corn), and a soil-only control. The relationship between bagrada bug feeding and oviposition was studied. Bagrada bugs deposited higher quantities of eggs next to some crop hosts, and while this was partly explained by feeding preference, other factors also drove oviposition. It was determined that bagrada bugs were more likely to place their eggs in shaded locations, and may even prefer non-plant shade over plant shade although this conclusion is only partially supported. Understanding the ovipositional biology for reproducing populations within fields could improve pest management of populations in non-crop areas.

A concentrated study tested the interactions between bagrada bugs and their non-crop hosts. The study followed high populations of bagrada bugs on shortpod mustard at a roadside site. At the start of the experiment, four large plots were used in which each individual plant was tagged. The bagrada bugs (adults

and nymphs) were counted on each plant for nine weeks. At the same time, plant characteristics (phenology, presence of basal leaves, and size at one time point) to determine how these characteristics affect bagrada bug populations were accessed. It was determined that all plant factors influenced bagrada bug populations, but these effect varied for adults and nymphs and varied through time. Project results indicated that plant factors could be used to predict populations on and movement from non-crop hosts, which could improve scouting and risk assessment.

The project staff examined how starvation and bug stage/sex affects dispersal of bagrada bugs. Individual bugs were measured for dispersal distance via walking in outdoor and laboratory environments. This type of information improved the project team's understanding of bagrada bug movement from non-crop hosts as weeds begin to senesce and food in these areas is no longer available. Starvation increased movement for some insect stages/sexes, but the effect depended on how long insects were starved for and the stage/sex of the insect.

Several project studies examined the damage potential of bagrada bug to cruciferous crops grown in the Salinas Valley. Caged plots of broccoli were infested with two densities of bagrada bugs to determine how plant stage susceptibility interacts with bagrada bug population density, starting at the cotyledon stage and continuing for two-week intervals through six weeks after germination and the cotyledon stage. Significant damage occurred when plants were exposed at the cotyledon stage (~12% mortality at high bug density of 0.5 bugs/plant), but no plant mortality occurred once plants had reached the 5-6 leaf stage. Effects on plant biomass generally mirrored these results, although the project team was unable to take this experiment to final yield.

This cage study was repeated, and further examined the damage to both broccoli and cauliflower. Caged plots with bagrada bugs at planting and were infested at weeks one, two, three, or four after planting. The plots were infested at a rate of one bug per two plants (12 bugs for broccoli plots, 6 for cauliflower plots). There were issues with the broccoli plots (other pest issues), so only cauliflower plots were examined. The project team did not find that bagrada bug caused significant damage to cauliflower at the project infestation levels, but there could be more nuanced effects to discover. Because of the limitations of the field experiments, a greenhouse experiment was also initiated to inspect damage on both of these crops. Examinations were similarly made on bagrada bug preference on germinating seeds of several cool-season vegetables in laboratory soil and in soil-less bioassays. The number of injured leaves per germinated seedling, the number of feeding punctures per germinated seedling, and the number of germinated seeds per five were tabulated. Arugula, broccoli, bok choy, cauliflower, kale, mizuna, turnip, lettuce, and sweet alyssum were examined in choice tests. Turnip, arugula, and bok choy were most preferred and lettuce and cauliflower were least preferred.

Two experiments were conducted that examined trap cropping in the form of a border and perimeter planting in a field experiment. Only broccoli plots that bordered on the field edge by a trap crop of transplanted alyssum that was either unmanaged, vacuumed weekly (mechanical removal), or treated weekly with organic insecticides, as well as to plots with unmanaged, direct-seeded turnip as a trap crop were used as a comparison. In this experiment, no significant differences between treatments was apparent, although there were some interesting trends that indicated that turnip might have potential as a trap crop. The project experiment was limited based on the size of the plots, which likely caused effects of individual treatments to be muted because of inter-plot movement of bagrada bugs. In 2016, the project team worked with a local

grower at a field of organic greens with a good likelihood of moderate to high bagrada bug populations based on populations the previous year. Plots were set up with each field/planting consisting of one replicate. One bed on the edge of the field was set up as the experimental area. This area was divided into three equal plots: 1) untreated turnip trap crop, 2) turnip trap crop treated with a mixture of organic insecticides (Entrust + Aza-Direct + M-Pede), and 3) was an empty plot with no trap crop. The project team planned to evaluate plant damage on brassicaceous salad crops in the interior of the field to determine if the trap crop protected the field from plant damage, but were unable to evaluate the degree of control provided by the trap crop because of extremely low insect populations. The project team was able to evaluate how well trap crop performed agronomically and how the trap crop compared to the nearby salad crop, and in this respect, the trap crop seemed very promising as a management tool.

Several trials of organically approved products were conducted. First, a field trial using the following treatments: 1) Untreated, 2) Azera (azadirachtin+pyrethrum), 3) Aza-direct (azadirachtin), 4) Pyganic, 5) Venerate, 6) Grandevo, and 7) Entrust was conducted. However, this trial had issues with low pest pressure. A laboratory assays with a number of these products to determine the residual efficacy of these insecticides when applied to foliage was also conducted. Finally, a field plot trial (0.5 acre plots) using Debug Turbo, Mycotrol-O, Azera + OroBoost, Venerate + Oroboost (1st spray) and Grandevo + Oroboost (2nd spray), Venerate + Oroboost + Pyganic (1st spray) and Grandevo +Oroboost (2nd spray). Two sprays were applied for all treatments, one week apart. This trial also had low bagrada bug populations.

There were also experiments that examined the chemical control of bagrada bugs. Using organic insecticides, laboratory and semi-field experiments were completed to determine sub-lethal effects of a number of insecticides on bagrada bug. It was determined the residual efficacy of some of these products by treating plants, allowing the insecticide to dry, and then adding insects. Efficacy of selected registered and experimental insecticides on bagrada bugs on broccoli were compared in field plots with applications from a backpack sprayer. Four neonicotinoid insecticides, one pyrethroid, one premix, and two other insecticides were utilized. Applications were made at planting or at emergence. In summary, Venom (dinotefuran) was fast acting on bagrada bug. At plant banded applications were effective, but delayed efficacy was seen with Admire Pro (imidacloprid) and Platinum (thiamethoxam). In general, pyrethroids and neonicotinoids had the better efficacy on bagrada bugs. The project team also tested drench applications of insecticides, including both systemic and non-systemic products, for management of bagrada bug in laboratory and field settings. In the greenhouse experiment, percentage of injured leaves, number of injury sites, and damage rating were significantly lower for transplants treated with acetamiprid, clothianidin, dinotefuran, imidacloprid, thiamethoxam, and cyclaniliprole compared with the untreated. Similarly, the transplants in the field experiments treated with acetamiprid, clothianidin, dinotefuran, imidacloprid, thiamethoxam, thiamethoxam + chlorantraniliprole, imidacloprid + β-cyfluthrin and cyclaniliprole had significantly lower damage ratings than those treated with chlorpyrifos, bifenthrin, tolfenpyrad, flonicamid, cyantraniliprole, spinetoram and the untreated control.

Outreach and extension of results was a significant component of the project. Therefore the project team used a number of opportunities to share project results, which included meetings, newsletters, articles, blogs, and peer-reviewed papers. Results were discussed at both branch and national meetings of the Entomological Society of America each year and at the International Heteroptera Symposium in 2017. At many meetings, results from separate parts of this project were presented by multiple researchers. The project team presented results at extension meetings in the Salinas Valley, including the 2014 Monterey County Entomology

Seminar, *Lygus bug and Bagrada bug management trials*, 2014 Pesticide continuing education workshop, *Biology and management of Bagrada bug*, CCOF Central Coast Chapter Meeting, *Organic control methods for Bagrada bug,* 2014 Ecofarming Conference, 75th Annual Meeting of the California Seed Association, Rancho Mirage, Stink bug Management Workshop, 2015 Monterey County Entomology Seminar, 2015 Salinas Valley Weed School, 2015 Vegetable Crops Program Team Meeting, UC Cooperative Extension Bagrada Bug Biology and Organic Management Meeting, and 2016 Monterey County Entomology Seminar. Three articles were published in issues of the "Bagrada Bug News", organized by California Certified Organic Farmers (CCOF) and several blog articles on the UC Agriculture and Natural Resources Entomology Blog. A number of peer-reviewed articles have been published covering the results on this project, including papers in *Journal of Entomological Science, Journal of Entomological Science, Arthropod-Plant Interactions, Crop Protection,* and *Arthropod Management Tests.*

Funds were used to solely enhance the competitiveness of specialty crops, primarily cruciferous crops.

The assistance of the vegetable production community in the Salinas Valley was very important for the successful completion of this project. Various Pest Control Advisers (PCAs) and industry cooperators have provided guidance for the project via formal advisory committee and through informal conversations. This community helped the project team find populations of bagrada bugs and their perspectives provided an overview of how populations of bagrada bugs were developing in crop fields. For the weed survey component of this project, the project partners helped identify sites and gave access to various farm properties. The project team worked with representatives from local agricultural companies and growers to obtain locations for research studies on trap cropping as a management tool. A greenhouse transplant facility also collaborated with the project team to obtain transplants for field experiments. The research on the damage potential of bagrada bug was conducted at a USDA research farm in the Salinas Valley. Many aspects of the project were supported by these various project partners.

Goals and Outcomes Achieved

The primary goal of the project was to generate research data on the biology, damage potential, and management for bagrada bug using both conventional and organic production tactics and to extend these research-based results to the grower community. All of the research activities supported this goal and to increase bagrada bug knowledge in the grower and pest management community. The data that was generated from the project experiments served as performance indicators over the course of the project.

The project team collected survey results at the annual Monterey County Entomology meetings in 2014, 2015, and 2016. Survey results assessed the economic impacts of local area as they relate to infestation patterns, yield loss research, pest management tactics, and increased bagrada bug awareness. In 2014, it was found that many of the respondents had experience with bagrada bug and were fairly knowledgeable about the pest's basic biology, damage, and management. The bagrada bug was less a concern to respondents in 2015 than in 2014 and their concern was even lower in 2016. This outcome could result from increased knowledge stemming from project.

During the annual meetings participants were evaluated as to their knowledge of this pest and appropriate management actions via an electronic response system ("clickers"). In 2014 and 2015 clicker surveys were used, and in 2016 a paper survey (clickers were not available) to poll attendants at the yearly Monterey County

Entomology Seminar. The survey questions aimed to both assess knowledge of attendants and to gain information that project could use to inform the project team's research and better target information.

In 2014, 84% of respondents correctly answered "looking for adults on [plants]" when asked the correct responses to the statement "Currently, monitoring for bagrada bugs in crops should involve…"). In 2015 and 2016, the question was slightly different, asking, "What methods did you use to determine when & if to treat fields?" This enabled the project team to assess what practices were being used for bagrada bug scouting, which was critical for targeting project research and information delivery. It was found that 22% of people in 2015 included an insecticide for bagrada bug when treating for other pests. This dropped to 11% of people in 2016. The number of people that treated based on infestations the previous year dropped from 6% in 2015 to 1% in 2016. It should be noted that this may have partly been due to changes in pest pressure, but could also be due to improvements in scouting and monitoring, which was a focus of the project. In addition, a large component of the project was on the role of weeds for population buildup of bagrada bug and using weeds for scouting. The response rate for those who treated based on seeing pests on nearby weeds increase from 7% to 25% between 2015 and 2016.

There were major successful outcomes from the research results, which transferred the results and knowledge to the members of the vegetable industry. Respondents were also willing to try alternative management tactics (e.g., trap crops), as a result of the project's promising outcomes.

The Salinas Valley Cooperative Extension meetings were essential for project research dissemination. The data gained has improved knowledge of the damage potential of bagrada bug for key crops and identified management tactics for both conventional and organic producers. The project data on non-crop hosts has improved understanding of the role of non-crop hosts for bagrada bug in the Salinas Valley. This has led to better recommendations on what fields and areas are most at risk and better recommendations on how to manage weeds to reduce the threat of bagrada bug infestation and how to scout for bagrada bug. The 2016 survey results indicated that the local pest managers applied an integrated pest management approach for the bagrada bug, which also has potential for additional improvement opportunities.

Beneficiaries

A diverse group of the vegetable industry benefitted from the project's work on bagrada bug. This included growers, PCAs, and other members of the vegetable production industry, which includes both conventional and organic vegetable producers.

Vegetable crops are integral to Salinas Valley agriculture and are grown on approximately 427,000 acres in Monterey County, with about 20 percent of this acreage planted with cruciferous crops. There are approximately 800 vegetable growers in the Salinas Valley (Monterey County), with an additional 50+ vegetable growers in each of the neighboring production areas (Watsonville, Santa Cruz County; Hollister, San Benito County). Many PCAs and pest managers also benefitted from the project, with a large proportion of this group in the region attending project presentations at Cooperative Extension and other meetings in the affected area. Specialty crop growers of cruciferous crops outside of the targeted research area benefit from the research since the bagrada bug are located across California. The project team shared research results with beneficiaries through a number of outlets (extension meetings, newsletters, blogs). Project result presentations have been well-attended, helping ensure that many members of the local industry benefit from the data results. The project has improved management of bagrada bug by helping pest managers better target insecticide

sprays and choose among alternative management options in both organic and conventional systems. A significant accomplishment has been the effort to improve scouting and risk assessment for fields through the effort on non-crop hosts and work to extend the knowledge about the role of non-crop hosts for bagrada bug populations and damage to the vegetable industry.

Lessons Learned

During the course of this project there were several setbacks that affected the project, and opportunities to learn from some of experiences. Additional data was generated that complemented the project, as well as opportunities to increase the effectiveness of the project. For example, there were a number of issues with the research on damage to broccoli and cauliflower from the bagrada bugs. This appeared to have resulted from some of the production practices used by the farm where the research was conducted. The project team had unfortunately assumed that "normal" production practices would be followed, especially as it pertained to irrigation. Also, the project team was unable to follow normal production practices because of the use of cages. Consulting more with somebody familiar with vegetable production about the many specifics of the research may have helped avoid these problems.

However, in the second year of the study the experimental design (including use of drip irrigation) was improved, but other pest issues emerged in the study plots. Unfortunately, this was unavoidable because of the inability to manage other pests in a conventional manner since the target of the research was also an insect and would be affected by implementing effective controls for those pests. There were delays setting up the greenhouse component of this project. This was primarily due to lack of space. While this is often an issue at universities, the delay may have been avoidable if the greenhouse studies were conducted concurrently with the field research. However, this would have lead to an unacceptable increase in the cost so it was deemed impractical. The project team also found that establishing good relationships with industry partners was invaluable to data collection and increased the ability to achieve project goals and to save money.

Flexibility was key to the project. In 2016, the project team attempted to investigate the utility of trap crops in a large-scale field experiment. Unfortunately, populations were very low during this year and no bagrada bugs appeared which precluded the project team's ability to evaluate the effectiveness of the experimental treatments. However, the project team remained flexible with research, and were able to reallocate some of the time that would have been used for this study and performed an additional study to address the same project objectives. This study made use of a localized high population of bagrada bug on shortpod mustard in a roadside population. While this site could not be used to investigate the utility of trap crops, it was able to examine the characteristics of non-crop hosts influence bagrada bug populations. Without this flexibility and investigative additional research questions, the overall research would have suffered and the same level of performance achieved could not have been achieved.

An unexpected result from this project was the documentation of an overall reduction in bagrada populations in 2016. This result was confirmed in discussions with collaborators on the project and on survey results. Overall, the project goals and outcome measures were achieved.

Additional Information

Links to publications and articles:

Importance of weeds for bagrada bug populations in the Salinas Valley (Monterey County Extension blog article)

Effects of Organic Insecticides on Incidence of Bagrada Bug Feeding Injury in Mizuna and Arugula (Monterey County Extension blog article)

Joseph S. V., I. M. Grettenberger, L. D. Godfrey, D. Zavala, and E. G. Bejarano. 2017. Effects of induced starvation on *Bagrada hilaris* (Hemiptera: Pentatomidae) survival. Journal of Entomological Science (in press).

Joseph S. V., I. M. Grettenberger, and L. D. Godfrey. 2017. Damage by *Bagrada hilaris* (Hemiptera: Pentatomidae) adults on germinating stages of arugula seed in a choice test. Journal of Entomological Science (in press).

Joseph, S. V., I. Grettenberger, L. Godfrey, and N. Zavala. 2017. Susceptibility of germinating cruciferous seeds to *Bagrada hilaris* (Hemiptera: Pentatomidae) feeding injury. Arthropod-Plant Interactions DOI 10.1007/s11829-017-9501-0. See Attachment 1.

Joseph, S. V., and L. Godfrey. 2016. Evaluation of at-plant versus foliar applications of insecticides for control of *Bagrada hilaris* on broccoli, 2014. Arthropod Management Tests 41. doi: 10.1093/amt/tsw089. (LINK)

Joseph, S. V., I. Grettenberger, and L. Godfrey. 2016. Insecticides applied to soil of transplant plugs for *Bagrada hilaris* (Burmeister) (Hemiptera: Pentatomidae) management in broccoli. Crop Protection 87: 68-77. See Attachment 2

Effect of insecticide application timing on feeding injury of bagrada bug in broccoli (*CAPCA Adviser*)

See Attachment 3 for photographs.

Bagrada Bug News No. 1 (CCOF newsletter) See Attachment 4

Bagrada Bug News No. 3 (CCOF newsletter) See Attachment 5

Bagrada Bug News No. 4 (CCOF newsletter) See Attachment 6

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 50	**Project Title:** Development of an RNAi-Based Biological Insecticide Strategy for Management of the Mealybug Complex in California Grapes	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB14050	**Date Submitted:** December 2017
Recipient Contact: Bryce Falk	**Telephone:** (530) 752-0302	**Email:** bwfalk@ucdavis.edu

Project Summary

Grapes are grown throughout California, with approximately 897,000 acres in production in 2016. As such, grapes, wine and associated industries are major contributors to California's economy. Yet grapevines can be affected by a number of different pests and/or pathogens which can have devastating economic and sociological effects. This project was focused on grapevine mealybugs and associated viruses. Multiple species of mealybug are very important pests in grapes and collectively may represent the most important overall pests for California grapevines. Mealybugs are destructive phloem-feeders, they reduce plant vigor, serve as vectors of grapevine leafroll-associated viruses (GLRaV's), and are very difficult to control, often requiring multiple pesticide applications. Although all mealybug species are pests, the vine mealybug is the most pestiferous because of its ability to rapidly reproduce and spread, and to efficiently vector GLRaVs. Vine mealybug is an invasive pest that was first found in California in 1994. Since then, it has continued to spread and is now found in 20 counties. New, sustainable, environmentally sound approaches to help control mealybugs (and the viruses they transmit to grapevines) would greatly benefit California grape production and associated industries. This project took efforts to develop a new approach to help manage mealybugs in grapevines. It involved RNA-interference (RNAi) as a tool to specifically target mealybugs.

Despite repeated insecticide applications, grapevine mealybugs and the viruses they transmit remain as important problems. Alternative strategies to help manage both are needed. The potential of using RNAi for insect control is very relevant today. A recent issue of Science suggested "smarter pest control." A section within that issue was dedicated to "Our pesticide planet" documenting the dependence on pesticides in traditional agriculture and arguing for new environmentally sound and sustainable approaches. One piece entitled "A Lethal Dose of RNA," discussed how new opportunities based on scientific research and understanding of RNAi could help contribute to better sustainability in agriculture by decreasing current dependence on numerous pesticides, and complementing other efforts (including biological control-based approaches). This project's objective was to develop new, sustainable and environmentally friendly RNAi-based approaches to help control mealybugs and the GLRaV's they transmit to grapevines which could lead to new management practices that are compatible with existing approaches, and which will benefit California and the grape and wine industries.

This project did not build upon previously funded Specialty Crop Block Grant Program project.

Project Approach

The project staff established colonies of the citrus mealybug on grapevine plants and the vine mealybug on squash fruits. Due to quarantine issues with the vine mealybug, project staff were careful not to allow for it to escape or colonize grapevines in the greenhouses.

The project staff established isolates of GLRaV-7 and Grapevine red blotch-associated virus which were used for cDNA cloning experiments.

The project staff were less successful in taking the biological materials to the next level which were the long term goals. It was challenging to establish the vine mealybug on model herbaceous plants such as Nicotiana benthamiana under controlled conditions, and thus project staff could not use the model virus, Tobacco mosaic virus, as hoped to do for initial experiments.

Furthermore, project staff faced a challenge in achieving the goal of developing infectious clones for either grapevine virus used, and were not able to accomplish it. This proved to be a set-back for this project and prohibited moving forward to test efficacy in grapevines (e.g. life table studies) and disseminating successes from the efforts to growers and scientific venues.

This project benefitted no other commodities other than California Specialty crops. The post-doc and the Principal Investigator (PI) oversaw all purchasing and spending relative to this project; both were actively involved in all aspects of this project. The PI reviewed and approved spending for the research as was approved in the project budget, and ensured that all activities and spending of project funds was directed to the grapevine mealybug RNAi project research.

All work was done by the PI and staff employed on this project; there were no project collaborators.

Goals and Outcomes Achieved

The project staff did not achieve the long term measurable outcomes as hoped. The project staff had good success with biology of the project, but were unable to transfer and grow the vine mealybug on herbaceous plants where project staff could determine effective RNAi targets, goal A: Identification of mealybug genetic targets or RNAi strategies. As mentioned in the project grant proposal, project staff were confident for a high probability of success per the University of California, Davis' previous work and assumed that this would be successful. The project staff were hoping to build from the previous expertise and accomplishments using Tobacco mosaic virus and herbaceous plant hosts. The project staff also did not accomplish development of plant virus constructs which could have been manipulated and used in grapevines, goal B: Development of a virus-based delivery system for grapevines. In retrospect goal B was quite ambitious, and effective completion of goal A was dependent on success with goal B. The project staff were confident and assumed high probability of success as the viruses closely related to GLRaV-7 had been engineered and was being used in field tests to express desired sequences in citrus and grapevines. Due to research efforts not leading to expected results, the primary project goal which relied on generating a recombinant virus to express sequences in grapevines was not achieved, and without this, project staff were not able to move onto accomplishing other goals established for this project. Thus, project staff were not able to generate data that they felt would be of use to disseminate to growers. The project staff were disappointed in lack of scientific success and translational applications of that success to agriculture. In retrospect, having preliminary data would have made the expectations and objectives more realistic.

The outcome measures were expected to be long term. The projects staff had expected to develop tools that could lead to longer term studies on grapevine mealybugs and virus interactions and use of RNAi for potential mealybug management strategies. Due to the unanticipated difficulties of working with the chosen system and the complexities of the GLRaV-7 infections, project staff did not achieve the goals which would have allowed

for continued, longer term efforts. However, unexpected new information did result from these studies but project staff did not have the time nor the funds to pursue those opportunities as the grant was ending.

The project staff did accomplish the initial short term goals and were able to generate scientific information regarding one of the candidate viruses, GLRaV-7. After struggling with generating infectious recombinant virus constructs, project staff utilized next generation sequencing to assess the GLRaV-7 isolate. The project staff found that GLRaV-7 can exist as a mixture of sequence variants or strains within a given plant. Thus, attempting to generate recombinant forms of GLRaV-7 must consider this first. This is important for future efforts and is important for understanding biological aspects of grapevine-virus interactions.

Important baseline data was generated on GLRaV-7 as being asymptomatic in grapevines under conditions tested, and that GLRaV-7 infections are complex, containing strains and variants of the virus. While the asymptomatic nature of GLRaV-7 was expected, the confirmation supported the reasoning to use it for the studies. The complexity of GLRaV-7 infections was unexpected; this suggested that using GLRaV-7 for biotechnological applications, such as proposed initially, will require a greater understanding of virus-host plant, and virus-virus interactions.

The major successful outcomes of this project related to the scientific knowledge gained. The project staff learned more about GLRaV-7 and about the complexity of virus infections in woody plants such as grapevines.

The project staff are currently looking for funding to continue this research and hope to finalize and publish results in 2018 Journal of Plant Disease.

Beneficiaries

Grape and wine production are key components of California's economy, wine grapes alone account for approximately 10% of California agricultural receipts and today over 95% of United States grapes/grape products are from California. In 2012, California wine grapes alone were valued at more than $3 billion. Furthermore, many parts of California's grape and wine production areas have thriving agritourism industries.

The project staff generated new information on the complexity of GLRaV-7 infections in grapevine plants. This information is relevant today especially regarding using plant viruses for biotechnological applications in cultivated plants such as grapevines. Thus, the accomplishments, which will be published in scientific journal of Plant Disease (2018) will benefit California, but also grape production in other states and even the world. The primary potential beneficiaries of this project are grape growers, vineyard managers, grape exporters, and grape/wine tourism. Due to unexpected results that did not generate successful project outcome, project staff did not generate information that would have affected immediate beneficiaries; and thus, did not disseminate it or lead to new approaches.

Lessons Learned

The project staff started this project based on previous work done by using model viruses, herbaceous feeding mealybugs and herbaceous plants. The assumption was that project staff could translate those accomplishments directly to new viruses and woody grapevines and the vine mealybug. This proved not to be the case. However, based on accomplishments reported in the literature by other groups, the hypothesis and strategies are contemporary and are worth pursuing, but not until more promising initial accomplishments

with the biology of grapevines and grapevine viruses are achieved, which was this project's goal. Furthermore, GLRaV-7 appears to be a good candidate virus for grapevine biotechnological applications. As reported by others, project staff did not see initially any negative phenotypes in GLRaV-7-infected grapevine plants.

The project staff did not expect the difficulties encountered regarding developing both viruses (GLRaV-7 and Grapevine redblotch-associated virus) as tools to address this project's objectives. Based on initial sequence analyses, it was believed that the GLRaV-7 was a pure isolate. However spending more than a year and a half trying to assemble it for use, it was concluded that it was not pure, but a mixture.

Project staff were too ambitious in the efforts basing the goals and objectives on results generated previously from experimentally much more simple systems. It was expected those accomplishments to translate to success with grapevines, uncharacterized viruses and the vine mealybug, which proved to be much more difficult than expected. If project staff would start over, they would first determine the purity of the virus (GLRaV-7) to be used and ensure that it is suitable for the objectives. Also assess RNAi effects on the vine mealybug by using in vitro assays versus waiting to do these studies on plants. More than one approach would complement the efforts and enhance the probability of at least some success.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 51	**Project Title:** Revealing the Epidemiology of Grapevine Red Blotch Associated Virus, an Urgent Need for California Grape Growers	
Grant Recipient: United States Department of Agriculture, Agricultural Research Service	**Grant Agreement No.:** SCB14051	**Date Submitted:** December 2017
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Project Summary

Red blotch (RB) is a recently recognized grapevine disease affecting wine grape production in California. RB symptoms resemble those of leafroll disease and potassium deficiency, and thus remained unrecognized until recently. United States Department of Agriculture, Agricultural Research Service (USDA, ARS) has identified a new DNA virus, "Grapevine red blotch-associated virus (GRBaV)," in diseased grapevines that has proven to be the causal agent of RB. The virus belongs to the family Geminiviridae, members of which are spread by insect vectors such as leafhoppers, treehoppers, and whiteflies. Laboratory tests have shown that the virus has infected hundreds of acres of Californian vineyards, including nursery increase blocks. Berries on diseased vines show delayed ripening and reduced sugar, resulting in wine of inferior quality and reduced revenues of as much as 90 percent. The purpose of this project was to determine potential vectors and alternate hosts, and to develop RB management guidelines.

Since the genome of this virus resembles members of the family Geminiviridae, which includes a majority of highly destructive viruses in Old and New World countries, observations indicated spreading of the virus in some vineyards, with both growers and grapevine nursery owners. Operators advocated for the investigation of the vector(s) that were responsible for the spread of GRBaV. Additionally, there was a need to look for alternative hosts of GRBaV, such as weeds and free-living grapevines in riparian areas. The information generated is fundamental to the investigation on the epidemiology of GRBaV and developing effective management guidelines applicable to commercial vineyards. This project documented the spread of GRBaV in different wine grape production regions in California, its presence in plant species found in vineyards, and potential hemipteran insect hosts prevalent in one vineyard where spread of the virus was observed. The project team also evaluated insect species for their ability to spread GRBaV under laboratory conditions.

This disease is of urgent concern to stakeholders in the grape industry. California is a major producer of wine grapes in the United States. North Coast vineyards ship wine $26 billion in value. The presence of GRBaV was associated with an 80% reduction in the value of premium wines. With so much attention given to leafroll diseases in the past and the acceptance of RB disease as a problem, stakeholders in 2013 highlighted the importance of finding evidence for the spread of the virus between grapevines, plant reservoirs within and near vineyards harboring GRBaV, and insect hemipteran vectors. Being a new virus, little is known on the epidemiology of GRBaV. Determining the insect species involved in GRBaV transmission is of utmost need to develop RB prevention and management guidelines to assist growers.

The initiation of this project was immediately followed by research grant opportunities to initiate studies along similar lines of work on RB disease by several commodity boards and the Pierces Disease Board of the California Department of Food and Agriculture.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Initial plot surveys showed an increase in the incidence of RB disease at the University of California Davis (UCD) Oakville station. Inspections were conducted to determine if there were grapevines in the wild that might have been infected with GRBaV located in the vicinity of vineyards with RB disease. The wild grapevines were assessed by means of polymerase chain reaction (PCR). Several of these grapevines, *Vitis* species (mostly hybrids of *V. californica* and *V. vinifera*), were found infected with GRBaV thus indicating the possibility of an insect vector. This was followed by examinations of weed species in the vineyards for virus infection. The project team examined over 200 weed plants in two years. GRBaV was not detected in any of these plants which indicated that the virus is probably restricted to *Vitis* species in its natural host range. This information was essential to develop GRBaV management guidelines.

The project team examined piercing and sucking insect species of the order Hemiptera, which includes aphids, leafhoppers, mealybugs, treehoppers and whiteflies, and are proven vectors of plant viruses. Inclusive examinations of these insects, by weekly sweeping of vineyard floors and occasional trapping of insects using light traps, exhibited the diversity of insect species in vineyards with RB disease. Further analysis of the insects was conducted and utilized the PCR method for the presence of GRBaV. The results indicated that leafhoppers of the genus Erythroneura and three cornered alfalfa treehopper (3CAH) as potential insect vectors of GRBaV. Transmission studies of the individual insects showed that the three cornered alfalfa hopper (*Spissistilus festinus*) is a vector of GRBaV under laboratory conditions. By using advanced digital PCR technology, the resulting data found extremely small amounts of GRBaV in grapevines.

A public announcement was made that covered essential information for stakeholders, such as; Grapevine RB disease, the virus, and potential vectors. This webinar that attracted an estimated 300 stakeholders from the United States, Canada, and other countries where grapevine culture is of national importance. The project results were then verified by researchers at Cornell University.

Last year, the project team initiated monitoring of seasonal changes in the population of 3CAH at the UCD research station in Oakville, California. This study indicated that the population of 3CAH has a small peak during the end of winter and early spring and a strong peak during late spring.

Originally two vineyard acres of Cabernet Sauvignon, a research station in UCD, were planned. However, there was a shortage of available virus-tested Cabernet Sauvignon grapevines free from GRBaV. This incidence decreased the establishment of the vineyard to one acre. In this vineyard, the project team attempted field inoculation of GRBaV using 3CAH.

An alfalfa patch was planted adjacent to the vineyard. Alfalfa was used as an alternate host to 3CAH. This allowed a sustainable and natural infestation of 3CAH within the vicinity of the vineyard, and enabled the project team to monitor spread of the virus under natural field conditions without insecticide treatments. In addition, girdling damage on the grapevines was monitored and was indicative of 3CAH feeding. Finally, caged uninfected 3CAH were used on grapevines to determine if grapes could successfully serve as a reproductive host for this insect.

The results obtained under laboratory conditions made a strong case for 3CAH as a vector of GRBaV. However, this insect species does not occur on grapevines as frequently as other treehopper species. *Tortstilus albidosparsus* is frequently noticed on grapevines. This also appears to be the case in Oregon vineyards where GRBaV spread has been observed by collaborators at Oregon State University. While the project team initiated transmission studies using *Tortistilus* species. In laboratory settings, future studies will have to address transmission under vineyard conditions to determine whether the *Tortistilus* species is an epidemiologically significant vectors of GRBaV. This involves examining girdled young grapevine tissue petioles for GRBaV and also proper DNA bar coding to identify this poorly studied insect genus.

This project solely benefitted specialty crops and specialty crop producers, specifically California grapes.

The project outreach partners were mainly the farm advisors affiliated with the University of California Agriculture and Natural Resources (UC-ANR) system. Project partners were highly involved in organizing meetings with growers and field days and hosting the project team members to provide presentations.

Goals and Outcomes Achieved

At least 90% of the growers and Pest Control Advisors (PCA) in California involved in winegrape production have been made aware of grapevine GRBaV. This was accomplished by numerous presentations made by the project lab members and UC Cooperative Extension Farm Advisors collaborators. The project team made 47 presentations at grower meetings and field days that were attended by an estimated 5,500 attendees that consisted of growers, PCAs, nursery and other stakeholders associated with the winegrape industry over the course of the project. Additional California winegrape producers who did not attend these presentations undoubtedly became aware of GRBaV and the role of potential vectors through the other mentioned sources (webinars, IPM Pest Alert, UCIPM website, YouTube videos, and word of mouth from others associated with the winegrape industry). It is estimated that there are about 5,900 winegrape producers in California.

The project developed primers and protocol for detection of GRBaV using an isothermal amplification method. The primers and protocol detection method will be used in the training of diagnostic labs, and it is also expected that this method is to be used by the growers in testing grapevines themselves. An abstract was submitted in March for presentation at the Annual Meeting of the American Phytopatholgoical Society held in San Antonio on August 2017. However, the abstract was withdrawn under a directive from the office of Tech transfer at UCDA-ARS. The USDA tech transfer group is currently evaluating if the primers and protocol for detection of GRBaV can be patented, and it is on hold until further tests can be conducted to gather additional data. The detection method is expected to be finalized in the fall of 2018. The evaluations of the weed species, wild grapevines for GRBaV infection, and insect species present in vineyards for their ability to transmit GRBaV have been completed and peer reviewed.

Two peer reviewed publications and text have been completed. They are: Evaluation of weed species and wild grapevines for GRBV infection (See Attachment 1), and Evaluation of insect species present in vineyards for their ability to transmit GRBV (See Attachment 2), and the spread of GRBV (See Attachment 3)

After the webinar in March 2016 which included updated information and an evaluation of the webinar, in subsequent face-to-face grower meetings, the team members gave talks and participated in Q&A sessions. Extension activities to educate stakeholders on the biology and epidemiology of GRBaV have

included nearly 1,000 stake holders at different conferences and grower meetings arranged by farm advisors. The highlight was a nationwide seminar that brought together all researchers involved with GRBaV.

For a multi-year project, the project team established a vineyard which is now two years old. This site provided and will continue to provide opportunities to study in GRBaV spread over several years. The adjacent alfalfa patch will serve as a permanent reservoir hosts of 3CAH for further research.

The project team continued to monitor experimental plots for GRBaV infection and treehopper population colonization. DNA extracts from eight insects, suspected to be *Tortistilus* species, were subjected to shotgun sequencing to determine mitochondrial genome sequence to aid in the bar coding of these insects. These results are expected to aid in the development of PCR-based identification of different insect species within *Tortistilus*.

Additionally, a manuscript on treehopper population dynamics is currently being written.

The following individuals conducted presentations the last year of the project:

Project Director

2/22/17 Portland, OR, 'Grapevine red blotch associated virus and its detection'. Oregon Wine Symposium, (300 attended – growers, nursery, consultants)

6/28/17 Invited talk was presented at the annual meeting of the Pacific Division of the American Phytopathological Society, at Riverside, California. "Grapevine red blotch virus, an emerging threat to wine grape production in the United States" (150 attended)

Graduate Student

2/8/17 Santa Rosa, California, 'Grapevine red blotch disease: the virus, its spread and a vector'. UC Cooperative Extension Sonoma County Grape Day, (220 attended – growers, nursery, consultants)

4/3/17 PBESA annual meeting. Portland, OR. "Seasonal dynamics of *Spissistilus festinus*, a vector of grapevine red blotch-associated virus, in Californian vineyards"-

5/9/17 Grapevine Virus Meeting. Davis, California. "Recent studies of reported GRBaV vectors" -

5/18/17 Foothill Grape Day. "Studies of the three-cornered alfalfa treehopper: vector of grapevine red blotch"

6/28/17 ASEV national conference. Poster presentation. Seattle, WA. "Feeding and Reproductive Hosts of the Three-cornered Alfalfa Hopper, a Vector of Grapevine Red Blotch-associated Virus"

Co-PI

2/22/17 Portland, OR, 'Vectors and Spread of Grapevine Red Blotch-associated Virus in California'. Oregon Wine Symposium, (300 attended – growers, nursery, consultants)

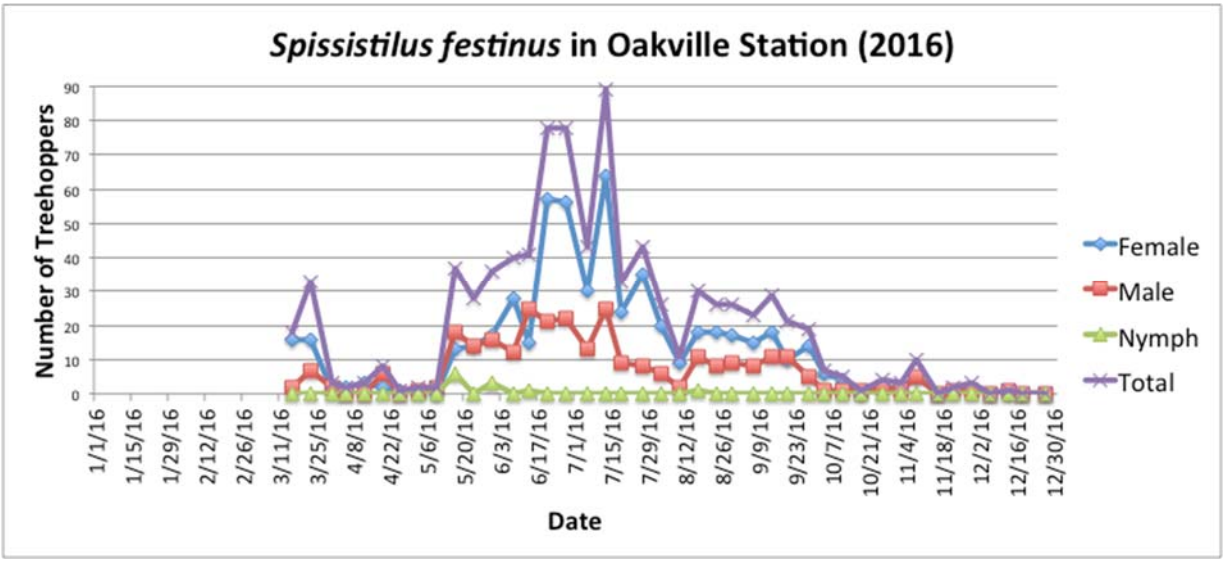
3/14/17 Davis, California. 'Red blotch-associated virus epidemiology studies'. CDFA-SCRGP Review, (10 attended – CDFA reviewer, Plant Pathology and Entomology department members)

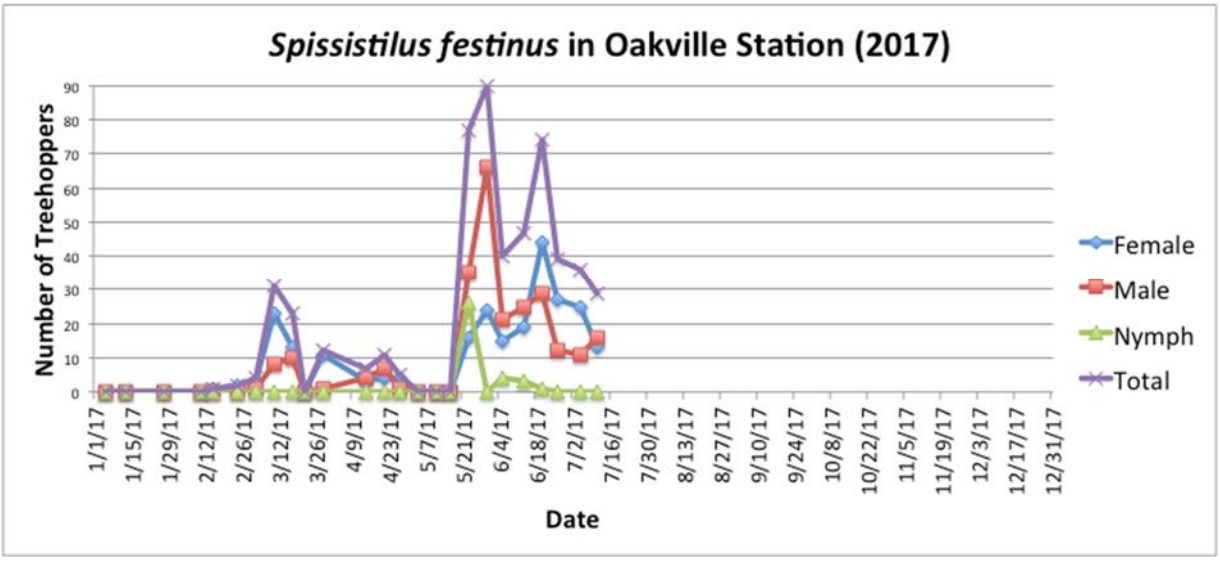
3/20/017 Paso Robles, California, 'Grapevine red blotch disease: the virus, its spread and a vector'. UC Davis Viticulture and Enology on the Road event, (150 attending – growers, consultants)

5/9/17 Davis, California. 'Grapevine red blotch disease spread and vector relationships'. Grapevine Virus Meeting. UC Davis Foundation Plant Services, (50 attended – growers, researchers, commodity board members)

6/2/17 Davis, California. 'Biology and role of treehoppers in grapevine red blotch disease'. CGRIC/CCRRF Research Committee Meeting, (40 attended – growers, nursery, research/ extension)

The project monitored the population dynamics of 3CAH and developed base line data using 1.5 years of weekly sweeping of the vineyard floor. The project team simultaneously monitored RB disease incidence in three different vineyards.





The project conclusions are expected to aid in protecting the wine industry of California that contributed to wine value of $34 billion in the United States. Identification of the vector of GRBaV is a critical need of the industry. Currently about 20% of wine grapevine acres are expected to be replanted because of RB disease. Knowledge of the vector biology of RB disease will help develop sustainable management of GRBaV in these replanted acres. By avoiding GRBaV, the project team are aiming to protect the value of premium wine in California and elsewhere in the United States where RB is now known to be present.

Beneficiaries

Beneficiaries of this project are vintners, growers, nurseries, and those connected with the regulation of pests and diseases at the California Department of Food and Agriculture and the USDA, Animal Plant Health Inspection Service. This project also benefitted extension educators, and enabled new information to disseminate to stakeholders and to academic researchers to pursue critical research needs**.**

More than 4,700 vintners and 5,900 grape growers in California and several hundred more in the United States will benefit from this project. California nurseries that market over 20 million grapevines every year also benefit from this project.

Lessons Learned

At the beginning of the project, the project team initially believed that Virginia creeper leafhopper (Eryhtroneura ziczac) was a vector of GRBaV however, this was found not to be the case. Finding 3CAH as a vector, both in the project team's studies and by researchers at Cornell University, has provided a new direction on the epidemiology of GRBaV. The discovery of the 3CAH as a vector was one of the most significant outcomes of the study.

The project team found vetch (*Vicia* species.) to also be an additional reproductive host of 3CAH. In controlled caging experiments, grapevines were also found to be reproductive hosts of 3CAH.

A majority of the project objectives were accomplished. The field trial to study temporal and spatial changes in the spread of GRBaV could not be started soon enough to permit data collection in the second and third year of the project. This was primarily due to difficulty in procuring sufficient numbers of virus-free grapevines, following the 2010 protocol prescribed by the National Clean Plant Network program.

The delay in obtaining the virus-free transplants pushed back the planting and subsequent data collection by one season. This delay did not substantially affect the project, only the first of four intended infestation dates was affected.

Additional Information

Attachment 1: Bahder, B.W., Zalom, F.G., and Sudarshana, M.R. 2016. An Evaluation of Flora Adjacent to Wine Grape Vineyards for the Presence of Alternative Host Plants of Grapevine red blotch-associated virus. *Plant Disease* 2016 100:8, 1571-1574
Attachment 2: Bahder, B.W., Zalom, F.G., Jayanth, M., and Sudarshana M.R. Phylogeny of Geminivirus Coat Protein Sequences and Digital PCR Aid in Identifying Spissistilus festinus as a Vector of Grapevine red blotch-associated virus. *Phytopathology* 2016 106:10, 1223-1230.
Attachment 3: Wunderlich, L. R., Bollinger, M.L., Shaffer, M., Preto, C.R., Bahder, B.W., Zalom, F.G., and Sudarshana, M.R. 2017. Investigating the spread and effect of *Grapevine red blotch virus* in California-grown Zinfandel. A conference paper accepted for presentation and publication in the conference proceedings. GiESCO 2017 International Meeting.

Project links:
https://www.youtube.com/watch?v=4UBEaokEGxw&list=PLK93eCG1nCqKFZWFWuMqKPyAvU-Qk--B3
https://www.ncipmc.org/action/alerts/redblotch.pdf

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
52	Development of Rapid, Portable Molecular Diagnostics for Important Soilborne Pathogens in California Agriculture	
Grant Recipient: United States Department of Agriculture, Agricultural Research Service	**Grant Agreement No.:** SCB14052	**Date Submitted:** December 2017
Recipient Contact: Frank Martin	**Telephone:** (831) 755-2873	**Email:** frank.martin@ars.usda.gov

Project Summary

Soilborne diseases can reduce yield and quality on all crops throughout the state of California and are difficult to predict, detect, and diagnose. These pathogens are particularly challenging due to the fact that they can survive in soil for many years and population levels can increase over time because of the broad host range of some pathogens. Frequently, these pathogens are present in a disease complex and getting a timely and complete diagnosis can be problematic. This problem is particularly acute for the strawberry industry, due to changes in the pre-plant fumigation strategies pathogens such as *Macrophomina phaseolina* and *Fusarium oxysporum* f. sp. *fragariae* have become a serious emerging problem and an old nemesis, *Verticillium dahliae*, continues to present challenges; all three pathogens cause similar symptoms and can be difficult to diagnose without culturing. Due to a wide range of *Fusarium oxysporum* taxa present in the soil and saprophytically on the roots further pathogenicity tests are needed to accurately identify if the pathogen is present. The ability to specifically detect which soilborne pathogen is causing a disease allows growers to apply effective control measures and assist growers in overall crop management. However, current detection techniques (including conventional isolation and DNA extraction followed by Polymerase Chain Reaction (PCR)) do not allow for a rapid diagnosis at a field level. New isothermal diagnostic assays would simplify this process and allow for a more rapid detection without the need for DNA extraction. The purpose of this project was to develop a rapid isothermal array-type detection method so the user could detect several important soilborne pathogens on plant material in the field within 10 to 30 minutes and begin implementing control strategies immediately. The assay would be sensitive, specific, require minimal training to accomplish, and utilize less sophisticated portable machinery. Due to the impact soilborne pathogens have on productivity and the diminishing options available for growers to manage the diseases they cause, this project focused first on strawberries and ornamental crops but will have broad applicability to other cropping systems, as several of these pathogens have a broad host range on many California specialty crops.

This project enhances specialty crops by providing specialty crop growers with tools to gather more information about whether a specific pathogen is causing disease. Currently obtaining this knowledge is laborious and either requires conventional isolation, or a DNA extraction followed by PCR. The proposed isothermal techniques would remove those steps and significantly reduce the time needed for making management decisions. Crop losses due to soilborne diseases can be significant, particularly with strawberry and ornamental crops; knowing the causal agent can have a meaningful impact on the economics of production. Fungicide applications can be an important control option in some cropping systems, but pathogen detection capabilities are important for timing applications and selection of the appropriate fungicide to control the pathogen (for example, *Phytophthora* and *Pythium* are not controlled by the same fungicides as the other pathogens included in this project). Also, fungicide control is not always feasible or effective with field grown crops and highlights a need for ensuring nursery plants are pathogen free prior to transplanting. The

ability to identify which soilborne disease is present on a plant should improve management capabilities, which in turn should increase profitability and competitiveness. This project would also enhances the export industry for strawberries and ornamentals by providing tools to address regulatory concerns of importing countries concerning plant material and pathogen movement. In addition, the diagnostic assays can be used at the point of entry to ensure imported plants are pathogen free as well. Two important emerging pathogens of the strawberry industry, *M. phaseolina* and *F. oxysporum* f. sp. *fragariae* are included in this project.

This proposal built upon a 2012 Specialty Crop Block Grant Program Project 51: *Improved diagnostics for Phytophthora plant pathogens important to California Agriculture*, which supported the development of an isothermal detection assay as sensitive as real time PCR for *Phytophthora* at a genus specific level and validation of a systematic approach for designing species-specific markers (e.g. *P. ramorum*). These markers were tested for sensitivity and specificity against a wide range of plant pathogens. A crude tissue extraction protocol was optimized and these assays were field validated by collecting over 200 plant samples from over 50 different hosts throughout California. A method was developed to confirm the identification of the species detected by DNA sequencing, thereby eliminating the need for traditional culturing. The 2012 Project 51 also supported the development of specific TaqMan molecular probes for non-native *Phytophthora* species that could pose a threat to California ecosystems and agriculture. Thirty-four probes proposed have been validated; these probes can also be used downstream for the development of isothermal species-specific assays. To ensure technology transfer, collaborations occurred between a variety of groups including California Cooperative Extension Agents, California Department of Food and Agriculture (CDFA) Plant Pest Diagnostic Center, and Pest Control Advisers (PCAs). The knowledge gained from the current project facilitated primer design and optimization of isothermal diagnostic assays for additional soilborne pathogens not covered in the 2012 Project 51. This project focused on two large specialty crop industries in California, strawberries and ornamental nurseries, worth an estimated $2.1 and $1.1 billion in the year 2012, respectively. It also differentiated pathogen groups that are controlled by different methods. For example, *Phytophthora* spp. are controlled using entirely different classes of pesticides than fungal pathogens. The technology developed in this project has directly supported the development of recombinase polymerase amplification (RPA) assays in the current project.

Project Approach

Identify, sequence, and align loci for isothermal markers: Illumina genomic sequencing was done for multiple isolates of *M. phaseolina* (15 isolates), *F. oxysporum* f. sp. *fragariae* (22 isolates), *Pythium* spp. (20 species) and *Rhizoctonia* spp. (15 isolates). Comparative genomics of assembled genomes was conducted to identify targets for developing diagnostic assays. An existing real time PCR assay for *Verticillium dahliae* (*V. dahlia*) was modified for use with RPA technology.

Develop isothermal markers: RPA assays were developed for all pathogens indicated above.

Test for sensitivity and specificity: Sensitivity and specificity were validated for all assays noted above. The RPA assay for *F. oxysporum* f. sp. *fragariae* targeting the Suga locus was found not to be specific so another locus was developed based on the comparative genomics analysis. Trials thus far indicate specificity but additional trials with isolates of *F. oxysporum* from strawberry roots that are thought to be not pathogens of strawberry are needed as project staff found the two loci commonly used for differentiation of isolates was not effective (isolates that were pathogens had the same sequence as some isolates that were not). Pathogenicity

tests take two to three months to complete, the last grouping has been set up and should be completed in beginning of February 2018.

Validate markers using environmental samples: All assays have been validated with environmental samples. In addition, tests were conducted to identify procedures for sampling tissue that would provide the optimal sensitivity of the assay.

Optimize detection of isothermal techniques using a variety of devices: The project staff have tested all assays in the T16 ISO instrument (sold by the marketer of RPA, TwistDx) as well as the field portable BioRanger sold by Diagenetix.

Transfer technology to cooperating laboratories: The project staff have transferred the *Phytophthora* and *M. phaseolina* assay to the University of California Cooperative Extension (UCCE) lab in Salinas, California and trained their personnel in its use. RPA assays for *V. dahlia* have been transferred to UCCE, the assays for *Pythium* and *F. oxysporum* f. sp. *fragariae* will be transferred once the validation has been completed.

The RPA assays for *Phytophthora*, *M. phaseolina* and *V. dahliae* have been transferred to researchers at Cal Poly and diagnosticians at Driscoll's Strawberry. The TaqMan assay for *M. phaseolina* has been transferred to Cal Poly as well.

Once the validation with pathogenicity tests of *F. oxysporum* f. sp. *fragariae* has been completed a workshop will be held to transfer the technology (TaqMan and RPA) to whoever wants to use it.

The project staff has hosted a scientist forum in the United States Department of Agriculture (USDA)-Animal and Plant Health Inspection Service (APHIS) lab in Beltsville, Maryland to train staff in the technique and let them borrow the Twista detection fluorometer to get started with the technology. Project staff presented results of the research at national scientific meetings and at local UCCE meeting targeting growers. The project staff have discussed the progress of validation of the assays with commercial diagnostic companies in the area as they are interested in using the technology once it has been fully validated; and discussed the technology with the California Strawberry Commission and California Leafy Greens Research Board.

Outreach and workshops on the technology--Post protocol on websites to facilitate tech transfer: A workshop scheduled for July 2017 was postponed until the assay for *F. oxysporum* f. sp. *fragariae* could be fully validated (anticipated early 2018). Notice of the technology and how it is currently being used in the University of California, Davis Cooperative Extension lab was posted on the blog: http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=24140

Write and publish scientific manuscripts to share technology with plant pathology community: Project staff have presented the results of the work at the annual meeting of the American Phytopathological Society in 2016 and again in 2017, totaling six presentations to approximately 2,000 in attendance. Project staff also presented results about the comparative analysis of *M. phaseolina* genomes at an international Plant and Animal Genome Conference in San Diego, California in 2017.

The collaborator, California State University, Monterey Bay (CSUMB), has developed and validated the diagnostic genus specific assays for *Pythium* and *Rhizoctonia solani* (*R. solani*) and binucleate *Rhizoctonia*

species. The genus specific has been fully validated for both taxa: *Pythium* and different anastomosis groups of *R. solani* and binucleate *Rhizoctonia* species, project staff are awaiting validation of species specific marker for Pythium and anastomosis specific for the *R. solani* which is expected to be completed in the beginning of 2018.

Goals and Outcomes Achieved

In a project funded by the California Strawberry Commission, 468 isolates of *M. phaseolina* recovered primarily from strawberry in California (but also other countries and included isolates recovered from other hosts in California) were genotyped with 24 simple sequence repeat markers. It was found that 98% of the isolates recovered from strawberry were in a single genotype that was very aggressive on strawberries (other genotypes were weakly pathogenic or not pathogenic on this host). This provided a comprehensive evaluation of pathogen population structure in California for development of a marker system that would be specific for the pathogen genotype aggressive on strawberry and a culture collection to draw from for validation of the marker system.

Genomic sequence data was generated for a number of isolates of *Pythium* spp., *Rhizoctonia* spp., *M. phaseolina*, and *F. oxysporum* f. sp. *fragariae* and comparative genomics used to identify unique regions that could be targeted for development of specific assays. A large culture collection of isolates was established to provide a resource for validation of the marker systems developed by this project. When project staff were not able to recover the necessary cultures, project staff contacted colleagues in the United States and overseas to obtain DNA from their isolates that was used in the studies.

Assays were validated using a range of culture extracted DNA as well as field samples collected by the lab staff and provided by the collaborating UCCE lab in Monterey County.

The long term goal of this project was to provide the agricultural industry with a rapid means for pathogen detection and identification directly in the field. The validation of the isothermal RPA assays for five major pathogens of strawberry, along with the previously developed assay for *Phytophthora*, brings the total number of RPA assays available to industry to six. The project staff will continue with the research past this grant duration to complete validation of all assays and make them available to end users.

Once the final validation of the *F. oxysporum* f. sp. *fragariae* RPA assay has been completed (early 2018), a workshop will be held for potential end users to transfer the RPA and TaqMan technology to their labs. The lab currently has a project with TwistDx, the company that has commercialized the RPA technology, where they have formulated kits with the *Phytophthora* primers and probe included to provide a more comprehensive evaluation of the technology. The hope is to have complete kits commercially available for diagnosticians to use. Currently a user has to add their own primers and probe to the kit, which adds another layer of complexity for the end user and makes it difficult for those without familiarity with molecular biology to use the technology (no experience with molecular biology is needed with the pre-formulated kits).

The project staff developed a TaqMan real time PCR assay for detection and quantification of *M. phaseolina* and *F. oxysporum* f. sp. *fragariae* (funding from the California Strawberry Commission supported comparison of the TaqMan assay with soil plate counts). The *M. phaseolina* assay has been validated for detection from plant tissue and for quantification of inoculum from the soil; the assay for *F. oxysporum* f. sp. *fragariae* is in the final stages of validation. Along with the previously reported soil quantification assay for *V. dahliae* these

assays will provide a rapid means for determining pathogen inoculum levels in field soil (results in days rather than three to six weeks) for the three major soilborne diseases of strawberry. This will support grower efforts to evaluate disease risk in specific fields prior to planting as well as assessing fumigation rates needed for pathogen control.

Outreach and workshops on the technology. Post protocol on websites to facilitate tech transfer. Write and publish scientific manuscripts to share technology with plant pathology community:
The project staff have presented the results of the research at national scientific meetings (oral presentations and posters to approximately 100 in attendance) and a grower meeting sponsored by the UCCE lab in Monterey County, California. A demonstration of the technique was done during the UCCE presentation to show the attendees how simple the procedure is.

The project staff have transferred the assays for *Phytophthora* and *M. phaseolina* to the UCCE lab in Monterey County.

The UCCE lab in Monterey County posted information to their website about the *Phytophthora* and *M. phaseolina* RPA assays and alerted the grower community to the enhanced diagnostic services they now offer. The project staff are also coordinating with this lab on continued validation of the markers to ensure they are working properly.

A workshop was planned for the end of July, 2017 but was postponed until early 2018 due to not having the *F. oxysporum* f. sp. *fragariae* RPA assay fully validated. This will be a hands on workshop with a full course syllabus describing the techniques for all six pathogens that assays have been developed for and providing a step by step process on how to order all components needed for the assays and well as an opportunity to run the assays in the lab.

RPA diagnostic assays were developed for the five major soilborne plant pathogens indicated in the project proposal (*M. phaseolina, V. dahliae, Pythium* spp., *Rhizoctonia* spp. validated, with *F. oxysporum* f. sp. *fragariae* in the final stages of validation of specificity).

The RPA technology has been transferred to the UCCE lab in Monterey County and information provided to several commercial companies. The project staff have had discussions about the technology with several commercial labs in the central coast area.

TaqMan real time PCR assays were developed for four major soilborne plant pathogens (*M. phaseolina, Pythium* spp., *Rhizoctonia* spp., *F. oxysporum* f. sp. *fragariae*) with validation of accuracy for rapid detection of pathogen inoculum density in the soil confirmed for *M. phaseolina* and in progress for *F. oxysporum* f. sp. *fragariae*. These assays can provide results on inoculum density in field soil in a matter of a day versus three to four weeks for conventional soil plating assays.

High quality genomes for two isolates of *M. phaseolina* have been assembled with annotation currently in progress. These assemblies served as an important reference for developing the genotype specific assay for isolates capable of infecting strawberry. An additional 15 isolates representing multiple genotypes have been sequenced with Illumina technology.

Twenty-two isolates of *F. oxysporum* f. sp. *fragariae* and other isolates of *F. oxysporum* recovered from strawberry but not pathogenic on this host were sequenced with Illumina technology and used to design the specific diagnostic markers

A computer software program was developed for high throughput screening of genomic sequences to identify unique loci that can be used for the development of specific molecular markers. This approach has been used for designing markers for two of the pathogens studied in this project (another approach was used for *Pythium* and *Rhizoctonia* spp. prior to the development of this pipeline) and should be useful for others as well.

Beneficiaries

The work completed by this project directly benefits the 400 strawberry growers, shippers and processors in California by providing a means for more accurate and timely pathogen diagnostics.

The validated RPA assays for *Phytophthora* and *M. phaseolina* have been provided to the collaborator at the UCCE office in Monterey County and the lab personnel were trained in their use; they are currently using the assays in their routine diagnostics for the strawberry industry. The project staff have discussed the assays for *Verticillium dahliae, F. oxysporum* f. sp. *fragariae, Pythium* and *Rhizoctonia* with them and will provide them as soon as field validation has been completed in beginning of 2018.

Commercial molecular diagnostic labs: The project staff have been contacted by several companies that provide molecular diagnostics for their clients about the assays. The project staff have provided reprints of published techniques and will have a workshop in early 2018 to transfer technology for the additional assays that have been developed. There is a high level of interest in the TaqMan assays for quantification of pathogen inoculum in field soil as growers currently lack a time efficient method for obtaining this information.

USDA-APHIS scientists from the regulatory lab in Beltsville, Maryland was hosted in the lab to teach the RPA assay for *Phytophthora* so the assay was available to a national audience.

Soilborne diseases are a significant problem for specialty crops in California, particularly in the strawberry and ornamental plant industry. This project's results will enhance the capabilities of diagnostic labs, Plant Pest Diagnostic Center, and PCAs for detection of soilborne pathogens in the field with a portable detection unit, ultimately benefiting many facets of California agriculture production. It would have a direct impact on all strawberry (over 400 farms in California) and ornamental producers. Improved diagnostic capabilities which are less expensive would also support the export market of plant material by addressing regulatory concerns of importing countries concerning pathogen movement and reduce the cost associated with quarantine management. This could have a significant impact on efficiency and early detection in all nurseries throughout the state; an industry worth over $3.7 billion that provides over 88,000 jobs.

Lessons Learned

It can be a challenge to develop diagnostic assays for a specific subgroup of isolates of a fungal species that are differentiated either by genotype or host range due to the difficulties of identifying unique sequences to use as a target for the assay. One of the more interesting accomplishments of this project was the use of whole genome DNA sequence data to accomplish this goal rather than surveying published sequences to see if something would work. The entire nuclear genome of multiple isolates of *M. phaseolina* representing

different genotypes were sequenced with Illumina technology and a comparative genomics pipeline was developed to identify a number of sequences that were unique to the pathogen genotype that was capable of aggressively attacking strawberry. Several of these loci were tested and one selected for designing a highly specific diagnostic assay that detects only the strawberry genotype. A similar approach using a more comprehensive software pipeline was used for designing a marker specific for *F. oxysporum* f. sp. *fragariae* (*F. oxysporum* is a common fungal species but isolates are highly specific for the hosts they can infect). This software pipeline will be useful for designing specific markers for other pathogens as well.

The goals of the project that were not achieved:
In the project plan, it was indicated that project staff would develop an assay for *Colletotrichum acutatum*, but since the diagnostic lab at Driscoll's (a commercial strawberry shipper) was developing a real time PCR assay for this pathogen, project staff held off of working with this species to reduce duplication of effort. Once their assay has been fully validated, project staff will work with them on transferring the assay to RPA technology.

RPA assay for *F. oxysporum* f. sp. *fragariae* - The TaqMan real time PCR assay that was developed based on the conventional PCR assay of Suga et al. (2013) was highly sensitive and specific but there were a small number of strawberry pathogens that were not detected by this assay (ca. 2%). From reviewing the sequence data the primers designed for the RPA assay should have been just as specific as the TaqMan assay, but due to differences on how primers anneal to the target sequence in RPA (in PCR it is controlled by annealing temperature, in RPA the process is less stringent as the complex formed by recombinase and DNA polymerase with the primer determines specificity) a specific RPA assay could not be developed after repeated attempts. Comparative genomics using Illumina genomic data from a number of *F. oxysporum* isolates provided a unique target for the assay with the specificity needed for the RPA assay. This assay is currently in the latter stages of validation and should be completed in beginning of 2018.

Additional Information

National Scientific Meeting Abstracts:

Miles, T.D., Burkhardt, A., Martin, F.N. (2016 meeting of the American Phytopathological Society). Utilizing mitochondrial loci to develop TaqMan and recombinase polymerase amplification assays for the genus *Pythium*.
Alyssa Burkhardt, Kevin Childs, Marina L. Ramon, Frank Martin (2016 meeting of the American Phytopathological Society). Improving genomic resources for the detection of *Macrophomina phaseolina* infection of strawberry
Alyssa Burkhardt, Tim Miles, Marina Ramon, Stave Koike, Frank Martin (2016 meeting of the American Phytopathological Society). Rapid Diagnostic Tools for Soilborne Pathogens of strawberry.
Alyssa Burkhardt, Kevin Childs, Marina L. Ramon, Frank Martin (2017 Plant and Animal Genome meeting). Improving genomic resources for the detection of *Macrophomina phaseolina* infection of strawberry
Alyssa Burkhardt, Marina L. Ramon, Steve Koike, Frank Martin (2017 meeting of the American Phytopathological Society). Rapid diagnostic tools for soilborne pathogens of strawberry.
Alyssa Burkhardt, Kevin Childs, Marina L. Ramon, Frank Martin (2017 meeting of the American Phytopathological Society). Genome Assembly and Comparison of *Macrophomina phaseolina* isolates on strawberry and alfalfa

Miles, T.D. and Martin, F.N. (2017 meeting of the American Phytopathological Society). Mitochondrial markers to detect *Pythium* at a genus and species-specific level using TaqMan and recombinase polymerase amplification

Web Postings:
UCCE blog posting titled "Rapid diagnosis of soilborne diseases of strawberry and other crops" posted on May 18, 2017. This posting alerted readers to the new isothermal diagnostic tests that we provided to the Monterey County Cooperative Extension lab for diagnosis of fungal diseases of strawberry.
http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=24140

Grower Meetings:
UCCE - Monterey County 2016 Plant Disease Seminar. Rapid molecular diagnostics for strawberry soilborne pathogens by Tim Miles and Alyssa Burkhardt. Presentation included a demonstration of the technology.

Workshops:
Project staff have been contacted by several research and regulatory personnel as well as commercial labs requesting information on the RPA assays and what was needed to set the technology up in their labs. A hands-on workshop was planned for 2017 but this was delayed so staff could include the fully validated version of the RPA assay for *F. oxysporum* f. sp. *fragariae*. Staff have already communicated with several labs, the California Strawberry Commission and the California Leafy Greens Resaerch Board to let them know another workshop will be held after the validation has been completed. When staff have received requests for information, reprints and separate write ups describing the technology and how to run the assays have been provided.

Manuscripts in Preparation and will be submitted in March 2018:
Burkhardt, A., Childs, K., Ramon, M.L., and Martin, F.N.. Comparative genomics of two isolates of *Macrophomina phaseolina*.

Miles, T.D. and Martin, F.N. Mitochondrial markers to detect *Pythium* at a genus and species-specific level using TaqMan and recombinase polymerase amplification

Burkhardt, A., Miles, T., Ramon, M.L., Koike, S.T., Martin, F.N. Diagnostic Tools for detection and quantification of *Macrophomina phaseolina* in soil and strawberry plants.

Burkhardt, A., Miles, T., Ramon, M.L., Koike, S.T., Martin, F.N. Diagnostic Tools for detection and quantification of *Fusarium oxysporum* f. sp. *fragariae* in soil and strawberry plants.
Herrera, J.C., Miles, T.D. et al. Diagnostic assay for detection of *Rhizoctonia solani* and binucleate *Rhizoctonia* spp.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
53	Evaluation of an Alternative Irrigation Water Quality Indicator	
Grant Recipient:	**Grant Agreement No.:**	**Date Submitted:**
The Center for Produce Safety	SCB14053	December 2016
Recipient Contact:	**Telephone:**	**Email:**
Bonnie Fernandez-Fenaroli	(530) 554-9761	bonnie@centerforproducesafety.org

Project Summary

Foodborne illness is a preventable public health risk caused by consumption of contaminated food containing harmful microbial agents. In recent years, agricultural water has been associated with an increasing number of foodborne illnesses, especially in fresh produce. Much has been debated and written about the inadequacy of current methods for routine monitoring and assessment of the microbiological quality of agricultural water used for irrigation, crop protection applications, and other preharvest inputs for fresh, edible, and perishable horticultural foods such as the diverse category of leafy greens. The lack of consistent correlation between chemical or biological indicators of fecal contamination at the local, regional, national, and global level is well documented in the scientific and public health literature. A generic fecal indicator organism, *Escherichia coli (E. col),* is currently used for monitoring microbiological agricultural water quality. *E. coli* is a non-pathogenic bacteria present in all warm-blooded animals. The presence of *E. coli* in agricultural waters indicates the possible presence of a pathogen; however, this traditional fecal indicator cannot quantify and identify different sources of fecal contamination. An alternative and well-established biological indicator of fecal contamination of water sources is the gram-negative obligate anaerobic bacterium *Bacteroides*. Tracking and differentiating animal sources of bacteria in the genus *Bacteroides* has long been a tool for evaluating fecal contamination of surface water used as drinking water sources and for recreational purposes.

Current microbial source tracking techniques are used to identify and quantify dominant sources of fecal contamination by using *Bacteroides* 16S ribosomal RNA (rRNA) gene sequences that are a very prominent component of gut microflora. The current project sought to determine whether *Bacteroides* markers could be an alternative and more predictive fecal indicator in different irrigation water sources. The overall objective of the project was to establish a baseline of preliminary data to support collective expert evaluations to replace quantitative generic *E. coli*–based irrigation water standards with a qualitative presence-absence standard based on *Bacteroides* as an improved indicator of fecal contamination and, more specifically, the presence of pathogens. (This qualitative presence-absence standard would actually be a semi-quantitative threshold based on a designed risk-assumption limit of detection.)

The publication of the Food and Drug Administration (FDA) Food Safety Modernization Act (FSMA) "Standards for the growing, harvesting, packing, and holding of produce for human consumption - Final rule" (Produce rule [PR]) on November 27, 2015, was anticipated during the proposal period and overlapped the research implementation period for this project. The regulatory provisions for agricultural water, as defined within the PR, established the compliance criteria for the standards, metrics, and corrective measures related to the required Microbial Water Quality Profile for produce covered by the rule. These requirements identified generic *E. coli* as the recognized fecal indicator bacteria (FIB), but the PR allows for scientifically valid alternatives. The produce industry has long recognized the limitations of *E. coli* as a FIB in common irrigation and produce production water sources in California and many of the Western states. However, multiple studies have shown low correlation of *E. coli* levels with actual pathogen presence or significance in water

sources. Despite being a routine and relative low-cost FIB test, there are a number of limitations, including instability during sample transport and variability of test results, even within recognized standard methods. Validation of an alternative FIB with greater predictive relevance to pathogen potential in water sources, particularly surface water, is of high interest and benefit to the industry.

This project does not build on a previously funded Specialty Crop Block Grant Program (SCBGP) project.

Project Approach

During the project, 691 surface water samples were collected, processed, and analyzed from multiple farm locations in California, Washington, Oregon, and Arizona. Sample collection was approximately evenly split between 2015 and 2016 and, as much as practical, the samples were collected from the same source-locations to allow for trending of results. As laid out in the approved Work Plan, all California samples were collected and processed at the University of California, Davis (UCD). All Washington samples were collected by collaborators and placed in insulated containers with gel refrigerant and then shipped to UCD for processing. Though limited in number due to lack of resolving a collaborative arrangement, the UCD lab collected and processed samples from southern Oregon. The majority of water samples from AZ were collected and processed by the Co-PI at the University of Arizona (UA), following standardized methods, with the exception of 102 stabilized samples shipped to UCD for pathogen detection with the ROKA Biosciences Atlas system. Following the objectives of the Work Plan, analysis of replicate homogenized surface water samples was conducted to contrast the primary *E. coli* quantitative method used by the produce industry (i.e., most-probable-number method) and the enumeration method specified by the PR (i.e., membrane filtration: colony forming units): a total of 1,382 *E. coli* analyses were conducted over the project period.

As membrane-filtered water samples for Total *Bacteroides* analysis can be stabilized by freezing, all 348 samples collected in 2015 were stockpiled awaiting finalization of standard curves and internal controls between UCD and UA, as described in the Work Plan. Implementing the Work Plan for testing Total *Bacteroides* levels in these water samples with two different genomic-based methods and conducting pathogen screening for Shiga toxin–producing *E. coli* (STEC), enterohemorrhagic *E. coli* (EHEC) and *Salmonella* in the samples brought the total number of analyses to 2,764. This moderately exceeded the planned number of tests from the projected baseline of at least 600 samples in the original Work Plan.

A great deal of effort was directed at making scientifically sound assessments of the two FIB in relation to qualitative detectable pathogen presence in representative surface water sources used for fresh produce production across the multi-state locations. Overall, the key significance of the project team's collective results is that *E. coli* levels were overwhelmingly in full compliance with both industry standards and the FSMA compliance standards in the Produce Rule. All test results were subjected to calculation of Geometric Mean and Statistical Threshold Value (STV), as required under the PR, using an FDA-vetted auto-calculator spreadsheet. Across all collected samples, only two date/location events resulted in an STV exceedance, which would require a 1-day preharvest interval to allow for the PR-specified 0.5-log CFU die-off corrective measure. This is a highly significant substantiation, by current testing requirements, of the general adequacy of surface water sources used for produce irrigation in the Western states.

The project provides further evidence of the limited insights that can be obtained by this FIB criterion, based on qualitative pathogen detection in the water sources from at least six liters of collected water (per sample), as described in the Work Plan. Seventy-two of the 348 samples (21%) in 2015, and 90 of the 343 samples

(26%) in 2016, were positive for either STEC/EHEC or *Salmonella* or both detected in the same sample. Of these positives, the levels of FIB *E. coli* would have been compliant, which further reinforces the limited correlation from a food safety perspective.

The general outcome for Total *Bacteroides* assessments was the same. In these surface water sources, there was significant variability in semi-quantitative levels detected by the DNA-based methods relative to *E. coli* and pathogen detection. In general, the team demonstrated a better fit of the AllBac genetic marker assays than the commercial assay kit (Genesig) in relation to *E. coli*, but neither provided strong predictive fidelity to pathogen detection.

The conclusion from these studies is that either FIB may provide good indication of a recent and high level of fecal contamination of a water source, but neither FIB is likely to provide a strong indication of bacterial pathogens in that water source. Regardless, the industry must implement one of the FSMA PR corrective measures for agricultural water sources, and further development of a standard method for AllBac testing in accredited labs is worth pursuing for the greater flexibility in overcoming sample-to-submission-compliance time barriers encountered by many farms.

It should be noted that the team had fewer than anticipated opportunities to follow the persistence of water-borne pathogens to the irrigated crop in Year 2 of the project because cooperating growers either switched to drip irrigation, well water, or antimicrobial-treated water.

All funds were used directly and specifically to address the issues outlined and for the benefit of specialty crops. Budget tracking and expenditure management were conducted by the principal investigator (PI) and the lab manager according to the specific SCBGP budget for this project and its objectives. Frequent lab meetings, e-mail communication, conference calls, and video conferencing were conducted to coordinate activities with the Co-PI at UA and to ensure the funds were applied to meet the scope of work for this project. All work conducted was specifically germane to the sustainability and competitiveness of specialty crops in all states involved in this project.

Grower cooperators in California, Washington, and Arizona were essential and instrumental in accomplishing the sampling phase of this project by giving access to private lands, which could be combined with public access locations, for sampling sites. During the early part of the project, the PI travelled to horticultural production sites in Oregon to collect initial samples and train project partners there in water sampling and sample submission protocols. The team's industry association collaborators in Washington (e.g., through the Washington Tree Fruit Commission) have been accommodating and effective in sample collection from multiple sites and types of surface water irrigation or micro-environment/orchard cooling water sources as well as sample submission for analysis.

Goals and Outcomes Achieved

Analysis of more than the original goal of at least 600 surface water samples from diverse fresh produce production districts was completed; this analysis was essential to develop validation data and performance criteria for alternative irrigation water quality standards to the current system based on indicator *E. coli*. Irrigation, foliar contact, and other agricultural water samples were tested for indicators and bacterial pathogens. The measurable outcome of qualitative and quantitative assessment of these water sources for

levels of FIB using four techniques and the associated three pathogen targets (human pathogenic *E. coli* [STEC and EHEC] and *Salmonella*) was fulfilled.

Outcome measures were planned for a two-season baseline assessment, and this assessment has been completed.

During the project period a total of 691 water samples were processed, which was an additional 91 samples compared with the original goal of ~600 water samples to be collected for analysis. Interest in the project has been high among specialty crop industry commodity boards and regional produce and horticultural associations. The results showed that the water testing, while required, indicated compliance but did not provide a strong indication of bacterial pathogens in that water source. The adoption of a real-time Total *Bacteroides* protocol will be partly dependent on the dissemination of the project results; the completion of the project was delayed by many months primarily due to various sampling issues in the spring of 2016. A white paper outlining the project results will be prepared for peer review by the United Fresh Produce Association's Food Safety & Technology Council to assess the support for pursuing the *Bacteroides* assay as an alternative water quality indicator, with expanded regional studies and interaction with potential test kit developers.

The original proposal planned to measure the success of this project "by the recognition and adoption of a real time Total *Bacteroides* protocol and semi-quantitative standard as a best practice for ag-water monitoring by a combination of at least five specialty crop industry commodity boards and regional produce or horticultural associations at the end of the two year project." Although there was wide and high interest in the project outcomes among various specialty crop industry commodity boards and produce associations, this specific performance measure was not achieved. The project results confirmed that water testing, while required, is of little benefit in most cases other than to show compliance. The research team expects adoption of the protocol and standard as an alternative water quality indicator by laboratories as the data from the completed project is disseminated and further evaluated. However, since the benefit of this protocol and standard was not dramatic, the adoption is unlikely to happen quickly.

Extensive spreadsheet compilations of all 691 samples have been compiled and verified to provide the individual and comparative data across years and multi-state locations. Data have been analyzed by the FDA-vetted FIB auto-calculator, and multiple data presentations have been prepared for dissemination.

This project resulted in a substantial body of new, detailed data with standardized assays on 691 surface water sources over diverse and numerous locations and times, which greatly increases the knowledge of microbial water quality in key specialty crop regions.

Beneficiaries

The tens of thousands of growers of fresh consumed specialty crops, both covered by FSMA regulations and those subject to industry-based audit standards will benefit from this project. The potential for changes in the economic impact of agricultural water testing compliance is uncertain as it revolves around rule making and future guidance documents from FDA.

Multiple stakeholders will benefit from the data developed by this project, including the specialty crop industry and supply-marketing chain, public health agencies, risk modelers, extension educators, and industry associations involved in training and guidance development.

The project PI, University of California, Davis, presented final research results in June 2016 at the seventh annual Center for Produce Safety (CPS) Produce Research Symposium in Seattle, Washington, to 315 symposium attendees. Interim results were presented previously at the 2015 CPS Produce Research Symposium in Atlanta, Georgia, to approximately 245 attendees. The symposium participants included California regional and national growers/shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provides expert panels to critique the research results after presentation by the researcher, which helps participants evaluate how the results can be used in their respective businesses.

Project results will be disseminated at industry meetings, and streamed through social media sources. Results are available online as follows:

Final reports submitted to CPS (after the June 2016 symposium) are posted on the CPS website: http://www.centerforproducesafety.org/grant_opportunities_awards.php.

CPS works with the scientists to publish results in scientific journals. Publication dates occur after the project is completed. Abstracts and awards can be found on the CPS website.

The Board of Directors and members of the Technical Committee of CPS distribute a series of information briefs throughout the year on the website and through presentations, meetings and webinars. An example of this would be the "CPS 2016 Research Symposium Key Learnings" on the CPS website at the following link: http://www.centerforproducesafety.org/amass/documents/document/365/CPS%202016%20Key%20Learnings.pdf.

The following websites provide additional resources on the final reports and symposium proceedings:
Center for Produce Safety: http://www.centerforproducesafety.org/resources.php
Produce Marketing Association: http://pma.com/ (e.g., http://www.pma.com/content/articles/2016/09/2016-cps-research-key-learning)
Western Growers Association: http://www.wga.com/ (e.g., http://www.wga.com/magazine/2012/03/08/2016-cps-symposium-highlights)

Lessons Learned

The team conducted hypothesis-driven research to determine whether the Total *Bacteroides* testing would substantially improve the value of water quality testing for growers. While the team believes the assay holds much promise as an improved system, the previously known and further verified low correlation with pathogens in typical surface water sources, within the limits of any survey, has not altered this perspective.

Additional Information

Extension and peer-reviewed publications are planned for 2017.

USDA Project No.:	Project Title:	
54	Investigation of risk criteria and foodborne pathogen reduction practices for irrigation water	
Grant Recipient: The Center for Produce Safety	**Grant Agreement No.:** SCB14054	**Date Submitted:** December 2016
Recipient Contact: Bonnie Fernandez-Fenaroli	**Telephone:** (530) 554-9761	**Email:** bonnie@centerforproducesafety.org

Project Summary

Fresh produce is increasingly recognized as a common vehicle for transmission of foodborne pathogens (Brandl 2006; Franz and van Bruggen, 2008). *Salmonella* spp., *Escherichia Coli (E. coli)* O157:H7, and *Listeria monocytogenes* are considered to be common foodborne pathogens associated fresh produce (Center for Disease Control (CDC), 2014), and are ranked among the top five pathogens contributing to illnesses, hospitalizations, or deaths in the United States during the outbreaks of foodborne diseases. Consumption of *Salmonella*-contaminated produce has led to several multistate and international outbreaks in recent years (CDC, 2005, 2007; Greene et al., 2008). *E. coli* O157 is typically responsible for most infections (80%) among the Shiga toxin–producing bacteria in the United States and in some European countries (Muniesa et al., 2006; Paton and Paton, 1998). *L. monocytogenes* was responsible for a 2011 produce-borne outbreak in the United States, with 147 illnesses, 33 deaths, and 1 miscarriage, due to consumption of cantaloupe (Food and Drug Administration (FDA), 2012). A considerable number of produce recalls have occurred in the past years as a result of the contamination by the three pathogens (FDA, 2004-2014).

Irrigation water may play an important role in contaminating vegetables and fruits with foodborne pathogens (Islam et al., 2004; Hintz et al., 2010; Solomon et al., 2002). Waste with the bacteria can enter the water through different ways, including sewage overflows, polluted storm water runoff, and agricultural runoff. The 2005 multistate *Salmonella* Newport outbreak associated with tomato and the 2006 multistate *E. coli* O157 outbreak associated with spinach were reported to be related to contaminated irrigation water (Bidol et al., 2007; Gelting et al., 2011). After irrigation with contaminated water, the bacteria can adhere to plants, enter into plants, and translocate to other organs of the infested plants, which would be difficult to be completely sterilized during typical washing and disinfection procedures, and may persist and multiply at any point along the farm-to-fork continuum from production to consumption (Barak et al., 2011; Danyluk, 2013; Franz and van Bruggen, 2008; Gu et al., 2011, 2013c; Miles et al., 2009; Solomon et al., 2002; Zheng et al., 2013). Therefore, minimizing the risk of contamination by human bacterial pathogens during the pre-harvest period would also be essential to reduce foodborne illness risks.

Fecal pollution, including *Salmonella* spp., *E. coli* O157:H7 and *L. monocytogenes*, is traditionally evaluated by detecting fecal indicator bacteria like fecal coliforms and generic *E. coli* (EPA, 2002). However, contradictory results have been reported as to the correlation between index or indicator organisms and the occurrence of human pathogens in surface water (Ahmed et al. 2009; Benjamin et al., 2013; Burton et al., 1987; Chandran and Hatha, 2005; Chandran et al., 2011; Gu et al., 2013a; McEgan et al., 2013; Rhodes and Kator, 1988). Chigor et al. (2010) reported that some environmental factors, including water turbidity and concentrations of nitrate, phosphate, and chloride, were positively correlated with the population of fecal coliforms in a river used for fresh produce irrigation in Nigeria. A study evaluating irrigation ponds in Georgia showed positive correlation between temperature, rainfall, populations of fecal coliform, and culturable

bacteria and the occurrence of *E. coli* O157, and a negative relationship between total nitrogen concentration, oxidation reduction potential (ORP), and dissolved oxygen concentration and the occurrence of this pathogen ($P < 0.05$) (Gu et al., 2013a). Another survey conducted in Central Florida presented different results on the relationship of environmental factors to the prevalence of *Salmonella* in surface water (McEgan et al., 2013). These studies showed regional differences for both occurrence/population of detected foodborne pathogens and the efficacy of indicators to predict the prevalence of the pathogens (Ahmed et al., 2009; Benjamin et al., 2013; Gu et al., 2013a; McEgan et al., 2013). Additional studies are necessary to evaluate and validate the efficacy of biological index organisms and physicochemical indicators on the prediction of foodborne pathogen contamination in major agricultural regions in the United States of America (U.S.). Previous studies about the impacts of bacterial communities on foodborne pathogens in irrigation ponds have demonstrated the probability of identifying alternative indicator microorganisms to economically and reliably predict the presence or absence of foodborne pathogens in irrigation water and the on-farm agricultural environment (Gu et al., 2013a, 2013b).

As part of the Food Safety Modernization Act (FSMA), the FDA issued a Proposed Produce Safety Rule, which included mandatory standards for growing, harvesting, packing and holding produce on domestic and foreign farms (FDA, 2013). Standards based on the presence/population of generic *E. coli* were proposed for agricultural water, including irrigation water. Farmers may use alternatives to requirements for testing water and taking action based on the results, but solutions to the issues, such as prevention strategies and suitable decontamination methods to treat the irrigation water if contamination occurs, are not provided in the proposed rule. Previous studies have reported multiple methods to disinfect foodborne pathogens in the postharvest period (Abadias et al., 2011; Gil et al., 2009; Selma et al., 2008; Suslow, 2001; Tomás-Callejas et al., 2012).

Information about practical decontamination methods to control foodborne pathogens for large irrigation systems is limited. The efficacy of commercial sanitizers, especially products approved by the Environmental Protection Agency (EPA) and/or the Organic Materials Review Institute for use in irrigation water, has not been evaluated. The impacts of water quality from various irrigation water sources (pond or well water at different locations) on reducing foodborne pathogens in irrigation water have not been sufficiently analyzed. The factors, such as water pH, conductivity, ORP, and population/diversity of microbial communities, could potentially affect the decontamination efficacy of sanitizers, and increase the minimum effective dose.

To better understand the prevalence of foodborne pathogens in irrigation water and assess the food safety risks, and science-based data on the occurrence/population of enteric pathogens in major agricultural regions associated with produce-borne illnesses are needed. The data gathered and researched in this project must be correlated to potential biological or physicochemical indicators. This project compares commercial sanitizers by investigating optimal treatment concentrations with irrigation water of different quality to lead to practical and economical solutions for reducing contamination and achieving the new standards for produce safety required by FSMA.

The Eastern Shore of Virginia (ESV) is a major U.S. agricultural region that has suffered from recurring foodborne illness outbreaks, which makes it an ideal location for surveys of farmers and other stakeholders and practical studies about foodborne pathogen contamination on produce. This project reports on the dynamics of important foodborne bacterial pathogens, *Salmonella* spp. and *L. monocytogenes*, in relation to irrigation water sources used for vegetable and fruit production, to provide produce growers with information about potential contamination risks. The data set illuminates the prevalence of these pathogens in relation to

environmental factors and bacterial communities, which helps to identify suitable indicators or index microorganisms for the food safety evaluation of irrigation water, and prevent pathogen contamination during the pre-harvest period. The project also evaluated practical sanitizing methods for the decontamination of the three important foodborne pathogens in irrigation water, which will benefit stakeholders, especially vegetable and fruit industries, to reduce the contamination risks of foodborne pathogens during production and achieve the new FSMA standards for produce safety.

This project did not build on a previously funded Specialty Crop Block Grant Program project.

Project Approach

Key activities and tasks performed for Objective 1 included (i) pond and well water sample collection from four vegetable farms, weekly for Salmonella enterica spp. isolation (392 samples), and monthly for Listeria monocytogenes detection (96 samples); (ii) water parameter measurement, temperature and rainfall data collection at the farms, and generic *E. coli* and fecal coliform assays; (iii) most-probable-number (MPN) analysis of collected water samples for Salmonella and *L. monocytogenes*; (iv) antimicrobial susceptibility testing of the Salmonella isolates; (v) determination of Salmonella serotypes of the isolated strains using standard protocol molecular serotyping analysis; and (vi) metagenomic analysis of bacteria in the water samples.

For Salmonella occurrence, spatial (farm location) and temporal (weekly) differences were found in surface pond water (Fig.1 – see Attachment). The prevalence of Salmonella spp. in tested four ponds of farms A, B, C and D were 18.4, 12.3, 24.5, and 22.5%, respectively. The average MPN values of Salmonella in the four ponds during the study were 0.43, 0.28, 0.75, and 1.82 MPN/L, respectively. There were no significant differences for Salmonella prevalence among seasons ($p > 0.05$). The major Salmonella serovars in ponds A-D were Thompson, Typhimurium, Thompson, and Newport, respectively (See Fig. 6-Attachment). In 2015 the top three serovars isolated from all pond water samples were Newport, Thompson, and Typhimurium (See Fig. 7-Attachment).

The wells tested at all farms (except farm B) were Salmonella-positive at certain time points in 2015 (Table 1-Attachment). Thompson was the major serovar of isolated Salmonella strains in the well water samples, followed by Typhimurium and Javiana (Fig. 8- Attachment). Salmonella Newport was only isolated from well water in Farm C. When 2015 data were compared with data from a pre-study performed in 2014, the observed prevalence of Salmonella in pond irrigation water was approximately the same (2014, 19.9%; 2015, 19.4%), whereas the average concentration in the water increased from 0.49 ± 1.66 MPN/L in 2014 to 0.82 ± 5.14 MPN/L in 2015. In 2015, all wells (except from farm B) were Salmonella-positive at certain time points in 2014, especially in farm D. The prevalence (<4%) of Salmonella in well water was significantly lower than that for pond water ($p < 0.01$), and had an average level value of 0.03 ± 0.15 MPN/L in 2014 and 0.05 ± 0.36 MPN/L in 2015.

No significant correlation was found between most water parameters and Salmonella occurrence in the tested pond and well water ($p > 0.1$, data not shown due to large size). Salmonella populations in pond water were positively correlated with water turbidity (Table 3-Attachment). However, the significant correlation was mainly contributed by tested water samples of pond water in farm D ($p < 0.01$). Water turbidity was not significantly correlated with Salmonella MPN values in Ponds A–C ($p > 0.05$). No significant correlations

were identified between tested weather parameters (temperature and rainfall) and Salmonella prevalence and levels in 2015.

Populations of fecal indicators including coliform and generic *E. coli* in irrigation pond and well water samples were detected during the study (Figs. 3, 4- Attachment). There were no significant correlations between fecal indicators and the prevalence/population of detected Salmonella enterica spp. The population density of coliform in most pond water samples exceeded the maximum detection limit (2,419.6 MPN/100 ml), which indicated that it is not a suitable indicator to evaluate the risks of foodborne pathogen contamination in surface pond water. However, coliform was positively correlated with Salmonella in well water (Table 4-Attachment), even though the significance was mainly contributed by the high correlation in well water of farm D ($p < 0.01$). Similarly, the concentration of generic *E. coli* in well D was also significantly positively correlated with Salmonella population ($p < 0.01$). Pond D had the highest Salmonella MPN values, and well D had the largest prevalence ratio compared with the ponds and wells at the other farms. The relative high levels of Salmonella in farm D compared to other farms on ESV might be caused by distinct contamination sources, which result in significant correlation to water turbidity in the pond and fecal indicator populations in the well. Nevertheless, even though farm D was observed to have relative higher risk of Salmonella contamination in pond and well water, the levels of fecal indicators, coliform and generic *E. coli* were not the highest among all the tested farms. The geometric mean and statistical threshold values of generic *E. coli* in the tested pond and well in farm D also achieved (lower than) the microbial standard of water quality for produce safety as per FSMA. The geometric means of ponds A–D and wells A–D in the sampling period (with 49 samples each) were 22.5, 6.3, 8.8, 5.7, 1.1, 1.0, 1.2, and 1.3, respectively. The statistical threshold values of ponds A–D and wells A–D in the sampling period (with 49 samples each) were 770, 62, 681, 28.7, 2.3, 0, 71.8, and 18.4, respectively. The high variance of the correlation of foodborne pathogens to contextual factors among different farms makes it challenging to identify a universal indicator to predict contamination risks.

Similarly, for Listeria monocytogenes occurrence in irrigation pond and well water there was an observable difference among ponds (Fig. 2-Attachment). Prevalence of *L. monocytogenes* in the four ponds tested at farms A, B, C, and D was 18.4, 12.3, 24.5, and 22.5%, respectively. Average MPN values of *L. monocytogenes* in the four ponds during the study were 0.43, 0.28, 0.75, and 1.82 MPN/L, respectively. For well water samples, *L. monocytogenes* was only isolated from Farm D in April and October 2015 (See Table 2- Attachment). Probably due to limited sample size (monthly instead of weekly detection), no contextual factors measured in this study were significantly correlated to *L. monocytogenes* population and prevalence (data not shown).

To analyze the correlation between Salmonella spp. and *L. monocytogenes*, Salmonella MPN data of the specific week in which Listeria detection was conducted were selected to compare the two foodborne pathogens. In addition, the average Salmonella MPN/L value of each month was also calculated for comparison. However, neither the population/prevalence of selected Salmonella MPN values per month nor the average Salmonella values were correlated with *L. monocytogenes* population/prevalence in pond and well water samples. Based on the monthly detection data, the average prevalence and population of *L. monocytogenes* is similar to that of Salmonella. However, *L. monocytogenes* has not been associated with any foodborne outbreaks traced back to Eastern Shore of Virginia (ESV), which might be due to the lower survival and transfer rate of this pathogen in the food commodities produced and transported in this region.

A total of 220 Salmonella isolates, including 171 from irrigation ponds and 49 from irrigation wells or creek water, were selected for antimicrobial susceptibility testing. Fourteen of the 220 Salmonella isolates (6.4%) were resistant isolates, including 10 isolates from pond water and 4 from well/creek water samples. All the resistant isolates collected from irrigation water were only resistant to one of the tested antibiotics. Tested isolates were resistant to ceftriaxone (n=6, 2.7%), streptomycin (n=2, 0.9%), tetracycline (n=1, 0.5%), cefoxitin (n=1, 0.5%), ampicillin (n=1, 0.5%), amoxicillin/clavulanic acid 2:1 (n=1, 0.5%), ciprofloxancin (n=1, 0.5%), and Ceftiofur (n=1, 0.5%). Even though most of the environmental isolates (93.6%) from irrigation water are not resistant to the tested antibiotics, the varying antimicrobial resistance of Salmonella isolates recovered from localized areas in ESV is cause for concern.

Based on 16s amplicon sequencing results, hierarchical clustering of samples based on the 50 most dominant class level taxa reveals a strong clustering associated with water source (Fig. 9- Attachment). The heatmap scale denotes log transformed proportion values (e.g., -1, ~10%; -2, ~1%; -3, ~0.1%). Similarly, hierarchical clustering of samples based on the 50 most dominant genus level taxa revealed a strong clustering associated with water source. According to the heatmap scale values, some taxa appear uniquely enriched in the pond samples (e.g., Linmohabitans) while others are most abundant in the well samples (e.g., Dechloromonas) (Fig. 10-Attachment). Beta-diversity (i.e., principal coordinate's analysis) was conducted based on Bray-Curtis distances, and points are colored to present dominant factors associated with community composition: water source status, and location and source combination. An effect of both water source and location was observed (see plot on the right, (Fig. 11- Attachment). For example, among well samples, well D (WD) has a distinct community, while WA and WB are much closer in community composition. There is substantial overlap in composition among pond samples from all four locations (Fig.11-Attachment). Relative abundance of dominant taxa of sampled irrigation water varied among different water types and locations (Fig. 12-Attachment).

Based on the taxonomic database, correlation analysis and Mann-Whitney statistical test were conducted to identify potential indicators for Salmonella and *L. monocytogenes* contamination in irrigation water. Due to the different distribution and occurrence of the tested foodborne pathogens, it was not beyond the team's expectation that different bacterial taxa were correlated with these two foodborne pathogens in sampled irrigation water. Abundance of the Bacteroides class is associated with Salmonella-positive status ($p = 0.003$), while Spirochetes class ($p = 0.007$) and the Rhodocyclaceae family ($p < 0.001$) are negatively correlated with *L. monocytogenes* prevalence (Fig.13-Attachment). Abundance of the Sphingobacteria class is associated with *L. monocytogenes*-positive status ($p = 0.027$), while the Gammaproteobacteria class ($p = 0.014$) and Acinetobacter genus ($p = 0.002$) are negatively correlated with *L. monocytogenes* prevalence (Fig. 14-Attachment). Based on the data, bacterial species of the Bacteroides and Sphingobacteria classes could be further tested as alternative/suitable indicator microorganisms for Salmonella and *L. monocytogenes*, respectively. Bacteria with a negative correlation with the tested foodborne pathogens could be potential biocontrol agents to mitigate contamination risks. Deeper sequencing and further computational analysis are underway to identify certain microbial communities/patterns that are associated with both foodborne pathogens for risk evaluation.

Key activities and tasks performed for Objective 2 included (i) pond and well water sample collection from the same four ESV vegetable farms during the May to October 2015 growing season (n = 24); (ii) preparation of Salmonella Newport, *E. coli* O157:H7 and *L. monocytogenes* inoculated to contaminate irrigation water samples; (iii) treatment of inoculated water with six different sanitizers (Table 5-Attachment) for 1- or 30-min

contact times, followed by pathogen detection as well as fecal indicator, water parameter, and bacterial community analyses of water samples ; and (iv) measurement of available active ingredients of the sanitizers in treated irrigation water samples.

Efficacy of sanitizers on foodborne pathogen deduction: A key finding from these experiments is that on the basis of the low population densities of foodborne pathogens in the irrigation water of this region (less than 2 log MPN/L), all the tested sanitizers are qualified for irrigation water decontamination.

Salmonella concentration, at all three inoculation levels of 7, 5, and 3 log CFU/ml, was significantly decreased after 1-min contact for all sanitizers compared with the control (CK) (Fig. 15- Attachment). However, the efficacy of low dose Sanidate 5.0 (S 5.0) and 12.0 (S 12.0) applications was significantly lower than the efficacy of most of other treatments after the short contact time. There were no significant differences between pond and well water samples for Salmonella levels after each treatment. However, it is notable that the pathogen was not detectable after treatment with Chlorine Dioxide Gas (CDG) Solution 3000 in well water samples at all three inoculation levels, whereas the corresponding pond water samples were still Salmonella-positive after enrichment. Similar results were observed for Ecolab XY-12 (XY) application to water samples at 5 and 3 log CFU/ml inoculation levels and for the high dose Sanidate 5.0 (S 5.0-HD) application to water at 7 and 5 log CFU/ml inoculation levels. Salmonella was not detectable after 30-min contact for most treatments, except the CDG application to pond water at an initial Salmonella concentration of 7 log CFU/ml (Fig. 16-Attachment).

Listeria monocytogenes and *E. coli* O157:H7 were relatively more tolerant to the tested sanitizers (Fig. 17–20- Attachment). After 1-min contact, *L. monocytogenes* was still detectable after most treatments (Fig. 17). *L. monocytogenes* concentration in both pond and well water samples with low dose Sanidate 5.0 and 12.0 treatments was significantly reduced compare with the control. After 30-min contact, all treatments efficiently reduced the pathogen populations in both pond and well water samples (Fig. 18-Attachment). *L. monocytogenes* was not detectable in all treated water samples with an initial bacterial concentration of 3 log CFU/ml.

After 1-min contact, *E. coli* O157:H7 was still detectable under all sanitizer treatments (Fig.19-Attachment). *E. coli* O157:H7 level was not significantly reduced under low dose Sanidate 5.0 and 12.0 applications to water at 5 and 3 log CFU/ml inoculation levels compared with the control, except for well water with Sanidate 12.0 treatment at 3 log CFU/ml inoculation level. Similar to Salmonella and *L. monocytogenes* deduction tests, after 30-min contact, all treatments efficiently reduced *E. coli* O157:H7 populations in both pond and well water samples (Fig. 20-Attachment). The pathogen was still detectable after enrichment in pond water samples treated with sodium hypochlorite (XY) at all 3 inoculation levels, while well water samples with the same treatment were Salmonella-negative. Similar results were observed with S 5.0-HD, S 12.0, and S 12.0-HD for water at the 7 log CFU/ml inoculation level; with S 5.0, S 5.0-HD, S 12.0, and S 12.0-HD for water at the 5 log CFU/ml inoculation level; and with CDG for water at the 3 log CFU/ml inoculation level.

Some of the pH changes after disinfectant treatments: Sodium hypochlorite (NaClO) and chlorine dioxide (ClO2) are the main active ingredient of sanitizers XY and CDG, respectively, and could produce hydroxide (OH-) after dissolving in water. In contrast, peroxyacetic acid (PAA) could reduce water pH. As expected, water pH values were generally increased after treatment with NaClO (XY) and ClO2 (CDG), and decreased after treatment with hydrogen peroxide and PAA (Sanidate 5.0 and 12.0) (Tables 6, 10, 14-Attachment). Most

Sanidate 5.0 and 12.0 treatments, especially at the high dose, result in significant pH deduction compared with the control. Irrigation water pH value in the fields was associated with plant growth and pesticide applications. Most nutrients for plant growth are plant available in the soil solution when the pH range is 6.0 to 7.5. In this study, pH values of collected water samples were above 7. Since pH deduction values after application of tested sanitizers were all less than 1, the pH of treated irrigation water was still in the proper range for plant growth.

Active ingredient residual percentage: The residual percentage of active ingredients of tested sanitizers varied after 30-min treatment (Tables 7, 11, 15). The depletion of free chlorine and chlorine dioxide in XY and CDG were significantly higher than PAA in the Sanidate products. Most of the active ingredient residual percentage values were not significantly different between pond and well water samples. The significantly higher PAA residual level in well water with S 5.0-HD treatment at 5 log inoculation level (Table 15-Attachment) was consistent with the detection difference of *E. coli* O157:H7 in respective water samples (Fig. 20-Attachment).

Impact of water parameters: Water turbidity was the only tested parameter significantly lower in well water compared with pond water samples in all foodborne pathogen sanitization experiments (Tables 8, 12, 16-Attachment). The higher turbidity in pond water may be associated with the detection difference of tested foodborne pathogens between certain pond and water samples under the same sanitizer treatment as mentioned above.

Association with fecal indicators: The concentration of coliforms and generic *E. coli* were significantly higher in pond water than in sampled well water (Tables 9, 13, 17-Attachment). However, the difference did not affect the general effects of tested sanitizers on the decontamination of foodborne pathogens. There were no statistically significant differences for the deduction of foodborne pathogens between pond and well waters for most sanitizer treatments. However, as mentioned above, the tested foodborne pathogens were still detectable after enrichment in certain pond water samples, while the corresponding well water samples under the same treatments were negative for target pathogens. Coliforms and generic *E. coli* in tested water samples were completely eliminated after all sanitizer treatments.

Key activities performed for Objective 3 were surveys and extension training. In November 2015, prior to instruction on FSMA and research results, a survey was conducted by the Principal Investigator (PI) and a food scientist research colleague at regional extension meetings. Survey results (n=256) showed an average response of “fair” for awareness of the FSMA Produce Safety and Preventative Control Rules. While many stakeholders were mildly familiar with FSMA, the average response of “I don't know” was selected in response to whether “a grower’s operation would be covered under the FSMA Produce Safety Rule.” Additionally, 91% of growers who responded to the survey felt they were most concerned or worried about the standards for agricultural water. Many growers requested a need for specialized training for only agricultural water standards, specifically for untreated surface water applications. A follow-up survey (after information transfer) indicated that 88% of growers were certain of whether their farms fell under FSMA rules, and 56% were still worried about the new water standards.

Results derived from this project about foodborne pathogen contamination in water samples and practical methods on irrigation water decontamination have been reported to stakeholders during field day and multiple extension meetings (see presentations and meeting abstracts listed in Additional Information). Final results were reported at the 2016 Center for Produce Safety (CPS) Produce Research Symposium in Seattle,

Washington and at the International Association for Food Protection (IAFP) annual meeting in St. Louis, Missouri.

All participating farms sampled for irrigation water produced specialty crops such as tomatoes and potatoes. Results derived from sanitizer evaluation tests will provide farmers with practical strategies to improve irrigation water quality for produce safety considerations. All activities conducted were reviewed and tracked by project investigators to ensure that grant funds were used to solely enhance the competitiveness of specialty crops. Financial records have been maintained and managed throughout the courses of this project to ensure compliance.

The project partners for this project are the CPS and the Virginia Polytechnic Institute (VPI). CPS managed the project and the VPI research team provided the expertise and performed the research studies. The principal investigator (PI) supervised experiments and provided the research facilities necessary for the completion of this project and provided education and training programs under Objective 3. Co-PI No. 1 provided the outbreak strains required for Objective 2 and performed antimicrobial susceptibility tests of *Salmonella* isolates collected from this study. Co-PI No. 2 oversaw the specific details of the proposed research objectives, conducted proposed experiments, and performed data analyses. Project collaborators at the FDA supported metagenomics experiments and data analysis.

Goals and Outcomes Achieved

Results derived from this project about identifying foodborne pathogen (Salmonella spp. and Listeria monocytogenes) contamination risks in water samples and the efficacy results of various sanitizers for irrigation water decontamination of major foodborne pathogens have been shared with stakeholders during numerous field day and multiple extension meetings (see presentations and meeting abstracts listed in Additional Information). In November 2015, prior to instruction on FSMA and research results, a survey was conducted by the PI and a food scientist researcher at regional extension meetings. Survey results (n=256) showed an average response of “fair” for awareness of the FSMA Produce Safety and Preventative Control Rules. While many stakeholders were mildly familiar with FSMA, the average response of “I don't know” was selected in response to whether “a grower’s operation would be covered under the FSMA Produce Safety Rule.” Additionally, 91% of growers who responded to the survey felt they were most concerned or worried about the standards for agricultural water. Many growers requested a need for specialized training for only agricultural water standards, specifically for untreated surface water applications. A follow-up survey (after information transfer) indicated that 88% of growers were certain of whether their farms fell under FSMA rules, and 56% were still worried about the new water standards.

To achieve zero risk for food safety is a long journey. Continuous education and training will be performed to improve current agricultural and production practices and prevent potential contamination of produce by foodborne pathogens. The team submitted two papers in 2016 on indicator investigation for *Salmonella* spp. and *L. monocytogenes* in irrigation water, and one paper on sanitizer evaluation for irrigation water treatment.

The results of this project provide growers with information that is necessary for them to determine if a contamination problem exists. Information has been provided to identify alternative suitable indicators for *Salmonella* and *L. monocytogenes* contamination in irrigation water. The efficacy results of various sanitizers to mitigate contamination of major foodborne pathogens in irrigation water has been shared and communicated with produce growers and other stakeholders.

In this study, the team detected the dynamics of Salmonella populations and distribution in irrigation ponds and wells on ESV. Correlation between foodborne pathogens (Salmonella spp. and Listeria monocytogenes) and contextual factors, including water parameters, weather information, and fecal indicators, has been analyzed. Bacterial community analysis through metagenomics study provides meaningful clues to identify suitable indicators and potential suppressors of foodborne pathogens in irrigation water. This information is vital as the FDA is going to mandate uniform regulations for food safety, inclusive of irrigation water standards. In addition, the efficacy of commercial sanitizers with different active ingredients used for irrigation water treatment has been evaluated. Relevant results derived from this study have been shared with vegetable growers and other stakeholders through extension talks, field days, and scientific meetings. Please see Attachment, Table 3 and four. Figure 1 to 4 do show the different levels of Salmonella (Fig. 1), Listeria monocytogenes (Fig. 2) , coliform and generic *E. coli* (Fig 3, 4) in the various ponds (or well water, Fig 4) when water was sampled at different times of the year. The outcomes of this research will benefit stakeholders especially vegetable and fruit industries to reduce the contamination risks of foodborne pathogens during irrigation and achieve the requirements of FSMA on produce safety.

The major outcomes of the project included the following: detection of the dynamics of Salmonella and Listeria monocytogenes population and distribution in four irrigation ponds on ESV; analysis of the correlation between foodborne pathogens and contextual factors, including water parameters, weather information, and fecal indicators; providing meaningful clues to identify suitable indicators and potential suppressors of foodborne pathogens in irrigation water through metagenomic analysis; and evaluation of the efficacy of six commercial sanitizers with different active ingredients used for irrigation water treatment.

Beneficiaries

Key beneficiaries of this project's accomplishments are produce (vegetable and fruit) growers in California, but also in the U.S. They will benefit from this research as well as the education and training to reduce the contamination risks of foodborne pathogens during irrigation. Other stakeholders in vegetable and fruit industries, including processors and shippers, will benefit from the research and information gathered in this project and disseminated.

At least three outbreaks of salmonellosis associated with contaminated fresh tomatoes have been traced back to ESV from 2002 to 2010, according to CDC reports. Salmonella contamination on tomatoes also raised questions about the safety of the water used for irrigating these products in this region. Producers are frequently questioned by retailers to certify product quality. With education about food safety and good agricultural practices in produce production, including from this project, no outbreaks of salmonellosis have been linked to the tomatoes produced in Virginia in recent years.

According to the most recent (2012) Census of Agriculture there are 42,729 farms of specialty crop produce growers representing $23.9 billion in sales in the state of California alone (http://www.agcensus.usda.gov/Publications/2012/Online_Resources/Rankings_of_Market_Value/California/index.asp), and the state has about 250 growers of fresh-market tomatoes. In Virginia, including ESV, there are 3,019 farms of produce crop growers representing $158 million in sales.

The project PI from Virginia Polytechnic, presented final research results in June 2016 at the seventh annual CPS Produce Research Symposium in Seattle, WA, to 315 symposium attendees. Interim results were presented previously in a poster session at the 2015 CPS Produce Research Symposium in Atlanta, GA, to

approximately 245 attendees. The symposium participants included California regional and national growers/shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provides expert panels to critique the research results after presentation by the researcher, which helps participants evaluate how the results can be used in their respective businesses.

Project results will be disseminated at industry meetings, and streamed through social media sources. Results also will be made available online as follows:
1. Final reports submitted to CPS (after the June 2016 symposium) are posted on the CPS website: http://www.centerforproducesafety.org/grant_opportunities_awards.php
2. CPS works with the scientists to publish results in scientific journals. Publication dates occur after the project is completed. Abstracts and awards can be found on the CPS website.
3. The Board of Directors and members of the Technical Committee of CPS distribute a series of information briefs throughout the year on the website and through presentations, meetings and webinars. An example of this would be the "2015 CPS Symposium Summary: Key Learnings and What They Mean for You" on the CPS website at the following link: http://www.centerforproducesafety.org/amass/documents/document/325/2015%20CPS%20Symposium%20Key%20Learnings%20web.pdf.

Lessons Learned

Salmonella populations of selected samples per month and the average MPN values of each month were not correlated ($p > 0.1$). Weekly differences of Salmonella occurrence and population in water samples among the same detection for the given month indicated that intensive sampling would be necessary to identify the accurate spatial and temporal pattern of the foodborne pathogen in irrigation water. In addition, the low probability and concentration of Salmonella in collected water samples indicate that large sample amount or additional replicates (>3) would be important to find out the real prevalence in environmental samples.

Distribution and diversity of Salmonella serovars varied among different types of water samples and in two sampling years, i.e. the dominant Salmonella serovar in well water samples collected in 2014 was Newport. Further genotypic analyses using whole genomic sequencing of selected Salmonella strains isolated from this study will be conducted and the data will be compared with, identified or sequenced clinical and environmental strains from former studies. In addition, survival comparison studies and genetic analysis will be performed to compare different strains isolated from this agricultural area, like strains of serovars Newport and Typhimurium, to identify specific bacterial properties and/or mechanisms that contribute to colonization and survival variances of Salmonella in different environments.

Microbial community analysis through metagenomics provides clues to identify suitable alternative indicators and/or potential suppressors of foodborne pathogens in agricultural water for produce production. Additional searches for Listeria and Salmonella enterica were performed using the high-resolution Resphera Insight protocol; however, additional sample data are required to provide sufficient frequency in the dataset to provide a complete confident positive call. Due to budget and time limitations, only monthly water samples tested for both foodborne pathogens were selected for metagenomic analysis. Further 16s amplicon sequencing of all weekly samples (392) and computational analysis are needed to achieve a final definite conclusion. In addition, metagenomic analyses to identify eukaryotes and metabolites in irrigation water samples are underway to investigate their relationship with foodborne pathogens and to evaluate their

potential as suitable predictors. Further data analysis will be performed by principal component analysis, partial least square, stepwise and canonical discriminant analyses to identify variables or a certain group (pattern) of variables that contributed most to the classification (pathogen presence/absence or different levels of Salmonella and *L. monocytogenes* populations). Additional results will be reported at the CPS Symposium. Results derived from this study provide information for local farmers and other stakeholders to recognize the contamination risks of agricultural production with irrigation in the major agricultural area of Virginia. The prevalence, population and diversity of Salmonella strains in major produce production regions, like California, Florida, Georgia etc., need to be compared to analyze the variance of foodborne pathogens for future outbreak prediction and mitigation.

Irrigation water was considered to be one of the main contamination sources of Salmonella in the fields. Suitable decontamination methods for large irrigation water system to control foodborne pathogens became an urgent request for vegetable and fruit farmers. The instant efficacy of hydrogen peroxide and peracetic acid (Sanidate 5.0 and 12.0) at low application levels on the disinfection of foodborne pathogens in irrigation water was relatively lower compared with sodium hypochlorite (XY-12) and chlorine dioxide (CDG300). For 1-min contact time, the population of tested foodborne pathogens treated with hydrogen peroxide and peracetic acid was significantly higher than water samples treated with sodium hypochlorite and chlorine dioxide. However, the residual concentration of the active ingredient of PAA was significantly higher than that of sodium hypochlorite and chlorine dioxide after 30-min contact time, which could prevent subsequent contamination. Further studies can be performed by inoculating additional foodborne pathogens into treated water samples after 30-min contact time to evaluate the prevention efficacy. So for instant treatment, sodium hypochlorite and chlorine dioxide products would be recommended. However, constant detection of active ingredients and refill of these products would be necessary to maintain the disinfection efficacy in agricultural water.

In conclusion, considering the low population densities of foodborne pathogens in the irrigation water of this region as detected in objective 1 (less than 2 log MPN/L), all tested sanitizers would be qualified for irrigation water decontamination. Further studies would be necessary to investigate the effects of various disinfectants and the application in large irrigation systems in specialty crop vegetable and fruit farms for food safety management.

The low correlation coefficient between fecal indicators, including generic *E. coli*, and the foodborne pathogens in irrigation water suggests that further efforts are needed to identify more suitable indicator microorganisms or other biological markers. In addition, the prevalence and population differences of foodborne pathogens (Salmonella spp. and *L. monocytogenes* in this study) in the same water samples as well as the high variance among different farms (locations) make it a challenge to use just one universal indicator or standard to evaluate contamination risks in agricultural water.

Metagenomics analysis, especially conducting computational analysis of sequencing data, is time consuming. Extra time for data analysis should be considered in a project plan when preparing the project proposal.

Additional Information

See attachments for tables and figures.

The following websites provide additional resources on the final reports and symposium proceedings:
Center for Produce Safety: http://www.centerforproducesafety.org/resources.php

Produce Marketing Association: http://pma.com
Western Growers Association: http://www.wga.com/

Meeting abstracts (published and presented, or submitted for presentation in 2016):

1. di Stefano, J., E. Brown, M. Duong, L. Yang, R. Boyer, G. Gu, S. Rideout. 2016. Antimicrobial resistance of *Salmonella enterica* environmental isolates from the Eastern Shore of Virginia. International Association of Food Protection (IAFP) annual meeting abstracts (submitted).
2. Gu, G., A. Ottesen, J. Zheng, D. Oryang, R. Boyer, L. Strawn, and S. L. Rideout. 2016. Diversity and dynamics of *Salmonella enterica* spp. in irrigation water and poultry litter amended fields on the eastern shore of Virginia. IAFP annual meeting abstracts (submitted).
3. Gu, G., J. Zheng, M. Reiter, L. Strawn, and S. L. Rideout. 2015. Prevalence and survival of *Salmonella enterica* spp. in irrigation water, poultry litter and amended soils on the Eastern Shore of Virginia. IAFP annual meeting abstracts 104: T7-12.
4. Allard, S., G. Gu, E. Reed, S. Rideout, J. R. White, S. Micallef, A. Ottesen and S. Gorham. 2015. Bacteria associated with tomato microbiomes: Ripe vs. unripe. American Society of Microbiology general meeting abstracts 104: P1-187.

Presentations:

1. Strawn, L.K., G. Gu, and S. L. Rideout. Research Efforts on the Eastern Shore of Virginia involving *Salmonella*. Delmarva Food Safety Task Force. Jan 2016.
2. Strawn, L.K., G. Johnson, D. Martin, K. Kniel, S. Rideout, and C. Walsh. “Best Management Practices for Del-mar-va Growers.” 1st Delmarva Food Safety Task Force Annual Meeting, Melfa, VA. 09 Dec 2015.
3. Strawn, L.K., R. Pfuntner, L. Truitt, G. Gu, S. Rideout. “*Salmonella* Research Targeted for Del-mar-va Growers.” Delaware State Agriculture Week, Harrington, DE. 12 Jan 2016.
3. Strawn, L.K., R. Williams, and S. L. Rideout. “Sanitizer Use Part 1 & 2.” Produce Packinghouse Workshop, Dayton, VA. 12 Nov 2015.
4. Strawn, L.K., and S. L. Rideout. “Good Agricultural Practices: Pre- and Postharvest Water.” Wegmans/VCE sponsored Good Agricultural Practices Training, Spotsylvania, VA. 27 Feb 2015.
5. Gu, G., and S. Rideout. Parameterizing QPRAM with data from *Salmonella enterica* contamination of tomatoes. Food safety project webinar. 26 Oct 2015.
6. Gu, G., and S. Rideout. Tomato, irrigation and fertilization studies for food safety research update. Eastern Shore AREC's Annual Field Day, Painter, VA. 11 Aug 2015.
7. Gu, G., and S. Rideout. Prevalence and survival of *Salmonella enterica* spp. in irrigation water, poultry litter and amended soils on the Eastern Shore of Virginia. 26th Eastern Shore Ag Conference and Trade Show. 11 Feb 2015.

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CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 55	**Project Title:** Contamination of Leafy Green Crops with Foodborne Pathogens: Are Wildlife a Problem?	
Grant Recipient: The Center for Produce Safety	**Grant Agreement No.:** SCB14055	**Date Submitted:** December 2016
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Project Summary

Major foodborne pathogens cause approximately 9.4 million illnesses, 56,000 hospitalizations and 1,400 deaths each year in the U.S. (Scallan et al. 2011). As such, foodborne pathogens have serious economic consequences for public health as well as food producers who face product recalls when foodborne pathogen outbreaks occur from their products. Based on 4,589 foodborne disease outbreaks in humans caused by major pathogens, Painter et al. (2013) estimated that 46% and 22% of the 9.4 million illnesses were caused by consumption of produce in general and leafy vegetables, such as lettuce and spinach, respectively; more illnesses were attributed to leafy vegetables than any other commodity. Most (89.8%) of foodborne illness attributed to leafy greens are caused by five pathogens (data analyzed from Painter et al. 2013), and three of these—norovirus (59.3%), *Salmonella enterica* (14.1%), and Shiga toxin–producing *Escherichia coli* (STEC; 5.7%)—have either a documented or hypothesized zoonotic component that can involve transmission from wildlife to agricultural crops and people. Of particular concern is that both nororviruses and bacterial pathogens can be internalized by lettuce and spinach, either through the roots, through leaf stomata, or through structural damage to the plant (Saldaña et al. 2011, DiCaprio et al. 2012). This internal contamination cannot be removed during processing and allows foodborne pathogens to enter the human food chain.

Wildlife have recently become a concern for spread of foodborne pathogens to vegetable produce fields, especially in leafy green crops (Langholz and Jay-Russell 2013). In general, the mechanism of contamination of leafy greens from wildlife is as follows: 1) wildlife carrying foodborne pathogens visit produce fields, 2) shed pathogens in their feces in the field, and 3) contaminate surfaces of produce with pathogens, which can potentially become internalized in the plants (Saldaña et al. 2011, DiCaprio et al. 2012, Langholz and Jay-Russell 2013). Outbreaks of human illness have been attributed to wildlife contaminating produce fields with foodborne pathogens (Erickson and Doyle 2012), but few studies have adequately documented the magnitude of the contamination of produce fields, especially in terms of wild ungulates, birds, and medium-sized mammals such as raccoons and coyotes.

Of the three pathogens listed above, all but human noroviruses have been documented in wildlife (Jay et al. 2007, Atwill 2008, Gardner et al. 2011, Kilonza et al. 2013). Noroviruses cause primarily gastroenteritis in humans, are highly contagious, stable in the environment, and have a low infectious dose (Koopmans and Duizer 2004, Scipioni et al. 2008). Although human noroviruses (GII strains) have traditionally been considered strictly human pathogens, there is recent evidence that these strains can also be carried by domestic animals (Mattison et al. 2007, Summa et al. 2012), with the potential for carriage by wildlife. However, to the research team's knowledge, wildlife have not been extensively examined for presence of human noroviruses and this project offered a unique opportunity to explore the potential role of wildlife in norovirus maintenance and transmission. Of particular interest is the potential for canids, such as coyotes and red foxes, to transmit GII strains of noroviruses (Summa et al. 2012). *Salmonella enterica* is considered one of

the most important human foodborne bacteria in industrialized countries, and wildlife have been pinpointed as a potential source of *Salmonella* contamination in leafy green crops (Hilbert et al. 2012). In a survey of samples taken from agricultural locations, Gorski et al. (2011) reported that wildlife samples had the highest *Salmonella* presence among sample types, including samples from soil, water, and cattle feces. Rodents trapped in agricultural fields were also found to be reservoirs for *Salmonella* and could play a role in its dissemination (Kilonzo et al. 2013). The role of wildlife in contamination of leafy green crops with STEC is also a concern. Multiple studies have suggested that both wild mammals and wild birds are capable of acting as reservoirs for *E. coli*; birds, in particular, may be able to move *E. coli* across long distances to, from, and among agricultural facilities (Van Donkersgoed et al. 2001, Havelaar et al. 2010, Carlson et al. 2011, Franklin et al. 2013). Wild ungulates are of particular concern with STEC contamination because of their association with a number of outbreaks in humans through contamination of crops and the environment (Cody et al. 1999, ProMED 2008, 2011). STEC has been found in relatively high incidences in elk and deer feces in Colorado (Franklin et al. 2013) and recently in antelope (Franklin, unpublished data).

In this study, the project team addressed the central question: Are wildlife a significant risk in contaminating leafy green produce? Although there is circumstantial evidence suggesting that wildlife may contaminate produce, the magnitude of the problem is poorly understood. For example, contamination of strawberries with *E. coli* O157:H7 that caused an outbreak in Oregon was attributed to deer, but transmission from deer to the field was not documented (Laidler et al. 2013). The team conducted this study on lettuce and spinach crop fields in the San Luis Valley of Colorado, where wildlife, such as mule deer, pronghorn, rabbits, black bear, and coyotes, have been opportunistically observed using leafy green fields.

Wildlife are increasingly being characterized as sources of foodborne pathogens in leafy green crops, therefore creating the timeliness and importance of this project. Current industry regulations require producers to excise portions of their crops around wildlife feces as a prophylaxis for potential contamination, which can often incur economic hardships on producers. Thus, understanding how often wildlife visit fields, whether they deposit feces in fields, and the degree to which their feces are contaminated with foodborne pathogens is critical for balancing agricultural production with wildlife management. This study attempted to clarify whether wildlife are a problem in leafy green production in the San Luis Valley, Colorado, by examining visitation rates by wildlife to lettuce and spinach fields and the degree to which wildlife feces are contaminated with foodborne pathogens.

This project did not build on a previously funded Specialty Crop Block Grant Program project.

Project Approach

The team conducted the research in the San Luis Valley in Saguache county, Colorado (Figure 1A – see Attachment 1). This area is the primary producer of leafy greens (lettuce and spinach) in the state, which is also the third largest U.S. producer of head lettuce (www.colorado.gov/cs/satellite/ag_markets/cbon/1251624936359). In addition, the San Luis Valley is a mountain-basin landscape, which is a fairly typical agricultural landscape in the western U.S. and shares similar characteristics to other leafy green production areas such as the Salinas Valley, California (Figure 1B – see Attachment 1). These shared characteristics include surrounding wildlife habitat in the form of public lands, a well-developed riparian system, and nearby wildlife refuges. Thus, the San Luis Valley may serve as a model system with attributes that are shared with other leafy green production areas. Leafy greens in the San Luis Valley are grown in circular, center-pivot irrigation fields (~790 m in diameter). Subsurface

groundwater is used to irrigate these fields; to date the water has been free of foodborne pathogens, which removes the confounding factor of indirect contamination of irrigation water by wildlife. In the San Luis Valley, planting dates for lettuce are 1 April – 10 July, and harvest dates extend from 15 June – 15 October, with the peak between 20 June and 20 September (NASS 2013).

The team sampled 10 crop fields (eight planted in lettuce and two planted in spinach) from June through September 2015. Fields were placed into two strata: fields in proximity to wildlife habitat, and fields not in proximity to wildlife habitat (Figure 2). Because of the large area covered by individual lettuce fields, each sampling unit was subdivided into 4 quadrants (Figure 3), which represented subsampling units. To determine the magnitude of wildlife contamination of leafy green fields, the team estimated four general metrics: 1. visitation rates by wildlife to produce fields, 2. density of wildlife visiting produce fields, 3. extent of fecal contamination of produce fields by different species of wildlife, and 4. the extent of contamination of leafy greens in proximity to feces shed by wildlife.

Field Work – Wildlife Visitation

Methodology: The team used estimation methods for wildlife visitation rates that account for imperfect detectability in sampling wildlife because wildlife species are never detected with perfect accuracy. Two primary approaches were used: distance sampling and occupancy estimation. Distance sampling is used to estimate the density of wildlife populations based on line transects where the data collected are distances to objects being surveyed from lines to estimate the object density. Occupancy estimation models use information from repeated observations to estimate detectability as well as the parameter of interest, such as presence/absence of wildlife in crops fields. Occupancy models can also incorporate numbers of observed animals to estimate abundance or density. These methods are used extensively in studies on wildlife ecology but rarely have been applied in studies at the wildlife-agricultural interface. Distance sampling transects were conducted along the edge of each quadrant. Transects were conducted by a single observer between 5:30 and 10:00 a.m., when birds were most active. For each survey, a single observer walked along the edge of the quadrant being sampled, for an average of 31 minutes (range:19 to 55 min) and recorded the distance, using a laser range finder, and the angular direction to each bird seen as well as species and number. Only detections within the field portion of the quadrant were included. For occupancy estimation, infra-red cameras were equally spaced along the edge of each sampled quadrant to capture images of wildlife entering the fields (Figure 3). Cameras were oriented such that edges of the field were monitored. Cameras were set to take a still image every 5 min and whenever motion was detected by the camera in order to maximize detection of the range of species visiting fields. Cameras were placed in all 10 fields to run simultaneously. Dependent on the planting schedule, cameras were moved to a new quadrant within each field every 4 weeks.

Distance Sampling Results: The team conducted 37 distance sampling transects on the 10 crop fields, and each field was sampled three–four times within June, July and August. A total of 246 birds from 13 species were detected, with the majority (73.6%) of detections being Horned Larks (Table 1). Horned Larks were also detected on the majority of transects (Table 1). Using distance sampling, densities were estimated based on all bird species combined and Horned Larks only. Under this analysis, the best supported detection model was a uniform detection function with a cosine series expansion for all species and a polynomial expansion for Horned Larks (Figure 4) when post-stratified by proximity to wildlife habitat. In both cases, models with a global detection function across stratum performed better than models with stratum-specific detection functions. Number of birds using crop field quadrants was calculated based on the density estimates, with the inference that these represented numbers using crop field quadrants in a 30-minute period during the morning

hours. All species and Horned Larks showed a similar pattern of higher abundance in crop fields further away from wildlife habitat (within the agricultural matrix) than those near wildlife habitat (Figure 5). Based on overall estimates (Figure 5), 5.4 birds/30 min (95% confidence interval [CI] = 3.2, 8.9) used crop field quadrants (11.8 ha) in the morning hours in fields near wildlife habitat, while 9.5 birds/30 min (95% CI = 6.8, 13.3) used crop field quadrants in the morning hours in fields further from wildlife habitat. A similar trend was observed for Horned Larks (4.2 birds/30 min [95% CI = 2.2, 8.1] near wildlife habitat; 8.9 birds/30 min [95% CI = 5.6, 14.0] further from wildlife habitat).

Occupancy Estimation Results: The team monitored wildlife incursion into agricultural fields for 16 weeks using 60 motion-activated cameras (6 cameras per field) that allowed for continuous monitoring of field edges and resulted in 1.7 million still images. To date, the team has analyzed nearly 400,000 images and has identified 4,222 images with animal activity, a detection rate of 1.2% of all images. Wildlife detected included coyotes, jackrabbits, rodents (Figure 6, Figure 7) and others (Table 2). Images were captured using both the motion-activated setting and the time-lapse setting, demonstrating the utility of using both methods when a range of species are being detected. This robust experimental design represents a novel methodology for documenting wildlife in agricultural areas, and the resulting images offer the most detailed camera dataset available on wildlife incursion into leafy green crop fields. Additional occupancy analyses will be run when the entire image dataset has been identified. These additional analyses include a comparison of animal incursion by taxonomic group in fields that are further away from contiguous wildlife habitat compared to those near wildlife habitat. In addition, the team will also compare wildlife presence/absence, as well as incursion rates, in fields with wildlife mitigation measures to fields without wildlife mitigation measures. These results will help inform producers what mitigation measures are useful and the most efficient use of these approaches in time and space.

Field and Laboratory Work – Sampling for Bacterial Contamination and Analysis
Methodology: The team collected fecal samples from the periphery of the 10 sampled fields using systematic searches. When animal tracks were encountered along the periphery of sampled quadrants, the team followed these into the field and collected any deposited feces. For feces collected in the crop field, the nearest crop plant was also collected for laboratory analysis. When possible, fecal samples were identified to species or species group and then collected for laboratory analysis. All fecal samples were placed in sterile bags and shipped overnight to the University of Wyoming for laboratory analysis. To increase sample size, the team also captured medium and small mammals and birds along the edge of crop fields between 23–30 September 2015. Rodents and lagomorphs were trapped using 40 Sherman and 20 medium and 10 large Tomahawk box traps placed along the periphery of quadrants in two fields planted with spinach. Sherman traps were placed every 15.5 meters, medium Tomahawk traps every 31.1 meters, and large Tomahawk traps every 46.6 meters. Traps were baited with oats and apples; large Tomahawk traps were also spayed with apple juice as an additional attractant for lagomorphs. Feces were collected from within traps or using swabs or fecal loops from captured individuals. Mammals were marked with ear tags to prevent multiple sampling from individuals and then released. Birds were captured using mist nets and baited box traps and held briefly in small cages ($\leq$15 min) to allow for defecation. If birds did not defecate while in the cages, they were swabbed cloacally to collect a fecal sample. Birds were banded with appropriately sized bands issued by the U.S. Geological Survey Bird Banding Laboratory. Fecal samples were placed in sterile bags and shipped overnight for laboratory analysis. In addition to fecal samples, spinach and lettuce samples were also collected from sampled fields and analyzed for bacterial contaminants. Fecal and crop samples collected in the field were analyzed for the presence of *Salmonella enterica,* STEC, and noroviruses. In this study, many of the fecal

samples collected were less than 0.1 g, which necessitated adaptation of the microbiological methods to accommodate these small sample volumes.

Bacterial Contamination Results: The team collected 361 fecal samples from wildlife: 174 from mammals, 184 from birds, and three from unidentified species from all 10 fields (Table 3). In addition, 168 spinach and nine lettuce samples were collected from six of the 10 fields and then analyzed at the University of Wyoming; 800 additional lettuce samples were collected and analyzed by Southern Colorado Farms. The majority of samples collected from mammals were from lagomorphs (rabbits) and rodents, predominantly Ord's Kangaroo Rats (Table 3). The majority of avian samples were collected from Passerines, predominantly from Horned Larks and unidentified passerine species (Table 3). There was no evidence for any *Salmonella* contamination in wildlife feces or crop samples; none of the samples yielded even presumptive positives. Although 12 of the wildlife fecal samples were positive for *E. coli*, none of the samples were positive for STEC. Samples positive for *E. coli* and samples with presumptive positive STEC were from both mammalian and avian species (Table 3). Specifically, 12 of the wildlife fecal samples yielded presumptive STEC isolates; however, polymerase chain reaction (PCR) analyses revealed that these isolates did not encode for Shiga-toxin genes. Thus, no STEC was identified. None of the 977 plant samples collected from crop fields were positive for either *Salmonella* or STEC. In total, 110 fecal samples were analyzed for the presence of norovirus GI and GII; 20 of these samples were processed using the viral RNA extraction method described by Pang et al (2005). However, when these samples were spiked with synthetic norovirus RNA it was clear that matrix associated real time reverse-transcriptase PCR (RT-PCR) inhibitors adversely impacted detection. Thus, the RNA extraction step was optimized to reduce RT-PCR inhibitors. The remaining 90 RNA samples were prepared using this optimized extraction method. Samples analyzed for noroviruses were collected from passerines (50.0%), lagomorphs (36.4%), rodents (8.2%), canids (1.8%), unknown species (1.8%), and crop plants (1.8%). Noroviruses were not detected within any of these samples.

In terms of overall accomplishments, the team found little evidence that wildlife are a problem in contaminating leafy green produce fields with foodborne pathogens in the San Luis Valley, Colorado. Although both spinach and lettuce crop fields were visited by a variety of mammalian and avian wildlife, the team found no evidence that feces deposited by these species were contaminated with the three pathogens tested. Thus, the magnitude of contamination of leafy green produce fields by these three critical foodborne pathogens causing human illness was apparently nonexistent. The three following factors could explain this lack of evidence for contamination:

(1) The team did not collect sufficient samples to detect the pathogens of interest. However, the prevalence of these pathogens in wildlife would need to be very low to avoid detection. In addition, the number of samples collected was a function of fecal deposition in fields by wildlife, which suggests fecal deposition was relatively low.

(2) The environmental and agricultural risk factors associated with other leafy green production areas were minimal in the San Luis Valley. Leafy green crops on Southern Colorado Farms are irrigated solely with well water, minimizing the potential for contamination from water. In addition, the climate conditions are different than the Salinas Valley, California, where outbreaks of STEC in leafy greens have occurred. As a high elevation mountain valley, the San Luis Valley is cooler during the growing season and receives substantially more solar radiation than the Salinas Valley (Figure 8). These may present gross climatic differences affecting bacterial persistence in the environment. The San Luis Valley also has half the cattle present and no presence

of feral pigs when compared with the Salinas Valley (Table 4). The Central Coast region of California has almost half the feral pig population in California (Waithman et al. 1999) whereas feral pigs have not been observed in the San Luis Valley. Both cattle and feral pigs were implicated in the 2006 outbreak of *E. coli* O157 in spinach that affected 26 states and Canada (Jay et al. 2007).

(3) The mitigation measures used by Southern Colorado Farms are sufficient to control problem wildlife, such as wild ungulates, that have a higher potential to contaminate crops with the pathogens of concern. Currently, Southern Colorado Farms uses wide buffer strips of barren soil, rodent control devices on the periphery of their fields, and electrical fences on the periphery of specific fields to exclude rodents and wild ungulates, such as antelope, from their crops.

The combination of factors two and three above may contribute most to wildlife being a minimal problem in contaminating leafy green crops in the San Luis Valley. However, this study was only based on a single year of sampling. If pathogen contamination by wildlife is episodic based on variation in environmental factors, then this study did not capture that variation. Although the team found no contamination with the pathogens investigated, wildlife did visit the crop fields. Some avian species, such as Horned Larks, had higher numbers visiting crop fields that were further from blocks of wildlife habitat than fields bordering those areas. This result is consistent with the ecology of some of these species, most of which are considered synanthropic. For example, Horned Larks are associated generally with areas of bare ground and avoid areas of tall vegetation, thus they are often associated with agricultural landscapes. Continued analysis of the images from the camera traps will further elucidate these relationships with other species.

This project focused on lettuce and spinach crops therefore the overall scope of the project benefitted only specialty crops.

The project partners were the Center for Produce Safety (CPS) and the U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services (USDA-APHIS-WS). CPS managed the project and USDA-APHIS-WS performed the research studies in collaboration with researchers at the University of Wyoming (UW). The Principal Investigator (PI) and USDA Co-PIs designed and conducted the field aspects of the project and were also responsible for the overall implementation of the study. The UW Co-PI conducted the laboratory analyses of samples collected in the field for the select foodborne pathogens. The PI and Co-PIs all participated in data summarization and analysis. The industry collaborator allowed access to their agricultural farm operation and provided valuable advice and logistic support.

Goals and Outcomes Achieved

In general, the activities of the study were completed as planned to determine whether wildlife represent a significant risk in contaminating leafy green produce. The team quantified wildlife species in the San Luis Valley leafy green production area, visitation rates, role of adjacent wildlife habitat, and collected samples to analyze contamination rates by three critical foodborne pathogens. In addition, the team met frequently with the industry collaborator at Southern Colorado Farms. The scope and preliminary analyses of this study were shared through various presentations in 2015 (see Additional Information section). Of particular note is that two of the presentations were to high-level administrators in the U.S. Department of Agriculture. Also, the PI and USDA Co-PI attended the annual meetings of the Colorado Fruit and Vegetable Growers Association in 2015 and 2016 and interacted with participants concerning this project. (The team did not receive an invitation to present results at the Governor's Forum on Colorado Agriculture as was initially indicated as a target.)

Once data analyses are complete, results will be conveyed to producers through the Colorado Fruit and Vegetable Growers Association and University extension services. Publications are being prepared for submission to peer-reviewed scientific journals.

Monitoring of project activity performance measures occurred as follows:
(1) Number of downloads of scientific articles posted on University of Nebraska Digital Commons (http://digitalcommons.unl.edu/) and the National Wildlife Research Center website: there are no downloads yet because the scientific manuscripts are still in preparation and have not been submitted for publication.
(2) Number of attendees at presentations: there were a total of 35 attendees at the three project-related presentations that the Principal Investigator gave in 2015 (one to the Colorado Ag Innovators and two to USDA officials – see Additional Information section) in addition to the 315 and 245 conferences attendees at the 2015 and 2016 CPS Research Symposium presentations.
(3) Number of outreach days spent with producers and industry representatives: 20 days, and this is an ongoing activity.

Outcome measures are not long term. However, the team plans to continue this line of research in different agricultural settings (e.g., mixed livestock-crop systems) to gain further insights into the role of wildlife in contaminating leafy green crops. No evidence of wildlife posing a substantial risk of pathogen introduction into leafy green crops was found during this study; however, it is possible that this risk is increased in areas where nearby livestock act as a pathogen source that wildlife then transfer via their movements into crop fields. By continuing this line of research in mixed livestock-crop systems, it can be determined if this risk primarily occurs in areas near concentrated livestock operations. If that is the case, mitigation measures could be targeted to these specific areas.

Almost all of the study accomplishments met the goals established for the study. However, the research team were unable to test certain hypotheses because those hypotheses were predicated on finding pathogens in wildlife. Wildlife visited leafy green crop fields to varying degrees in the San Luis Valley, Colorado, but the team found no evidence of *Salmonella enterica*, STEC or noroviruses in the feces of wildlife in and around those fields. This may partly be due to sample size, minimal environmental and agricultural risk factors, and existing mitigation measures.

In this study the team documented incursions of both avian and mammalian wildlife into lettuce and spinach fields in the San Luis Valley, Colorado. Key baseline data that has been gathered for the project include the density of wildlife visiting produce fields, the visitation rates by wildlife, the extent of fecal contamination of produce fields by different species of wildlife, and the extent of contamination of leafy greens in proximity to feces shed by wildlife. However, none of the three targeted pathogens, *Salmonella enterica*, STEC or noroviruses, were detected in wildlife feces deposited in and around crop fields. Also, none of these pathogens were detected in the crop samples. The overall results suggest that there may be substantial differences between growing regions in terms of the potential for wildlife to contaminate crop fields. The findings also suggest that, in this study system, low levels of wildlife incursion do not necessarily directly translate to crop contamination. Wildlife incursion leading to contamination of leafy green crops in the San Luis Valley of Colorado appears to be a low risk, albeit high consequence, event.

The team examined wildlife incursion into leafy green crops in the San Luis Valley of Colorado to elucidate where these events occur, the wildlife species involved, and how many individuals were seen during incursion

events. Data looked at incursion and pathogen contamination in relation to field distance to wildlife habitat and in relation to targeted mitigation efforts undertaken by the producer. Occupancy methods using camera traps and distance sampling detected occasional incursion by a wide range of species. Horned larks (*Eremophila alpestris*) were the most common avian species encountered, and they were more abundant in crop fields further away from wildlife habitat than those near wildlife habitat. Camera data resulted in 1.7 million still images and these images documented rodents, coyotes, and lagomorphs moving through fields. Additional occupancy analyses will be run when the entire image dataset has been identified. The team also collected 361 wildlife fecal samples and 177 spinach and lettuce samples. Twelve of the wildlife fecal samples were presumptively positive for Shiga toxin–producing *E. coli* (STEC) but negative on subsequent confirmatory tests. None of the samples were positive for *Salmonella enterica*, or noroviruses. The findings suggest that, in this study system, low levels of wildlife incursion do not necessarily directly translate to crop contamination. Current restrictions on the presence of wildlife feces in crop fields require excision of a substantial portion of crop, which causes economic hardships on producers. Rather than requiring omnibus restrictions and regulations across all growing regions to limit wildlife incursion into crops, the team suggests developing regional restrictions based on differences in environmental conditions, agricultural practices, and risk of contamination by wildlife.

Beneficiaries

Direct beneficiaries of this project include California leafy greens producers. The Colorado Fruit and Vegetable Growers Association also benefited because their members can use this information to implement similar mitigation measures in their own production fields. Also, current restrictions on the presence of wildlife feces in crop fields require excision of a substantial portion of crop, which causes economic hardships on producers. In addition, recent complimentary research suggests that some practices put in place to limit wildlife incursion, such as removal of surrounding vegetation, may actually increase contamination risk.

This project will benefit the 90 plus member companies of the California Leafy Green Products Marketing Agreement (LGMA) that work with hundreds of farmers in California to produce and handle lettuce, spinach and other leafy greens products. According to the California Agricultural Statistics Review 2014–2015, the lettuce production alone is valued at $2 billion annually. Locally, at least two organizations (Southern Colorado Farms and the Colorado Fruit and Vegetable Growers Association [CFVGA]) will benefit from this study by having a better understanding of the risks of crop contamination from wildlife. The CFVGA is comprised of more than 150 grower members throughout the state, as well as representatives of allied industries. At a larger scale, the project findings suggest that, in this study system, low levels of wildlife incursion do not necessarily directly translate to crop contamination and rather than requiring omnibus restrictions and regulations across all growing regions to limit wildlife incursion into crops, the team suggests developing regional restrictions based on differences in environmental conditions, agricultural practices, and risk of contamination by wildlife. This idea has national implications.

Lessons Learned

The primary lesson learned was that methods used to understand wildlife ecology are adaptable to agricultural settings and are useful when trying to understand the effects of wildlife on agricultural systems.

In this study the team applied a number of methods used in wildlife ecology, such as distance sampling and camera traps, where there was considerable uncertainty as to whether they would be effective in an

agricultural setting. Novel modifications to both methods allowed them to work well for estimating wildlife incursions into crop fields.

The team did not anticipate that all of the samples taken would be negative for the three pathogens examined. This negative information was ultimately useful for making comparisons with regions where pathogens have been routinely found in wildlife.

The team felt that all of the goals and outcomes were achieved in this study and have led to stronger relationships with producers. These relationships will allow future research, beneficial to both producers and researchers, to occur.

Additional Information

See Attachment 1 for Figures 1–8 and Tables 1–4.

The PI from USDA-APHIS-WS presented final research results in June 2016 at the seventh annual CPS Produce Research Symposium in Seattle, WA, to 315 symposium attendees. Interim results were presented previously in a poster session at the 2015 CPS Produce Research Symposium in Atlanta, GA (with approximately 245 attendees). The symposium participants included California regional and national growers/shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provides expert panels to critique the research results after presentation by the researcher, which helps participants evaluate how the results can be used in their respective businesses.

Project results will be disseminated at industry meetings, and streamed through social media sources. Results are also available online as follows:

1. Final reports submitted to CPS are posted on the CPS website: http://www.centerforproducesafety.org/amass/documents/researchproject/377/CPS%20Final%20Report_Franklin_January%202016.pdf
2. CPS works with the scientists to publish results in scientific journals. Publication dates occur after the project is completed. Abstracts and awards can be found on the CPS website.
3. The Board of Directors and members of the Technical Committee of CPS distribute a series of information briefs throughout the year on the website and through presentations, meetings and webinars. An example of this would be the “2015 CPS Symposium Summary: Key Learnings and What They Mean for You” on the CPS website at the following link: http://www.centerforproducesafety.org/amass/documents/document/325/2015%20CPS%20Symposium%20Key%20Learnings%20web.pdf.

The following websites provide additional resources on the final reports and symposium proceedings:

CPS: http://www.centerforproducesafety.org/resources.php
Produce Marketing Association: http://pma.com
Western Growers Association: http://www.wga.com/

Presentations:

A.B. Franklin (PI). 1 Dec 2015. Wildlife-borne Pathogens: Implications for Agricultural and Human Health. Presented to: Colorado Ag Innovators, Fort Collins, CO. [15 attendees]

A.B. Franklin (PI) and S. Bevins (USDA Co-PI 1). 17 July 2015. Effects of Wildlife-Associated Pathogens on Food Security and Safety. USDA Deputy Under Secretary Elvis Cordova, Fort Collins, CO. [10 attendees]
A.B. Franklin (PI). 23 June 2015. Contamination of leafy green crops with foodborne pathogens: Are wildlife a problem? [Poster]. Center for Produce Safety Research Symposium, Atlanta, GA. [245 attendees]
A.B. Franklin (PI) and S. Bevins (USDA Co-PI 1). 22 April 2015. Effects of Wildlife-Associated Pathogens on Food Security and Safety. USDA Deputy Under Secretary Gary Woodward, Fort Collins, CO. [10 attendees]

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CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
56	Rapid Bacterial Testing for On-Farm Sampling	
Grant Recipient: The Center for Produce Safety	**Grant Agreement No.:** SCB14056	**Date Submitted:** December 2017
Recipient Contact: Bonnie Fernandez-Fenaroli	**Telephone:** (530) 554-9761	**Email:** bonnie@centerforproducesafety.org

Project Summary

Recently, the Centers for Disease Control and Prevention have determined that the majority of foodborne illness is attributable to leafy green vegetables. The recent outbreaks associated with fresh fruits and vegetables have resulted in an increased interest in the ability to rapidly and cost-effectively perform on-farm validation. The Center for Produce Safety (CPS) will partner with the University of Massachusetts (UM) to develop a rapid detection dipstick. Diagnostics are being developed for use in non-laboratory settings by utilizing bacteriophages. This project proposes the development of a dipstick for the rapid detection of *Salmonella* species (spp.) in agricultural samples. Following a sample pretreatment, the bacteriophages will be used to infect *Salmonella* spp. in the sample. Within 45 minutes, the increase in bacteriophage can be quantified with a simple lateral flow device. Preliminary results for an *Escherichia coli* (*E. coli*) sensor suggest a very low limit of detection (<10 CFU/mL). If successful, the detection system will empower farmers to perform tests on-farm with rapid results and at low-cost. This ability will then enable more risk-based testing of agricultural waters following heavy rains or high flow.

Currently, there are no pragmatic bacteria detection methods that can be used in settings with low resources such as a farm. As produce-related foodborne illness continues to be a major concern, there is a vital need to provide farmers with tools to validate the safety of the agricultural water (both rinse and irrigation) that comes in direct contact with food. Testing of this water will be required by the Food Safety Modernization Act, yet there remains no suitable detection method to be used on-farm.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

A combination of a genetically engineered bacteriophage amplification assay and a dipstick assay has been designed for the detection of indicator organisms and potential pathogens in agricultural samples. The assay is designed to be low-cost and easy-to-use. Successful deployment of the test will empower farmers to perform risk-based testing, in addition to periodic testing, without incurring significant costs. The following is a summary of these accomplishments.

Objective 1 – Phage screening

Agricultural water sampling: The team worked on agricultural water samples as well as producing models to be used for research. Additionally, the team tested the project's bacteriophage-based method to separate bacteria from agricultural water. That method is a novel bacteriophage-mediated separation, concentration, and detection of *E. coli* O157:H7 using bacteriophages conjugated to magnetic particles. The separation was directly compared to a commercially available immunomagnetic separation kit (Dynal; Oslo, Norway). *E. coli* was inoculated into agricultural water samples collected from irrigation sources in Western Massachusetts. The separation efficiency (% of inoculated bacteria recovered) was estimated by quantitative polymerase

chain reaction (qPCR) of the captured bacteria. The team compared the results to drinking water and found a slight decrease in sensitivity when testing in the irrigation water (Figure 1 – see Attachment).

Characterization of water samples: The physiochemical properties of postharvest agricultural water were examined. Benchtop trials were then performed to determine if organic load generated using paddle mixers or blenders better replicated organic loads found in the field evaluations. Samples were pulled from 10 farms engaged in postharvest produce washing and cooling processes. These samples were analyzed for physiochemical properties, including turbidity, chemical oxygen demand (COD), oxidation reduction potential (ORP), and pH. The studies suggest that although outliers are not uncommon, the samples were relatively similar (Figure 2 – see Attachment).

Bacteriophage selection: Bacteriophage S16 was selected (in collaboration with Sample 6 Technologies; Woburn, Massachusetts) due to its specificity to *Salmonella* spp. Additionally, the *E. coli*-specific phage T7, and the *Salmonella*-specific phage P22 were used for optimization and modeling. The approved method used engineered bacteriophage and did not require antibodies. Phages were genetically engineered to express a reporter enzyme during infection, thus allowing an additional assessment of the bacteria's viability. The project's alternative scheme required the optimization of affinity tags, which were on the reporter enzyme. This was performed by testing two affinity tags and two locations on the enzyme. The better performing tag was used in the remaining experiments.

Objective 2.1 – Separation methods
Filtration: The purpose of this objective was to find a concentrate and separate bacteria from large samples. The team looked at several strategies to accomplish this in "dirty" samples. Traditional methods of separating bacteria from food routinely involve stomaching, blending, and shaking. However, these methods may not be efficient at removing all the bacteria from complex matrices. The team investigated the benefits of using enzyme digestion followed by immunomagnetic separation to isolate *Salmonella* from spinach and lettuce. Enzymatic digestion using pectinase and cellulase was able to break down the structure of the leafy green vegetables, resulting in the detachment and release of *Salmonella* from the leaves. Immunomagnetic separation of *Salmonella* from the liquefied sample allowed an additional separation step to achieve a more pure sample without leaf debris, which may benefit additional downstream applications. The team investigated the optimal combination of pectinase and cellulase for the digestion of spinach and lettuce to improve sample detection yields. The concentrations of enzymes used to digest the leaves were confirmed to have no significant effect on the viability of the inoculated *Salmonella*. Recovery of the *Salmonella* from the produce after enzyme digestion of the leaves was significantly higher ($P < 0.05$) than traditional sample preparation methods to separate bacteria (stomaching and manual shaking). The results demonstrated the potential for enzyme digestion prior to separation to improve the efficiency of bacteria separation and increase the likelihood of detecting pathogens in the final detection assay.

Magnetic particle separation: Magnetic separation of the bacteria using phages for attachment was developed for both magnetic nanoparticles as well as micro-scale particles. The particles were compared to the gold standard, namely immunomagnetic separation. It was clear that outside of biological conditions, the phages had significantly higher capture efficiency (Figure 3 – see Attachment). This result is important because most food and food-related matrices are typically outside of biological conditions with regard to pH, temperature and salinity. Therefore, the team's phage-based magnetic particles will provide a greater assurance of the capture of indicator and pathogenic bacteria.

Continued optimization: The team has optimized and is continuing to optimize the separation methods to improve assay performance by looking at various sizes of magnetic particles as well as conjugation methods used to attach the phage to the particle. Also, the team is continuously optimizing enzyme cocktails as new ones are available. This activity has led to additional digestion products for higher risk foods, such as sprouts, which could benefit from improved testing. Therefore, the success of the current project has led to the investigation of additional applications that will improve the safety of produce.

Objective 2.2 – Dipstick
Membrane selection – The accepted scheme for detection using genetically engineered bacteriophages made use of reporter enzymes expressed with an affinity tag that binds onto cellulose pads. The team performed optimization assays that quantify the enzymatic color change directly on the dipstick pad (Figure 4 – see Attachment). Plastic sheets and cellulose pads were selected from a large sampling based on performance, cost and ease of manufacturing.

Blocking optimization – The signal on the cellulose pad is a result of a reaction between the alkaline phosphatase (produced during the phage infection with the host bacteria) and the substrate, which forms a blue precipitate following the reaction. To maximize the signal on the pad, the team needed to reduce the amount of precipitate that adsorbs to the plastic backing. Several blocking agents were tested, including polyvinyl acetate (PVA), casein, Triton X100, and a combination of these (Figure 5 – see Attachment). PVA (1%) in combination of casein (1%) was shown to greatly blocked substrate binding on the plastic. The images also were quantified with ImageJ (computer application) to better determine an optimal blocking solution.

Dipstick optimization (using T7): The dipsticks were optimized with respect to temperature and time required for binding of the reporter enzyme. Additionally, the quantification method was optimized to allow for a direct reading of the results without the need for user interpretation.

Dipstick performance evaluation: The enzymatic reaction on the dipstick was optimized and characterized. With the aid of the Talbert Research Group (Iowa State University) the enzyme dynamics immobilized on the cellulose pads via the affinity tag were characterized. The team found that while the activity of the enzyme decreased slightly, the affinity tag allowed the localization of the signal on the cellulose pad and therefore improved performance.

Objective 3 – Validation
While the team optimized the individual steps of the proposed assay, new materials (enzymes, phages, substrates) are continuously becoming available. Therefore, this ongoing process results in an ongoing improvement in performance. It was not possible to inoculate low concentrations of bacteria onto the spinach or lettuce leaves to determine a limit of detection for the overall assay. This is because a significant proportion of the bacteria are killed during the drying step following spotting onto the leaves. Unfortunately, because the bacteria adhere to the leaves in a multilayer, it was not possible to determine the number of “viable” bacteria at the start of testing. Rather, the team is currently performing a direct comparison to current methods in order to determine the improvements over the current state of the art.

The Principal Investigator (PI) presented interim research results at the 2016 CPS Research Symposium in Seattle, Washington.

All grants funds were used to solely enhance the competitiveness of specialty crops.

The project partners are CPS and the UM. CPS managed the project and the team at UM performed the research studies. In addition, the team used the input from collaborators (extension associates and farmers) in order to design a more user-friendly and cost-appropriate detection assay.

Goals and Outcomes Achieved

A combination of a genetically engineered bacteriophage amplification assay and a dipstick assay were designed for the detection of indicator organisms and potential pathogens in agricultural samples. The separation of *Salmonella* spp. and *E. coli* O157:H7 from agricultural samples was targeted and capture efficiency was determined. Low numbers of bacteria (10 CFU/mL) could be detected by using the engineered phages. The team made significant improvements in methods to rapidly and cost-effectively detect pathogens and indicator organisms from leafy green produce (spinach and lettuce). Specifically, these improvements include: 1) a more efficient method for removing bacteria from the surface of leafy greens, 2) a method for separating bacteria on leafy green vegetables into a liquid sample, 3) a method for concentrating and washing bacteria from liquid samples, and 4) a low-cost method to rapidly detect bacteria from concentrated liquid samples. These steps represent a complete sample-to-results strategy and can be interchanged or merged with additional strategies, allowing a better path to commercialization and implementation.

Although significant improvements were made in bacteria detection from produce samples, the team plans to continue improvement strategies. In addition to the five peer-reviewed manuscripts already published from the project results, several more papers will be prepared and submitted (see list of publications in Additional Information).

While the project planned on performing a validation study from sample to results using personnel not affiliated with the project, the team experienced some delays due to timing and relocation of the PI's research group to Cornell University (from UM). Also, because the bacteria adhered to the spinach or lettuce leaves in a multilayer, it is unfortunately not possible to determine the number of "viable" bacteria at the start of testing. The team is instead currently performing a direct comparison to current methods to determine the improvements over the current state of the art.

The team has shown that the use of enzyme digestion as part of the sample preparation of leafy greens allows almost double the recovery of bacteria into a liquid sample. Additionally, the team showed that the use of magnetic phages allows a significant improvement in the capture efficiency when concentrating bacteria in liquid samples, as compared to immunomagnetic separation. The phages were especially advantageous in non-biological conditions with regard to temperature, pH, and salinity. This result is important because most food and food-related matrices are typically outside of biological conditions with regard to pH, temperature and salinity. Therefore, the method's phage-based magnetic particles will provide a greater assurance of the capture of indicator and pathogenic bacteria.

The team also demonstrated the ability to detect low numbers of bacteria using engineered phages. With this method, the team was able to detect 10 CFU/mL, which was the lowest dilution due to the complexity and reliability of preparing samples at lower concentrations. Lastly, the team has shown that genes for engineered reporter enzymes that bind to filter paper can be incorporated into the genome of bacteriophages, allowing

concentration of signals and therefore a lowering of detection limits. These improvements can be used together or separately to improve alternative strategies, thereby allowing a more impactful output.

There are several major successes in this project. A significant success is the improvement of yield when separating bacteria from leafy greens. In this step the separation efficiency was doubled, as compared with current separation methods, thereby resulting in a liquid sample that can be utilized in many detection strategies. This method is relatively inexpensive and can be relatively easily implemented in parallel with current methods, allowing for a reduction in false-negative test results.

Beneficiaries

The project was designed to benefit several links in the produce safety chain, including farmers, wholesalers, retailers, testing companies, and regulators. Additionally, beneficiaries to improvements in produce safety will always include consumers. Specialty crop produce farmers, specifically leafy green growers, will be direct beneficiaries for this project.

The economic impact as a result of improved testing using the methods developed in this project would be mostly experienced through reduced recalls and food waste and improved consumer confidence. A low estimate of the costs of a total recall is $1 million per recall, which is based on recent United States data that indicate that 52% of food recalls each cost $10 million or more, while 48% of food recalls cost less than $10 million (http://www.gmaonline.org).

This project also will benefit the >90 member companies of the California Leafy Green Products Marketing Agreement (LGMA) that work with hundreds of farmers in the state to produce and handle lettuce, spinach and other leafy greens products. According to the California Agricultural Statistics Review 2015–2016, the lettuce production alone is valued at >$2.2 billion annually.

Final research results were presented in June 2017 at the 8th annual CPS Research Symposium in Denver, Colorado, to 325 symposium attendees. Interim results were presented previously in an oral presentation at the 2016 CPS Research Symposium in Seattle, Washington (315 attendees), and in a poster session at the 2015 CPS Research Symposium in Atlanta, Georgia (245 attendees). The symposium participants included California regional and national growers and shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provides expert panels to comment on the research results after presentation by the researcher, which helps participants evaluate how the results can be used in their respective businesses.

Project results will be disseminated at industry meetings, and streamed through social media sources. Results will also be made available online as follows:

1. Final reports submitted to CPS (after the June 2017 symposium) are posted on the CPS website: http://www.centerforproducesafety.org/grant_opportunities_awards.php.
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Produce Marketing Association: http://pma.com
Western Growers Association: http://www.wga.com

Lessons Learned

While the sample preparation developed in this project has been shown to be a significant improvement, more work needs to be performed on bacteriophage engineering and cocktail development to ensure thorough detection. This work will need to be ongoing, as bacteriophages and their bacterial hosts are constantly evolving and gaining new strategies to infect and/or avoid one another.

One unexpected outcome was that the team gained a useful understanding of the genetic engineering of phages as well as their adsorption mechanisms. This knowledge will be very useful in the design and implementation of future strategies for produce safety.

Although the goals and outcomes were planned with a reasonable timeline, admittedly, the largest disruption to the project was the relocation of the project PI from UM, Amherst, to Cornell University. This move was unforeseen during the planning stages and implementation of the project. Also unforeseen was the extensiveness of the transition, which included students working on the project who then were required to be retrained in new facilities, wait for new equipment to arrive, and take additional classes as part of new program requirements. Although this disruption was significant it only affected the timeline and is not expected to affect future outcomes and impacts of the project.

Additional Information

See Attachment for Figures 1–5.

Publications stemming from this research project, with funding acknowledgements:

1. Wang D, Chen J, Nugen SR. Electrochemical detection of *Escherichia coli* from aqueous samples using engineered phages. *Analytical Chemistry* 2017; 89(3): 1650-7.
2. Wang Z, Wang D, Chen J, Sela DA, Nugen SR. Development of a novel bacteriophage based biomagnetic separation method as an aid for sensitive detection of viable *Escherichia coli*. *Analyst* 2016; 141(3): 1009-16.
3. Wang D, Wang Z, He F, Kinchla AJ, Nugen SR. Enzymatic digestion for improved bacteria separation from leafy green vegetables. *Journal of Food Protection* 2016; 79(8): 1378-86.
4. Jackson AA, Hinkley TC, Talbert JN, Nugen SR, Sela DA. Genetic optimization of a bacteriophage-delivered alkaline phosphatase reporter to detect *Escherichia coli*. *Analyst* 2016; 141(19): 5543-8.
5. Wang Z, Wang D, Kinchla AJ, Sela DA, Nugen SR. Rapid screening of waterborne pathogens using phage-mediated separation coupled with real-time PCR detection. *Analytical and Bioanalytical Chemistry* 2016; 408(15): 4169-78.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 57	**Project Title:** Rapid Tests to Specifically Differentiate Clinically Significant from Environmental STEC Towards Reducing Unnecessary Crop Destruction	
Grant Recipient: The Center for Produce Safety	**Grant Agreement No.:** SCB14057	**Date Submitted:** December 2017
Recipient Contact: Bonnie Fernandez-Fenaroli	**Telephone:** (530) 554-9761	**Email:** bonnie@centerforproducesafety,org

Project Summary

There is ample evidence that produce samples sometimes contain pathogens of serious potential human health consequences, although these are exceptionally rare events, relative to the scale of production and consumption. After the *Escherichia coli* (*E. coli*) O157:H7 outbreak on spinach in 2006, the programmatic testing of leafy greens at preharvest, incoming raw material, and/or finished packaged product greatly increased. A group of bacterial pathogens, Shiga toxin–producing *E. coli* (STEC), was recovered from diverse fresh produce from multi-year sampling programs conducted by the United States Department of Agriculture (USDA) and the Food and Drug Administration (FDA), largely at wholesale distribution centers. Leafy greens, herbs, and specifically spinach were singled out for concern due to a STEC prevalence rate exceeding 50% of the total isolates recovered. Many producers use pre-screening of field lots, especially leafy greens and herbaceous culinary herbs, for bacterial pathogens, including STEC. Unfortunately, not all testing platforms rapidly distinguish STEC likely to cause human illness from those that lack the genetic traits necessary for human infection.

Due to the high perishability of these commodities, testing can lead to destruction of a field due to false association with presumptively dangerous STEC. The project hypothesis was that the combined objectives of protecting consumers, reducing food loss, and improving sustainability could be enhanced by applying new advancements in specific detection of clinically relevant STEC to risk management decisions and better defining the role of wildlife as vectors of preharvest contamination. This study was a starting point for a longer-term effort to consolidate and clarify the available information on risk associated with the diverse STEC group and to present this information in a guidance format that can help form industry-based standards of practice. An objective of this study was to explore the development of a set of recommendations relative to rapid virulence profiling and its application to routine compliance and lot acceptance testing for fresh produce.

Shortly after a multi-state outbreak of *E. coli* O157:H7 on mesclun (spring mix) lettuce in May–June 1996 (originating from a small farm near the Central Coast of California, involving at least 61 victims, 21 hospitalizations, and three cases of hemolytic uremic syndrome), large salad processors increased their testing of agricultural inputs and/or product for this specific pathogen. At the time, and realistically up to late 2006, rapid commercial kit methods validated or performance tested on lettuce and leafy greens for *E. coli* O157:H7 were largely non-existent. After the *E. coli* O157:H7 outbreak on spinach in 2006, the focus of commercial lot acceptance testing was limited to the O157 group, although it was widely known that non-O157 STEC also were isolated from the consumer bags of spinach associated with the 2006 outbreak lot code. At the time, the general industry attitude towards focused testing was dictated by several limiting methodological factors in the detection and confirmation of STEC as frequent human pathogens associated with farm-gate produce as well as the predominance of the O157:H7 type in U.S. outbreaks.

Since then there has been a rapid expansion of platforms, kits, pathogen targets, and diversity of approaches to lot acceptance criteria. In parallel with the experience and policy development at the Centers for Disease Control and Prevention (CDC), the USDA Food Safety and Inspection Service (FSIS), and within the meat industry, there has been a gradual but accelerating shift in product testing criteria and policies for the group of pathogens that includes enterohemorrhagic *E. coli* (EHEC) and STEC. Some commercial kit test systems screened for the top-seven EHEC (O157, O26, O45, O103, O111, O121, O145), based on the premise that these subtypes are responsible for over 85% of clinical cases. However, due to the increasing recognition of diverse STEC in clinical cases, many commercial service labs have more recently been using detection and lot acceptance systems that employ the least diagnostic genetic markers for this group, namely the presence of *eae* (intimin; attaching and effacing) and *stx* (either of two key forms [*stx1*, *stx2*] of Shiga toxin) in an enrichment culture without cultural confirmation. Presence of these two markers, alone or being contributed individually by independent cell lines, has resulted in frequent crop destruction involving many acres and substantial economic loss at the individual grower level. First-hand knowledge from extension involvement in such decisions supports the reality of non-harvest or finished product destruction of five to over 200 acres for multiple farm and handler operations in each year since 2007. Although the total acreage destroyed is a fraction of the total annual production, estimated at less than 2% of volume, these losses can be substantial for an individual.

Some of these crop destruct decisions have arguably been made with only marginal risk-based data. The perishability of the crop and the reality that current methods for cultural confirmation among the non-O157 STEC may take as long as eight to 18 days, or may never be successful in a presumptive positive enrichment, preclude the use of culture techniques in lot acceptance decisions. In the absence of a clear and consistent policy, there was disbelief and resentment among the grower-suppliers in the necessity for uniform crop destruction or recalls in every case of detection of *eae* and *stx*, alone, based on limited molecular evidence. These markers are known not to be unique to EHEC/STEC and may not be present in the same cell in a mixed enrichment culture or even in an *E. coli* but carried in a different genus of related bacteria. This fact, and the associated fact that not all environmental STEC are equally infectious or recognized as pathogenic to humans, provoked passionate discussion on the need to develop and standardize criteria for rapid virulence profiling that would be necessary before a lot acceptance decision is finalized. A major focus of this concern is around the belief that unnecessary crop and product destruction is diametrically opposed to sustainability initiatives; all inputs are wasted and re-plant intervals may be as long as one year in some non-regulatory schemes.

There is ample evidence to support that produce samples do contain clinically relevant and serious non-O157 EHEC/STEC. There is an abundance of publications evaluating prevalence, frequencies, and diversity of this diverse group of pathogens but few look beyond the major serotypes or differentiate general risk from human health risks. Research has identified differential virulence between bovine vs. human clinical *E. coli* O157 but studies of this type do not appear to apply broadly to the complex class of STEC.

The industry's current perspective on non-O157 EHEC and STEC seasonal and geographic prevalence on lettuce, leafy greens, and several other commonly tested fresh produce commodities emanates mainly from data generated by a few contract testing service laboratories. Most utilize AOAC-Research Institute certified test methods accessible for purchase by any lab, and one lab—IEH Laboratories—provides pathogen testing services to the produce industry primarily using a proprietary system that has received AOAC Performance Tested certification. Public data disclosure of product testing for leafy greens is almost exclusively based on

this IEH dataset, and is held by many to reflect the reality of EHEC and STEC prevalence and consumer risk-exposure potential. While it is reasonable to draw preliminary conclusions in regards to contamination sources, seasonal patterns, or specific regional production from this data, it is important and prudent to develop additional science-based views of the validity of the testing outcomes. Confirming the prevalence of clinically-relevant STEC in environmental samples, product samples, and root cause investigative samples is critical to addressing risk-based questions. The ramifications of product testing design and implementation are being experienced across many commodities and no longer restricted to lettuce and leafy greens.

The ROKA Atlas EG2 test is known to detect pathotoxigenic *E. coli* O157 and STEC with a characterized determinative virulence factor. This promising technology uses a novel single genetic marker as a surrogate for the detection of pathogenic STEC. This study evaluated the potential utility of single marker technology for the detection of non-O157 STEC in ag-environment samples.

This project was initiated and objectives developed directly from a California leafy green industry request during a period when a persistent increase in field and finished goods rejections, due to STEC-positive test results, was causing unacceptable losses. Food loss and food waste is a topic of keen focus as increased attention is being given to food security. A shift in testing platforms had been widely adopted, and strong disagreement as to whether the results were false positives was being debated among growers and handlers. An objective, science-based approach was warranted.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Calibration of standardized protocols and operator proficiency assessments: Several rounds of verification, standardization, and proficiency training were conducted to ensure technical execution of the multiple STEC detection platforms and genetic markers. Two lab assistants and one postdoctoral researcher were trained on the ROKA system and real-time polymerase chain reaction (PCR) assay.

Analysis of retained STEC cultures from Lab Rapid Response collections: The project staff screened all of the 120 feedlot surface and spinach samples received from U.S. Meat Animal Research Center (MARC), and more than 600 isolates from the principal investigator's lab collection. These were characterized by ROKA reaction and 12 Marker Profile Group patterns. This confirmed the basic functionality of the ROKA EG2 platform and identified the need for secondary rapid confirmation tests to minimize the potential for false positive results leading to crop destruction.

Conducting of deferred pathogen detection tests on ROKA Transfer Tubes and retained enrichments from industry submissions: Due to limited actual vs. projected submissions, project staff only had access to 25 samples not pre-screened with a ROKA system but reported as presumptive positive for EHEC/STEC. The test showed that 13 of the 25 were false positive by genetic marker screening.

Recovered isolate characterizations: More than 600 potential STEC isolates from diverse farm, animal, and crop sources were characterized for virulence-associated markers. A total of 32 different Marker Profile Groups were identified. Long term, a micro-array test platform, direct from the enrichment culture, may be the preferred detection method to ensure elimination of both false-positive and false-negative results, which are equally troubling. Overall, 29.4% (n=52) of the produce/environmental samples were positive for STEC

by single marker analysis, in contrast with 39.1% (n=69) by real-time PCR three-marker screening, which is very likely to be a consequence of signal from target genes carried by different cells/strains.

Conducting of initial study site evaluations and coordination/informational meetings with enrolled cooperators: For targeted pre-trial environmental sampling, a total of 177 samples were tested. Samples of basil, bok choy, leeks, kale, chard, collard, parsley, soil, and water were collected, which provided over 350 isolates for molecular and cultural confirmation. Both known EHEC and STEC isloates were correctly idenitifed by the ROKA system.

Bird trapping, STEC detection and recovery assessments / environmental sampling and detection activities: More than 1,300 samples from birds were tested in two study sites. The majority of those trapped were passerine (songbird) species. The results of the bird trapping suggest that only a small proportion of birds carry EHEC/STEC, and some species may be more prone than others. For example, golden-crowned sparrows forage on the ground, where they spend most of their time. Red-winged blackbirds are also ground foragers, and they breed in wet places like marshes and are known for their association with cattle and other livestock. However, the STEC finding for ruby-crowned kinglets was surprising as they feed on insects pecked from the surface of leaves and branches. The results also indicated that there is a strong seasonality of carriage of EHEC/STEC by birds, but this differs between taxonomic orders (spring and summer in Anseriformes; fall in Passeriformes). To the project staff's knowledge, this is the first report of EHEC/STEC isolated from the feet/feathers of birds, which raises further questions on the potential of transmission and contamination by birds. The conclusion was that the general frequency of internal or external carriage of STEC is likely to be low. Industry standards and food safety policy may benefit from deemphasizing knee-jerk reactions to farm specific bird intrusion and develop grower guidance and decision trees for an assessment of risk, which would include both quantitative assessments, flocking behavior, general bird species assessments, and other relevant factors.

In June 2017, the final research results were presented at the Center for Produce Safety (CPS) Research Symposium in Denver, Colorado.

This project was entirely focused on California specialty crops.

This project benefitted from the contributions of several partner categories, including: (1) leafy greens handlers and grower/shippers, who provided access to regional production sites for environmental and crop sampling as well as access to laboratory microbiological samples early in the project work plan; (2) service laboratories, in particular Primus Labs (Santa Maria, California) that provided enrichment cultures and presumptive STEC isolates from commercial leafy greens samples by permission of grower clients; and (3) ROKA Biosciences, that provided technical support to resolve performance of the Atlas STEC testing platform and genetic analysis of environmental isolates that did not fully match the anticipated profile as clinically significant pathogens.

Goals and Outcomes Achieved

Over the course of the project period, more than 600 samples from diverse agricultural production and farmscape environments were collected and analyzed by several test methods for the presence of STEC contamination. Also, 120 retained samples from pre-project commercial and research lab isolations were screened. All confirmed *E. coli* were further genetically characterized with 12 virulence-associated genetic markers. The activities required multiple trips to commercial production farms for collection of crop samples,

irrigation water, and soil samples. During the project period, 177 purified samples from produce/environment, and 120 retained enrichments were tested for STEC single marker (Atlas system®), STEC marker profiles (*stx*1/2 and *eae*) by real-time PCR, and cultural assessment. In addition, 164 retained isolates were examined for STEC single marker and three-target STEC marker profiles; additionally, 25 strains recovered from commercial labs from positive enrichments were characterized by PCR.

The project target and performance measure was adoption of the test method at least five major stakeholders and inclusion into produce industry standards and audit criteria documents at the end of two years. The data developed during the execution of this project clearly demonstrated the likely potential for false positive outcomes of commonly used rapid tests for clinically significant Shiga toxin–producing *E. coli* (STEC) as an operational definition used by the FDA. The surrogate virulence marker, *ecf1*, utilized by the ROKA Bioscience Atlas™ EG2 system in this project was shown to eliminate false positives and substantially reduce false negatives in the diverse samples evaluated. During the project period, several contract service labs in California and other regions adopted the Atlas™ platform for routine preharvest, raw material, and finished product testing. Among these, Primus Labs, Silliker Labs, and Mérieux NutriSciences offered ROKA Atlas™ EG2 for STEC screening as specified by their clients and produce retailers requiring product testing from their suppliers. It is not possible to obtain complete client lists however the project PI has personal knowledge that, at minimum, more than five major leafy greens growers, handlers, and processors utilized this system based on the information communicated during stakeholder meetings and at the CPS Annual Symposium. A number of factors prevented this single test method from being adopted as a lasting requirement of audit standards, but its use became a common benchmark of performance for rapid test kits.

In a separate, related objective to generate additional isolates for genetic characterization, birds were captured and sampled at two study sites in 2015 and 2016. One of the study sites is a commercial produce ranch in San Benito County, on the Central Coast foothills. The other site is a National Wildlife Refuge in Yolo County on the delta of the California Central Valley, where land use is predominantly agriculture. In both sites, mist nets and traps were placed in proximity to a water body (reservoir or river). Forty-four sampling events took place over a period of a year (e.g., two sampling days per site and month). Nine to 10 nets were used year-round. Mist netting was supplemented with ground traps at each site. Both sites were adjacent to cow-calf beef cattle herds on rangeland. The project staff were able to collect cattle fecal samples from the Yolo County site, but did not have access to the cattle herd in San Benito County. Cattle feces were collected monthly throughout 2016. “Convenience” fecal samples were collected from wildlife (e.g., deer, feral pigs) observed during visits.

Of the 400 purified STEC colonies recovered from all environmental project sources, 32 variants of the combined 12 identity-confirming or virulence-associated genetic markers were observed (Marker Profile Groups). Of these, the ROKA system positively identified 97% of those that met FDA criteria as STEC of presumptive clinical significance for human illness.

Over the course of the project period, early in the project performance period, only 25 presumptive positive enrichment samples were obtained from commercial testing labs. Of these, eight Marker Profile Groups were observed, including those aligning with environmental isolates, as above. Twelve samples yielded colonies confirmed as presumptive clinical STEC and were positive by ROKA, while 13 samples were determined to be false positive in the original platform detection screening, based on our 12 Marker Profile patterns and a negative reaction by ROKA.

Of the 1,369 bird-associated samples, including 54 bird species from the study areas, 0.7% were positive for a presumptive clinically significant STEC. In addition, 12.5% of composited samples of Canada goose fecal mass were positive for a presumptive clinically significant STEC.

In summary, without comment to the need or advisability of pathogen testing of fresh produce in food safety programs, project staff achieved its performance goal to expand and confirm the scientific basis for a rapid two-step detection protocol for routine compliance and lot acceptance testing of the presence or absence of clinically significant EHEC/STEC for fresh produce. Major service labs that are utilized by the fresh and fresh-cut industries rapidly adopted the study outcomes, in collaboration with and complimentary studies conducted by ROKA Biosciences, early in the project performance period. The application of this two-step protocol remains in use today, and the original issue of potential false-positive test results has been managed to a minimal occurrence across the industry (personal communication with several large handlers).

The long-term outcome to screen thousands of clinical STEC isolates, planned for project beyond the scope of this project period, was initiated by both FDA and CDC researchers independently, and therefore this plan was abandoned since strain transfer was not anticipated.
For Objective 1, to test retained *E. coli* O157:H7 negative leafy greens samples for evidence of clinically significant STEC, project staff screened all of the 120 feedlot surface and spinach samples received. These samples were characterized by ROKA reaction and the 12 Marker Profile Group patterns.

For Objective 2, to test *E. coli* O157:H7–negative but STEC-positive enrichments from commercial preharvest, raw material, and packaged leafy greens and culinary herb products for evidence of clinically significant STEC, 25 such samples were obtained early in the project, predominantly from collaborative partner Primus Labs (Santa Maria, CA). After the two-step detection protocol for the ROKA platform was confirmed and adopted by the service labs, all other leafy greens handler sources of commercial presumptive positive and negative enrichment samples became unavailable. The project staff's response was to expand the internal effort to collect environmental, crop, soil, and water samples at a special on-farm study site with a local commercial mixed-produce grower/shipper. In addition, multiple opportunistic samples from domesticated animal and wildlife were obtained to screen for isolates that are more diverse.

For Objective 3, to characterize cultures identified as positive and negative by the ROKA Atlas EHEC screen for clinically relevant virulence markers by diagnostic multiplex PCR, the goal was accomplished by screening over 1,900 enrichment samples and 600 isolates to characterize the confidence level of accuracy of the ROKA detection systems in minimizing both false-positive and false-negative outcomes of STEC-targeted testing.

For Objective 4, to characterize the clinical significance of EHEC/STEC isolates from nuisance bird populations exhibiting flocking and foraging behavior in leafy green vegetable fields, project staff captured and sampled birds at two study sites in 2016 as described above. A total of 1,369 bird-associated samples were collected, including 54 bird species from the study areas, and 0.7% of samples were found positive for a presumptive clinically significant STEC. In addition, 12.5% of composited samples of Canada goose fecal mass were positive for a presumptive clinically significant STEC. Relative to the initial goals, significant adjustments had to be made due to the loss, and therefore extended delay, of access to the major study site planned for this objective. A change of ownership resulted in withdrawal of permission to trap birds at one study site, and no comparable replacement site could be found in 2015. By 2016, project staff had secured the

permission to conduct these studies and, with an additional opportunistic site added, completed the characterizations to the best of their ability and degree of flexibility in the access allowed.

Since the end of 2015, commercial producers in California alone have tested tens of thousands of samples of diverse leafy greens, culinary herbs, and other fresh and fresh-cut produce. The concerns for economic losses due to false-positive reports have essentially ceased to be raised to project staff's extension program or at industry meetings. The project staff hold this to be the major success of the project. In addition, the project outcomes further supported prior CPS research that showed, while birds can be a source of clinically significant STEC contamination, the prevalence is very low. Current data do not support implementing environmentally damaging measures or immediate crop destruct or broad-scale buffering in response to minor bird presence or intrusion to leafy greens fields. Science-based best practices regarding bird intrusion is a major successful outcome.

Beneficiaries

The key beneficiaries include diverse grower/handler sectors of the fresh leafy greens and produce industry by the clarification and expansion of the available information on risk associated with the diverse STEC group. This information has and will continue to help inform industry-based standards of practice. In addition, the outcomes will benefit risk and policy dialogue among the industry, public health agencies and regulators, as well as consumer and environmental management advocates. Growers and those responsible for the stewardship of the farmscape and watershed are benefitting by the reduced hyperbole surrounding the need to push back or destroy wildlife habitat in frustration from excessive crop destruction due to false-positive STEC test results.

California growers, shippers and processors responsible for an estimated 65% of the domestic packaged salad supply are direct beneficiaries of the primary project outcome. It is estimated that over 100 million servings of these specialty crop products are consumed every week across the U.S. in foodservice and retail-purchased home meals. Consumers benefit from accurate pathogen test outcomes, whether positive or negative in increased confidence in food safety and sustainable farming and farm stewardship practices.

The principal investigator from the University of California, Davis presented final research results in June 2017 at the 8th annual CPS Research Symposium in Denver, Colorado to 325 symposium attendees. Interim results were presented previously in a poster session at the 2016 CPS Research Symposium in Seattle, Washington (315 attendees), and the 2015 CPS Research Symposium in Atlanta, Georgia (245 attendees). The symposium participants included California regional and national growers/shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provides expert panels to discuss the research results after presentation by the researcher, which helps participants evaluate how the results can be used in their respective businesses.

Project results will continue to be disseminated at industry meetings, and streamed through social media sources. Results will also be made available online as follows:

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Produce Marketing Association: http://pma.com
Western Growers Association: http://www.wga.com/

Lessons Learned

In retrospect, this project might have been best positioned as a one-year effort to focus solely on the issue of extending pre-project experience in genetically profiling on-farm, product testing, and environmental isolates. Once the key obstacle to essentially eliminating false positives was accomplished, the supportive industry lost interest in broader goals. As the project staff sought to extend knowledge of the diversity of the types of isolates that may be missed by the ROKA system and other platforms, the planned project objectives resulted in partial frustration due to the lack of broader participation. The project staff were fortunate that an unplanned grower cooperator stepped up to participate.

One key unexpected outcome was accomplished collaboratively by providing ROKA scientists with environmental isolates to conduct deeper genetic analysis. The results demonstrated that rare STEC isolates have lost the *ecf1* surrogate marker (false negative) and more frequent isolates retain *ecf1* (molecular positive) but lack the Shiga toxin genes. This was the basis for the two-step screening.

Additional Information

Interim results were presented to stakeholders and at conferences during the entire project period, in addition to presentations or posters at the annual CPS Research Symposium (2015–2017):

Single marker detection and virulence gene profiling of non-O157 STEC in produce and associated farmscape samples. Poster: July 9, 2017. International Association for Food Protection (IAFP) Annual Meeting, Tampa, FL.

Produce Testing: Current state, benefits and challenges. January 29, 2017. Western Growers Association Lunch & Learn Webinar.

Developing a Comfort Level with Myths, Mysteries, and Befuddlements in Pathogen Testing on Fresh Produce. September 23, 2016. Bonduelle Foods – Management Group, UC Davis Mann Lab.

Micro Testing and Rapid Pathogen Test and Hold Challenges. September 13–15, 2016. Fresh-Cut Products: Maintaining Quality and Safety, Buehler Alumni Center, UC Davis.

STEC Testing in Soil, Manure and Compost. August 24–25, 2016. CDPH/FDB and CalFERT Commodity Specific Training, Soil Systems and Management with Soil Amendments of Biological Origin, California Department of Food and Agriculture, Sacramento, CA.

Preharvest to Postharvest Produce Safety: Preparing for FSMA. May 17, 2016. HRT 200B, Horticulture and Agronomy Graduate Group, UC Davis.

Basics of Microbiological Testing for Key Compliance Expectations of FSMA. May 4, 2016. Western Food Safety Summit, Hartnell College, Salinas, CA.

Developing a Comfort Level with Myths, Mysteries, and Befuddlements in Pathogen Testing on Fresh Produce. February 25, 2016. What Microbial Testing Can and Can't Do For You – A PMA Webinar.

Practical Issues and Current Systems in STEC Detection during Crop Input and Produce Lot Acceptance Testing. February 23, 2016. National Advisory Committee on Microbiological Criteria for Foods STEC Subcommittee, Washington, DC.

New Developments in Rapid Pathogen Testing. January 6, 2016. CA Melon Research Board Annual Meeting, San Diego, CA.

Clarifying the issues surrounding product testing for EHEC/STEC. November 2, 2015. Advanced Produce Safety Workshop: A Science-based Framework, UCD Postharvest Technology Center.

Clarifying the Issues Surrounding Product Testing for EHEC/STEC. September 6, 2015. CA Leafy Green Research Board and Central Coast Grower Shipper Association Special Meeting, Salinas, CA.

Applied Research on Microbial Safety of Perishable Horticultural Food Crops. June 26, 2015. CDC DFWED Seminar Series, Atlanta, GA.

Applied Research on Microbial Safety of Perishable Horticultural Food Crops. May 12, 2015. Walmart Food Safety & Health Emerging Issues Series, Bentonville, AK.

Overview of Microbial Food Safety Challenges for the US Fresh Produce Industry. April 23, 2015. FSMA Implementation and Food Safety Concerns, BABCOCK Laboratories Inc. Team Event, Riverside, CA.

Key Safety Challenges for the Fresh Produce Industry. April 17, 2015. California Chapter, American Society of Farm Managers and Rural Appraisers, Inc., Agribusiness Conference, Paso Robles, CA.

Microbial Testing Considerations. January 22, 2015. Quality and Safety of Fresh Cut Products, Cardiff, Wales.

USDA Project No.: 58	Project Title: Enteric Viruses as New Indicators of Human and Cattle Fecal Contamination of Irrigation Waters	
Grant Recipient: The Center for Produce Safety	**Grant Agreement No.:** SCB14058	**Date Submitted:** December 2017
Recipient Contact: Bonnie Fernandez-Fenaroli	**Telephone:** (530) 554-9761	**Email:** bonnie@centerforproducesafety.org

Project Summary

Currently, irrigation water quality is being evaluated with the 1973 United States Environmental Protection Agency (EPA) recreational water quality standards of geometric mean of <126 *E. coli* per 100 ml as a way of indicating the safety of irrigation water for use on fresh produce. Originally, these criteria were never intended to be applied to risks associated with irrigation management of edible crops as they were developed for evaluating the risk of illness (1 in 10,000) to humans that came into contact with surface waters for recreation purposes (e.g., swimming, boating etc.). However over the last 40 years, there have been few advances in the development of better methods that improve risk-based assessments for evaluating the presence or absence of fecal contamination in irrigation waters for fresh produce. Thus, without being able to improve exposure data and accurately determine the presence/absence or relative level of fecal contamination, more accurate risk-based analysis cannot be conducted and setting better "risk relevant" standards regarding improved regulatory efforts of irrigation waters has remained problematic.

To develop a better indicator organism(s) and methodologies that go with implementing such a change, targets must be identified that better fit the definition of an effective microbial indicator. Human enteric viruses replicate (i.e., multiply) in the epithelial cells of the gastrointestinal tract and, upon excretion, are able to survive longer outside the host environment than enteric bacteria such as *E. coli*. Enteric viruses include a wide range of human foodborne pathogens that have evolved thermal stability (42–50 °C) and pH stability (pH 3–9) in the extracellular environment. Such stability is largely associated with the small size (30 nm) and robust protein coat called the capsid that enables the virus to bind to the host cells. These features are known to play an important role in the mechanisms of virus survival and transport in the environment.

Several novel viruses have only recently become realized as a potential improvement on traditional indicator organisms. These viruses are advantageous for several reasons. First of all, viruses require a host to replicate and therefore are in no danger of re-growth once released into the environment, making them ideal static target organisms that can be more easily quantified and correlated with the amount of fecal contamination present in a sample. They are almost always found in an equal or higher abundance than pathogenic organisms, providing a more conservative estimate of the level of fecal contamination that improves the level of detection and provides a more quantifiable range of fecal contamination. This will allow for an improvement of exposure assessments for risk analyses. Viruses are also generally host-specific, allowing for the specific detection of fecal contamination for both cattle and humans that commonly contaminate source water through either runoff events or direct sewage infiltration. This makes them ideal as both a microbial source tracker and sensitive microbial indicator. Additionally, previous research has shown that the level of virus shedding for the model organisms proposed showed little seasonal variability and was highly abundant in fecal materials. Aichivirus has been detected in high numbers in both raw and treated sewage in the United States, Japan, Venezuela, and Tunisia, and in shellfish in France. Pepper mild mottle virus (PMMoV) was

found to be the most abundant virus in fecally contaminated waters worldwide; enteroviruses were also commonly found in contaminated waters. Adenovirus was one of the longest-lived viruses in environmental waters because of its high level of resistance to ultraviolet light.

Nevertheless, only recently have methodologies improved enough for the realization of low cost and rapid detection methods for viruses from environmental source waters. Traditional virus absorption–elution methods were developed for concentrating viruses from water for culture-based applications, and relied on large volumes (>100-liters), expensive filter cartridges (>$200), and multiple-day, labor-intensive procedures. The high cost, long turn-around times, and poor concentration efficiencies associated with these methods have, in the past, prohibited their widespread use as an effective tool for environmental virus monitoring. The recent development of new methodologies like the "negatively charged membrane method" allowed for vast improvements in the concentration and detection of viruses for detection using molecular methods. This new concentration technique required smaller water volumes of only a few liters, utilized an inexpensive filter medium (<$5), and could be conducted in less than one day. These improvements made it possible to apply environment virus detection as an effective tool for evaluating irrigation water quality.

With the upcoming implementation of the Food Safety Modernization Act's Produce Safety Rule that required additional testing of irrigation water quality using existing methods (i.e., testing for *E. coli*), there was an even greater need for improved indicator organisms for irrigation waters that would provide "risk-relevant" information for growers to help them make informed management decisions.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The team identified a workflow and protocols for using the "negatively charged membrane method" to optimize cost and time requirements for surveillance of novel viral indicator organisms.

Initially, 10 4-liter irrigation water samples were collected from various canals in Yuma, AZ, and brought back to the University of Arizona on ice for processing via concentration using HA filters. For nine of the 10 samples, 3-liters were successfully passed through an HA filter to concentrate the viruses in the sample. For the 10th sample, only 2.5-liters was passed through the filter before it clogged. Based on these preliminary tests, it appeared that a volume of 3-liters was optimal for this method with these surface irrigation waters (2 to 3-liters was proposed). All samples with less than 3-liters filtered were recorded so that this lower volume could be taken into consideration in any subsequent quantification of viral genome copy numbers.

Subsequently, an additional 30, 4-liter samples were collected from Yuma and in California's Imperial Valley. Unlike the 10 previous samples, many of these remaining 3-liter samples could not be successfully filtered using the HA filters alone. Due to this issue, a number of pre-filter types were evaluated for their ability to remove water components that were clogging the filters, while still successfully allowing smaller particles, such as viruses, to pass through. After numerous tests, a filter with a pore size of 20–25 microns in diameter (Whatman 41; 90 mm diameter) was determined to be optimal. The filter was pre-soaked in three percent beef extract as a blocking buffer to take up available sites on the filter that could otherwise cause indiscriminate binding of viruses to the filter.

In addition to the appropriate volume to be filtered, it was also necessary to determine if filters could be

shipped on ice from collaborators in other regions without a loss in virus integrity. To determine this, four 3-liter volumes of dechlorinated tap water were seeded with a known amount of poliovirus (an enterovirus) and the water was concentrated using the established HA filtration method. Following this, half of the samples were placed in petri dishes wrapped in parafilm and stored on ice in a cooler for two days to simulate overnight shipment from other regions. The other half of the samples were processed/eluted immediately. The recovery efficiency of the virus was compared for the two methods. No significant differences were observed and it was determined that collaborators in other regions could send already concentrated samples on filters on ice through the mail overnight without any appreciable loss of virus integrity. This resulted in a significant savings in shipping costs for the samples since it was not necessary to ship multiple liters of water per sample.

The team also assessed the occurrence of various viruses in irrigation waters of varying quality using quantitative polymerase chain reaction (qPCR) assays for application as novel viral indicator organisms in relation to traditional cultural methods among and between irrigation districts.

To evaluate the use of novel viral indicator organisms for human and cattle fecal contamination, four irrigation regions were chosen that specialized in fresh produce from around the country: Yuma, AZ; Maricopa, AZ; Imperial Valley, CA; and an area near Atlanta, GA. Samples were collected between November and March for two years (2015 and 2016). A small set of samples was also collected during the middle of summer (August 2016) in Yuma to look at seasonal variations. Sampling locations were chosen that represented a variety of canal characteristics such as main canals and lateral canals, cement lined and unlined canals, urban and rural canals, and irrigation ponds. In addition, data collected from previous studies regarding the occurrence of fecal contamination and the presence of pathogens in the irrigation water in these regions were studied to ensure that areas with historically low contamination and higher contamination levels were included. This included 30 different locations from irrigation canals in Yuma, 30 locations from canals in Maricopa, 30 locations from irrigation canals in the Imperial Valley, and four large irrigation ponds in Georgia. The irrigation ponds in Georgia included one pond next to a large dairy farm and another in which cattle had direct access to the water. All of the ponds could be directly accessed by local wildlife.

A total of 330 samples were collected: 190 samples collected from Yuma (150 in the winter, 40 in the summer), 60 samples from Maricopa, 60 samples from California, and 20 samples from Georgia. Bacterial sampling for both indicator organisms (total coliforms and generic *E. coli*) and pathogens (*E. coli* and *Salmonella*) was conducted for comparison purposes. Physical/chemical data were collected for metadata purposes: air temperature, water temperature, relative humidity, pH, electro-conductivity, and the amount of total dissolved solids were recorded in the field using a multi-parametric sensor; water turbidity (cloudiness) was measured in the laboratory. To determine the number of indicator organisms present, a 100 ml volume was quantified for total coliforms and *E. coli* using the Colilert Quanti-Tray 2000 system. The most probable number (a statistical estimate of the number of coliforms/*E. coli* in the sample) was obtained following the manufacturer's procedure. For *E. coli* and *Salmonella* spp., a 1-liter grab sample was concentrated using membrane filtration (0.45 µm pore size; 47 mm diameter) and the filter was placed in tryptic soy broth (TSB) overnight at 37°C for the enrichment of injured cells. This method reduced the number of false-negative results by up to ten-fold compared to direct selective enrichment.

For *E. coli,* the enriched culture was used to inoculate test tubes containing 10 ml of *Escherichia coli* broth with an inverted Durham tube. Following incubation at 44.5°C for 24 hours (or at 48 hours if negative after 24 hours), the tubes that exhibited both bacterial growth (turbidity) and the production of gas (bubbles in the

Durham tube) were subcultured onto mEndo agar plates with overnight incubation at 44.5°C. Darkly pigmented colonies were transferred via the streak for isolation method onto tryptic soy agar (TSA) plates and incubated at 37°C overnight. Colonies were tested for the presence of an oxidase enzyme and the production of indole. These purified presumptive *E. coli* cultures (oxidase-negative, indole-positive) were then tested using API 20E biochemical strips to confirm this identification. Isolates confirmed as *E. coli* were tested for the presence of *E. coli* virulence genes using primers described by Wahl et al. (2011) that recognized the Shiga-toxin genes (*stx1, stx2*) and the membrane protein intimin gene (*eae*). The presence of either of the Shiga toxin genes indicated that an isolate was a Shiga toxin–producing strain of *E. coli* (i.e., STEC). This method was modified for conventional polymerase chain reaction (PCR). For *Salmonella* species, bacteria from the TSB were further enriched in tetrathionate broth for 24 hours at 37°C. A subsequent enrichment was performed in Rappaport Vassiliadis broth for 24 hours at 37°C and samples streaked for isolation onto xylose lysine deoxycholate agar plates for the selection of *Salmonella* spp. Suspect colonies (black centers) were transferred to TSA plates and oxidase-negative cultures further confirmed as *Salmonella* spp. through API 20E biochemical strips.

The samples were processed for viruses using the optimized HA filtration method: 3-liters of each sample were passed through stacked pre-filter and HA filters to concentrate the viruses (down to 10 ml). Following elution from the filters, the samples also underwent a secondary concentration step to further reduce the volume to ~0.65 ml using Centriprep centrifugal ultrafilters. These secondary concentrates were frozen and stored at −80°C pending further evaluation by quantitative polymerase chain reaction (qPCR).

In the detection of viruses by qPCR, inhibitory substances could reduce viral nucleic acid extraction efficiency and interfere with cDNA synthesis and/or polymerase activity that strongly affect the molecular detection and quantification of viruses in environmental samples. To monitor the extraction-qPCR efficiency, the team used murine norovirus as an internal process control for the processing of all samples. This was necessary as some environmental samples had inhibitory substances that could reduce the extraction and qPCR efficiency. The viral nucleic acid was extracted from 200 µl of each sample using a MO BIO PowerViral Environmental RNA/DNA Isolation Kit (MO BIO, San Diego, California) to obtain 100 µl of extracted RNA or DNA. In a previous study, the team found this kit to be more efficient in the extraction and purification of viral nucleic acids from environmental water concentrates than two other widely used commercial kits. Virus data was collected using qPCR and reverse transcription (RT)-qPCR assays to detect and quantify viral genomes from bovine polyomavirus and bovine adenovirus (Wong and Xagoraraki 2011), human adenoviruses (Ko et al. 2005), Aichivirus and enteroviruses (Hata et al. 2014), PMMoV (Haramoto et al. 2013), and murine norovirus (Kitajima et al. 2010) using specific Taqman probe-based assays. qPCR assays were performed with a LightCycler 480 Real-Time PCR Instrument II (Roche Diagnostics, Mannheim, Germany). Basically, reaction mixtures (25 µl) consisted of 12.5 µl of LightCycler 480 Probes Master Mix (Roche Diagnostics), forward and reverse primers, probe, and 5 µl of DNA/cDNA template. Serial ten-fold dilutions of the standard plasmid DNA containing inserts of the amplification region were used to generate a standard curve, and thus quantitative data on cDNA copy numbers were obtained. qPCR fluorescence readings were collected and analyzed with LightCycler 480 Software version 1.5 (Roche Diagnostics).

Results were as follows:
General water quality parameters: The physical/chemical characteristics and the microbial quality of the irrigation water varied greatly between regions. The results for the various irrigation water quality parameters and the traditional indicator organisms (total coliforms and generic *E. coli*) are shown in Table 1. All regions

differed significantly ($P \leq 0.05$) in the following parameters: conductivity, total dissolved solids, air temperature, and relative humidity. The pH of the samples collected from California was significantly higher than the samples collected from both regions in Arizona. The water temperature in Yuma, AZ was significantly lower in the winter than the temperatures in Maricopa, AZ and California. And the turbidity of samples collected from Yuma, AZ was significantly higher than of samples collected from California. The numbers of coliforms and *E. coli* also varied between regions. The number of total coliforms was significantly different from all four regions with only one exception – the levels of total coliforms found in samples collected from California and Georgia were not statistically different. A similar result was found for *E. coli* levels – all the regions had significantly different levels of *E. coli*, with two exceptions (Georgia *E. coli* levels were not statistically different from levels in Yuma AZ and California).

Table 1. Irrigation water quality in each region.

Irrigation water quality by region (geometric means)										
Region	Season	Physical / Chemical Parameters							Colilert	
		H_2O Temp (°F)	Air Temp (°F)	Relative Humidity (%)	pH	Conduct.	TDS (ppm)	Turbidity (NTU)	Coliforms (MPN/100 ml)	*E. coli* (MPN/100 ml)
YUMA, AZ	summer	84	95	23	8.7	1209	765	4.0	1396	5
	winter	57	66	30	8.8	1236	920	2.2	268	4
MARICOPA, AZ	winter	71	85	12	8.5	1415	1000	2.5	683	27
CALIFORNIA	winter	66	77	22	8.9	1115	792	3.0	1663	10
GEORGIA	winter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1474	9

Occurrence of STEC in irrigation waters: The occurrence of generic *E. coli* in irrigation waters as measured by the enrichment/selection method ranged from 74% in Yuma, AZ to ≥98% in Maricopa AZ, California, and Georgia. Although generic *E. coli* was isolated from nearly all the samples in Maricopa AZ, California, and Georgia, and the majority of samples in Yuma AZ, none of the *E. coli* isolates tested positive for any of the virulence genes (*stx1*, *stx2*, *eae*). Therefore, no STEC were identified in any of the samples.

Occurrence of *Salmonella* species in irrigation waters: The occurrence of *Salmonella* species as measured by the enrichment/selection method was 15% for Yuma AZ, 22% for Maricopa AZ, 35% for California, and 40% for Georgia. Since these samples were all enriched for *Salmonella*, no quantitative data is available. However, despite the occurrence of *Salmonella* being fairly high (15–40%), the levels of *Salmonella* were likely low in these samples given the absence of illness outbreaks linked to these regions.

Occurrence of virus indicators/pathogens in irrigation waters: The results for the viruses are shown in Table 2. Neither of the bovine species was found in any of the irrigation water samples from any of the four regions, including from irrigation ponds with direct inputs from cattle. This result could be due to the efficiency of the method and the limit of detection of the assays. The bovine viruses could be present in these waters, but not at high enough levels to be detected in a 3-liter sample. Aichiviruses were detected in only three samples and adenoviruses from five samples. The enteroviruses were detected in 27 samples from two regions. Notably, all 20 samples collected from Georgia were positive for enteroviruses. The primers used to detect the

enteroviruses via qPCR will detect numerous animal enteroviruses as well as human enteroviruses. The most commonly detected virus was PMMoV, which was found routinely in all regions in 34% to 63% of samples.

Table 2. Occurrence of viruses in irrigation waters from four different regions in the United States.

Agricultural Region	Bovine Polyomavirus	Bovine Adenovirus	Aichivirus	Pepper Mild Mottle Virus	Adenoviruses	Enteroviruses
Yuma, Arizona	0/190 (0%)	0/190 (0%)	3/190 (2%)	65/190 (34%)	3/190 (2%)	7/190 (4%)
Maricopa, Arizona	0/60 (0%)	0/60 (0%)	0/60 (0%)	38/60 (63%)	0/60 (0%)	0/60 (0%)
California	0/60 (0%)	0/60 (0%)	0/60 (0%)	28/60 (47%)	2/60 (3%)	0/60 (0%)
Georgia	0/20 (0%)	0/20 (0%)	0/20 (0%)	12/20 (60%)	0/20 (0%)	20/20 (100%)

Overall for all of the samples, weak correlations were observed between the following parameters and microbial concentrations: Air and water temperatures (r = 0.83), air temperature and the relative humidity (r = −0.44), water temperature and the relative humidity (r = −0.29), total coliforms and *E. coli* (r = 0.32), *Salmonella* and total coliforms (r = 0.47), water temperature and total coliforms (r = 0.41), and turbidity and total coliforms (r = 0.33). None of the viruses measured could be correlated with any of the other measured parameters. This was most likely due to the low levels of occurrence of most of the viruses examined.

The team estimated the amount of fecal contamination present in irrigation water samples based on quantitative values of an indicator virus, PMMoV.

Estimated fecal contamination and calculated pathogen of interest concentrations: PMMoV, enteroviruses, Aichivirus, and human adenoviruses were detected in some of the 330 irrigation water samples collected. The viral content of 2.8 ± 0.52 liters of each sample were concentrated using a negatively charged membrane filtration method and a secondary concentration step to produce a final volume of 0.636 ± 0.053 ml. DNA or RNA was extracted and viral copies were identified and quantified using qPCR.

Fecal contamination levels were estimated based on quantitative values of an indicator virus, PMMoV, which was found in the greatest number of irrigation water samples. PMMoV concentrations were related to recorded PMMoV concentrations of 1.5 x 10^6 to 2.2 x 10^7 virus copies/ml raw sewage and human feces (Rosario et al. 2009) to estimate the levels of human fecal presence in the sample using the equation below. This equation was applied to each sample individually. The PMMoV genome copies per 1 ml raw sewage value were randomly generated from the range given above, assuming a uniform distribution across the range. Samples that were below the detection limit of the assay for PMMoV were assigned the value of 1 x 10^{-5}.

$$\frac{\boldsymbol{estimated\ volume\ (ml)\ raw\ sewage}}{\boldsymbol{volume\ (ml)\ irrigation\ water}} = \frac{measured\ copies\ PMMoV}{1\ ml\ irrigation\ water} \times \frac{1\ ml\ raw\ sewage}{copies\ PMMoV}$$

Using the estimated quantity of fecal contamination for each sample and known concentrations of pathogens in human sewage and cattle feces, the theoretical quantity of four pathogens of interest (human norovirus,

rotavirus, *E. coli* O157, and *Shigella*) within each sample was calculated using recorded levels of these pathogens in sewage/feces (Table 3) and the following equation:

$$\frac{y\ pathogens}{mL\ irrigation\ water} = \frac{mL\ fecal\ matter}{mL\ irrigation\ water} \times \frac{x\ pathogens}{mL\ fecal\ matter}$$

Table 3. Recorded levels of pathogens of interest in sewage

Pathogen	**Concentration in raw sewage**	**Assumption**
E. coli O157	0.1–1 CFU/ml (Nwachuku & Gerba 2008)	Uniform distribution
Shigella	1 x 10^3 CFU/ml (National Resource Council)	Point-estimate
Rotavirus	0.0098 FFU/ml (Hejkal et al. 1984)	Point-estimate
Norovirus	2 x 10^2 PDU/ml (Lodder & de Roda Husman 2005)	Point-estimate

These estimates of the amount of each pathogen of interest in irrigation waters were used in the quantitative microbial risk assessment. The team provided improvements to exposure data regarding risk associated with fecal contamination on fresh produce from irrigation water.

Quantitative microbial risk assessment (QMRA) was a valuable tool to predict risk associated with exposure to microbial pathogens. Predicting this risk could help to identify large scale trends and to predict the impact of water quality on food safety. This study aimed to assess the risk associated with the consumption of fresh lettuce contaminated with enteric pathogens via irrigation water. Irrigation water samples from Arizona, California, and Georgia were screened for human adenovirus and enteroviruses and the proposed fecal indicator, PMMoV. The following pathogens of interest were also considered important for this risk assessment: Human norovirus, rotavirus, *E. coli* O157, and *Shigella*. Concentrations of pathogens of interest were estimated using measured PMMoV concentrations and known concentrations of PMMoV and the pathogens of interest that were shed in human or cattle feces. These values were then incorporated into known risk assessment models to further evaluate the potential risk posed by the consumption of contaminated fresh produce at a specified point along the farm-to-fork pathway. (For background details on the QMRA see Additional Information.)

Results were as follows:
This risk assessment did not account for microbial decay or removal at any subsequent point on the farm-to-fork pathway beyond harvest. It assumed that the microbial concentration estimated to be on the produce surface at harvest was what would eventually reach the consumer. This ignored continued microbial decay post-harvest, microbial removal via washing sanitization, and other forms of microbial reduction from the produce surface. There were numerous such circumstances and conditions that would result in a decrease in pathogen levels on produce prior to it being consumed. As such, this was an extremely conservative estimate of risk. The actual risk of illness to the consumer would be much lower.

Observed viral pathogen levels and associated risk*:* Adenovirus was detected in 1.5% of samples (5 of 330) with an average concentration of $1.9 \times 10^3 \pm 2.0 \times 10^3$ genome copies per milliliter. Enteroviruses were detected in 8.2% of samples (27 of 330) with an average concentration of $1.4 \times 10^5 \pm 4.9 \times 10^5$ genome copies per milliliter. Assessing risk only from the adenovirus-positive samples results in a potential risk of adenovirus infection of 0.62, which translated to a risk of 62 cases of infection per 100 exposures in 1.5% of the sampled population. The risk of enteroviral infection in the portion of the population positive for enteroviruses was 1.0, which translated to a risk of 100 cases of enteroviral infection out of 100 exposures in 8.2% of the sampled population. The risk of infection calculated using only the non-detect samples of adenovirus and enteroviruses was 1.2×10^{-8} and 3.5×10^{-6}, respectively, which translated to a risk of 1.2 cases of illness in the adenovirus non-detect population per 100,000,000 exposures and a risk of 3.5 cases of illness in the enterovirus non-detect population per 1,000,000 exposures.

Fecal matter concentration in irrigation water and estimated risk for pathogens of interest: The amount of fecal concentration across all samples was $7.6 \times 10^{-7} \pm 6.1 \times 10^{-6}$ ml raw sewage per 1 ml irrigation water, assuming a normal distribution of values. This level of fecal contamination was used to predict the contamination levels for the pathogens of interest: norovirus, rotavirus, *E. coli* O157, and *Shigella* (Table 4). The estimated levels of risk associated with these pathogens based on these contamination levels in irrigation water are also indicated.

Table 6. Estimated pathogen levels in irrigation water samples and the associated risk of illness following one exposure.

Pathogen of interest	Estimated concentration	Risk of Illness (per exposures)
Norovirus	$3.2 \times 10^{-4} \pm 3.9 \times 10^{-3}$ PDU/ml	1.8 per 100,000,000
Rotavirus	$1.6 \times 10^{-8} \pm 1.9 \times 10^{-7}$ FFU/ml	6.4 per 1×10^{11}
E. coli O157	$9.9 \times 10^{-7} \pm 1.4 \times 10^{-5}$ CFU/ml	2.8 per 1×10^{14}
Shigella	$1.6 \times 10^{-3} \pm 2.0 \times 10^{-2}$ CFU/ml	4.6 per 1×10^{10}

This risk assessment was worst-case scenario and did not include removal or pathogen die-off post-harvest. Pathogens were infrequently detected and as such, the assumed risks were very low in the majority of the samples. In the small percent of the samples in which adenovirus and enteroviruses were present, the risk was significantly higher. Limitations of the study included sample size and processed volume, which may have impacted the outcome. Estimated concentrations of fecal contamination as well as the calculated risk from estimated pathogens were very low.

All grant funds were used to solely enhance the competitiveness of specialty crops. Fresh produce types grown in Arizona were considered specialty crops and all of these crops were irrigated via open conveyance canal systems using surface waters. In this project, the team developed an alternative fecal indicator organism for assessing the microbial quality of irrigation waters. This will lead to guidance on better management strategies to reduce the risks associated with pathogens for water resources used for the irrigation of specialty crops that are eaten raw. This will lead to improved produce safety and increased consumer confidence in these specialty crops.

The project partners included the Center for Produce Safety and the University of Arizona. The Center for Produce Safety managed the project and the University of Arizona performed the research studies. The project Principal

Investigator (PI) oversaw all aspects of the project and supervised all of the field and laboratory work. The PI was also responsible for all data analyses and project reporting. The team collaborator in Georgia conducted the field sampling in that region and shipped filters to the University of Arizona for processing by project personnel. The project co-PIs performed the quantitative microbial risk assessment and assisted the PI with the data analysis and drafting of reports.

Goals and Outcomes Achieved

The project resulted in the development and evaluation of a novel sampling method for viruses in irrigation waters using small volumes that were feasible for collection by growers. In addition, the development of a more accurate and quantitative method for the detection of fecal contamination in irrigation water will provide the industry with a necessary tool to evaluate water quality through a more scientifically based approach targeting a novel indicator organism that better fits the definition of an effective indicator organism. With this information, growers and government agencies will have a statically driven approach to setting limits of fecal contamination that are acceptable for irrigation purposes. From the results of this study, pepper mild mottle virus (PMMoV) appeared to be a good candidate for a new indicator organism for fecal contamination of irrigation waters.

This study resulted in a QMRA using observed PMMoV levels in irrigation waters from four regions in the United States to estimate the levels of pathogens of interest and the risks to consumers of fresh produce associated with their presence in waters used to irrigate such crops. Quantitative data regarding the level of fecal contamination present in irrigation water through this new viral target was obtained, so that useful estimates for the amount of fecal contamination and the presence of various pathogens in irrigation water could be made. This data could be used for even more improved exposure assessments of fecal contamination found in the various irrigation waters by including post-harvest outcomes for pathogens on produce, such as removal through washing/sanitization or microbial die-off during processing and transport, prior to the produce reaching the consumer. With such information, major information gaps regarding exposure will be available for more sophisticated risk analyses to be conducted.

The QMRA performed in the current study resulted in an extremely conservative estimate of risk. Future studies should try to develop data to fill the gaps between an irrigation event using contaminated water and the survival/persistence of specific pathogens between this event and subsequent harvest, processing, and transport. One long-term outcome included the publication of project results in peer-reviewed scientific journals–at least two publications were drafted. These publications were both related to the occurrence and relative abundance of the proposed viral indicators in this study and the use of PMMoV to estimate the amount of fecal contamination and thus the predicted amount of pathogens present in irrigation waters. These are estimated to be submitted to journals for peer review in early 2018.

Interim results of this study were communicated to stakeholders and others on an ongoing basis throughout the project term, including:

(i) Yuma Safe Produce Council's Water 101 workshop in Yuma, AZ, in 2015 (40 attendees);
(ii) University of Arizona's School of Animal and Comparative Biomedical Science's "State of the Science for Irrigation Water" presentation in October 2016 (25 attendees);
(iii) SWESx (Department of Soil, Water and Environmental Science) Earth Week presentation at the University of Arizona in March 2016 (75 attendees) and March 2017 (75 attendees);
(iv) Arizona Water Association's Annual Research Workshop in Phoenix, AZ, in January 2017

(110 attendees);

(v) To the food safety audience at the annual Center for Produce Safety Research Symposium:
   a. Atlanta, GA, in June 2015 (245 attendees)
   b. Seattle, WA, in June 2016 (315 attendees)

Final research results were presented in June 2017 at the 8th Annual Center for Produce Safety Research Symposium in Denver, CO (325 attendees). The symposium participants included California regional and national growers/shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. These annual symposiums provided expert panels to critique the research results after presentation by the researcher, which helps participants evaluate how the results could be used in their respective businesses.

In addition, the final project results of this study were also conveyed to stakeholders via websites and social media:

(i) The project final report was posted on the Center for Produce Safety's website: http://www.centerforproducesafety.org/grant_opportunities_awards.php.
(ii) The project team also planned to post on the University of Arizona's Yuma Agricultural Center Facebook page (https://www.facebook.com/FoodSafety101) as well as the University of Arizona's Food Safety Consortium website (http://cals.arizona.edu/fsc/) in early 2018.
(iii) The Board of Directors and members of the Technical Committee of the Center for Produce Safety will distribute a series of informal briefs throughout the year online and through presentations, meetings and webinars.

All of the proposed goals were met for this project, which included:

(i) Development of a more accurate and quantitative method for the detection of fecal contamination in irrigation water by targeting novel indicator organisms.
(ii) Obtaining quantitative data regarding the level of fecal contamination present in irrigation water through the new viral target (pepper mild mottle virus, PMMoV).
(iii) Performing improved exposure assessments of fecal contamination found in the various irrigation waters.

The team was however, unable to collect the full number of samples originally proposed for the project due to some delays in the method development; 330 samples were collected out of 450 samples that were planned. Also, due to the numerous delays in the project, it was winter 2016 by the time the team was ready to sample in Georgia and Wisconsin. Water samples in Georgia were then collected, which included irrigation ponds that added diversity to the types of irrigation waters included in the study. But, unfortunately, it was no longer possible to sample from Wisconsin as the water was frozen over. Therefore, to meet the original plan to sample four regions, the region of Maricopa in Arizona was added to the project. Although both this region and Yuma are in Arizona, the waters in Maricopa came from a different source and were of a different quality than the water in Yuma. Maricopa sampling was included for this reason and also because Maricopa had historically higher levels and greater incidence of both bacterial pathogens (*Salmonella* and *E. coli*) and viral indicators, such as the pepper mild mottle virus, which were investigated during this study.
Major successful outcomes for the project included:

(i) Collection of 330 irrigation water samples from four regions in the United States.
(ii) Development of a practical method for detecting viruses in small volumes (3-liter samples

concentrated to 10 ml) of irrigation waters collected.

(iii) Identification of a human fecal virus (pepper mild mottle virus, PMMoV) that showed promise as an indicator of fecal contamination of irrigation waters.

(iv) Successful estimation of the amount of fecal contamination present in irrigation water in different regions based on measured levels of this fecal indicator virus.

(v) Use of these estimates of fecal contamination to perform a quantitative microbial risk assessment to determine the risks of foodborne illness from consumption of fresh produce irrigated with contaminated water based on these levels of fecal contamination for various pathogens (both bacterial and viral) of interest.

Beneficiaries

This project's accomplishments affected all specialty crop growers that needed to collect information regarding the quality of their irrigation water prior to its use in irrigating crops—this included over 2,000 growers in the Southwestern United States. For example, in Arizona there were 2,716 farms of produce crop growers, representing $764 million in sales in the state.

Beneficiaries of this project included growers, irrigation district managers, produce processing companies, consumers, and government agencies. The current study resulted in the development and evaluation of a novel sampling method for viruses in irrigation waters using small volumes that were feasible for collection by growers. In addition, the development of a more accurate and quantitative method for the detection of fecal contamination in irrigation water will provide the industry with a necessary tool to evaluate water quality through a more scientifically based approach targeting a novel indicator organism that better fits the definition of an effective indicator organism. With this information, growers and government agencies are provided a statically driven approach to setting limits of fecal contamination that is acceptable for irrigation purposes.

Lessons Learned

A key lesson learned was the importance of concentrating water samples in order to detect viruses. The team compared the recovery efficiency of the virus (filtered from water samples) by two methods and determined that research collaborators in other regions could send already concentrated water samples on filters on ice through the mail overnight without any appreciable loss of virus integrity. This resulted in a significant savings in shipping costs for the samples since it was not necessary to ship multiple liters of water per sample.

Many other lessons were learned from this project, including the following: Physical/chemical and microbial parameters of irrigation water could vary significantly between different regions. It was feasible to sample small volumes (~3 liters) of irrigation waters to detect indicator viruses that were found in high numbers in human and animal feces. These viruses could be used for the routine monitoring of irrigation water quality. The presence of fecal indicator viruses can point to changes in water quality and may correlate with the presence of pathogens. PMMoV was readily detected in irrigation water samples (between 34% and 63%) and could be used to estimate the amount of fecal contamination in the water. Cattle viruses did not appear to be good fecal indicators in irrigation waters in the regions included in the current study. Estimates of fecal contamination obtained using PMMoV could be used to perform a quantitative microbial risk assessment to determine the risks of foodborne illness caused by various pathogens as a result of consuming fresh produce irrigated with contaminated water. The QMRA performed in this study resulted in an extremely conservative estimate of risk. Future studies should try to develop data to fill the gaps between an irrigation event using contaminated water and the survival/persistence of specific pathogens between this event and subsequent

harvest, processing, transport, etc.

As mentioned previously, one unexpected outcome was that HA filters became clogged upon filtration of the 3-liter volumes from some irrigation water samples, which delayed much of the sample collection. The filtration method was eventually optimized with the use of a pre-filter, but the sampling delay, in turn, resulted in subsequent delays with the cultural and molecular analyses.

The Work Plan timeline had to be revised because of unexpected delay that arose from having to optimize the water filtration method to remove water components that were clogging the filters before the entire water volume could pass through, while still allowing smaller particles, such as viruses, to pass through. That delay affected the sampling schedule, sampling sites, and subsequent cultural and molecular analyses. Although the team had underestimated how significant differences in physical/chemical parameters of irrigation water among the different regions would affect the filtering method, the regional difference among irrigation waters was an important finding in the study.

Additional Information

Various assumptions were made when conducting the QMRA:

1. This risk assessment stops at the point of harvest and does not account for microbial decay post-harvest, microbial removal due to washing or sanitization, or other methods of microbial removal or decay post-harvest. As such, this is an extremely conservative approach.
2. Incorporated aspects of two irrigation systems. The volume of irrigation water that clings to one gram of lettuce was derived from dunking lettuce into water and assessing the volume it retains. This is somewhat representative of spray irrigation; however, it should be considered the most conservative approach of water exposure during spray irrigation. To incorporate parameters of a more realistic irrigation method for lettuce, the recorded viral transfer rates of a viral and bacterial surrogate during furrow irrigation were applied to the concentrations of pathogens within the irrigation water, whether observed or estimated. For example, the viral transfer rate recorded was 1.5%. Therefore, 1.5% of the observed adenovirus concentration was applied to the model.
3. Assumed that all observed viral genome copies detected by qPCR are infectious.
4. Applied known indicator/pathogen concentration ratios in sewage to estimate non-measured pathogen concentrations in irrigation water. Assumed the same die off rates (and all other relevant parameters) within the canal and irrigation system between indicator and pathogens.
5. Assumed a certain consumption volume per day, not annually.
6. Exposed group: adults aged 30 to <40 years
7. Assumed a single irrigation event with the contaminated water as the only input of pathogens to the produce surface.
8. Samples with values below the detection limit of the assays were assigned a value of $1x10^{-5}$ genome copies per liter.

Indicator organism selection: Because of its prevalence in irrigation waters in the current study, PMMoV was used as an indicator virus to estimate human fecal levels in the irrigation samples. PMMoV was abundant in human feces and was non-detectable in most animal feces, lending to its host specificity properties. It was nonpathogenic to humans, demonstrated weak seasonality, and was more resistant to environmental factors than bacterial indicators.

Pathogen selection and hazard identification: Enterovirus and adenovirus were selected for this risk assessment based on the hazard they pose to human health. Human adenovirus is pathogenic and can cause enteric, respiratory, and eye infections in humans. Enteroviruses can cause hand, foot, and mouth disease in humans. The pathogens of interest, norovirus, rotavirus, *E. coli* O157, and *Shigella*, were selected based on their negative impact on human health and annual cost of treatment; each of these pathogens poses a unique threat to human health. The high impact of each pathogen warrants further investigation into the risks posed by direct exposure to irrigation water contaminated at estimated levels.

Exposure assessment: This risk assessment assumed an adult aged 30 to <40 years consuming lettuce irrigated with water contaminated at the levels observed or estimated for either the observed pathogens (adenoviruses and enteroviruses) or the estimated pathogen of interest. The dose (λ) received was calculated using the following equation, modified from a dose calculation previously recorded by Hamilton et al. (2006) to include a pathogenic transfer rate recorded by Stine et al. (2005):

$$\lambda = M_i M_b (p * c_{iw}) V_{prod} e^{(-k_{Viral\ decay} t)}$$

Where M_b = human body mass (kg), M_I = daily consumption per capita per kg body mass (g/kg*ca*day), p = percent pathogen transfer from irrigation water to the surface of lettuce, c_{iw} = concentration of enteric viruses in the irrigation water (PFU/ml), V_{prod} = volume of irrigation water captured by the product, k = kinetic virus decay constant, and t = time between the irrigation event and harvest. This equation is for a single irrigation event with the contaminated water as the only input of pathogens to the produce surface. The information for each of these variables for the exposure assessment is provided in Table 5.

Table 5. Values for variables used in the exposure assessment.

Variable	Variable Description	Value	Reference
M_i	Body mass (kg) of adult aged 30 to <40 in the US	80.8kg	USEPA 2011a
M_b	Lettuce consumed daily per capita per kg body mass of adult aged 30 to <40 in the US	0.23g	USEPA 2011b
c_{iw}	Concentration of viruses in irrigation water (copies/ml)	Observed or estimated for this study	
V_{prod}	Volume of irrigation water captured by the produce (ml/g)	0.108	Hamilton et al. 2006
p	Percent transfer of pathogen content in water to the produce surface	$1.5x10^{-2}$ based on viral surrogate PRD1 $7.0x10^{-5}$ based on bacterial surrogate *E. coli* 25922	Stine et al. 2005
$k_{Viral\ decay}$	Kinetic virus decay constant (per day)	0.69 (general viral) 0.35 (applied to bacterial: based on *Salmonella* die-off rates)	Hamilton et al. 2006 Stine et al. 2005
t	Time between last irrigation and harvest (days)	4 days	Recommended by FSMA for water of inadequate quality

Dose-response assessment: Each pathogen, measured and estimated, was recommended to best fit either the exponential model or the beta-Poisson model (Table 6). Norovirus was assigned the exponential model as previously recorded due to limited knowledge of norovirus dose-response behavior (Masago et al. 2006):
Exponential response model:

$$P(response) = 1 - \exp(-k \times \lambda)$$

Beta-Poisson response model:

$$P(repsonse) = 1 - \left[1 + \lambda \frac{(2^{\frac{1}{\alpha}} - 1)}{N_{50}}^{-\alpha}\right]$$

Table 6. Models and best fit parameters for each pathogen. All parameter and best fit models were based on the QMRAwiki (accessed 12 March 2017 http://qmrawiki.canr.msu.edu), unless otherwise specified.

Pathogen	**Best Fit Model**	**Optimized Parameters**	**LD_{50}/ID_{50}***	**Response**
E. coli EHEC	Exponential	$k=2.18\times10^{-4}$	3.18×10^{3} CFU	shedding in feces
Shigella	Beta-Poisson	$\alpha=2.65\times10^{-1}$, $n=1.48\times10^{3}$	1.4×10^{3} CFU	positive stool isolation
Rotavirus	Beta-Poisson	$\alpha=2.53\times10^{-1}$, n=6.17	6.17 FFU	infection
Norovirus	Exponential	k=-log $0.5/ID_{50}$ ID_{50} was set to 10 (10 was selected to lower the ID_{50} and therefore create a more conservative estimate of risk	10	infection
Adenovirus	Exponential	$k=6.07\times10^{-1}$	1.14×10^{0}	infection
Enterovirus	Exponential	$k=1.85\times10^{2}$	1.85×10^{2}	infection

* LD_{50} = lethal dose 50%; ID_{50} = infectious dose 50%

Risk analysis: The risk assessment was run using the Simulación 4.0 add-on for Excel. Each described scenario was run for a total of 10,000 iterations. Adenovirus and enteroviruses were below the limit of detection in 98.7% and 91.5% of the samples, respectively. The samples with non-detectable viral pathogen levels were given a small, non-zero value of 1×10^{-5} to demonstrate the potential undetected virus, but with the very low possibility of it being present. For each observed viral pathogen, the previously described best-fit models and parameters were applied to the portion of the population that was below the detection limit of the assays. Given that all pathogens were estimated at the same value (1×10^{-5}), the model was run using a single point estimate.

The detectable adenovirus and enterovirus risk assessment was run using the previously described best-fit models and parameters. Using a Monte Carlo simulation, the risk model was run a total of 10,000 iterations,

randomly selecting from the distribution of the viral pathogen. Adenovirus-positive samples exhibited an inverted gamma distribution. The positive enterovirus population was assigned a normal distribution that was truncated at the 1st and 99th percentile during the Monte Carlo analysis. Pathogen concentrations based on fecal contamination estimation were run using the previously assigned best-fit models and parameters. Each concentration range was sampled using Monte Carlo simulation.

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CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
59	Improving Pasteurization Validation Methods for Pistachio Processing	
Grant Recipient: The Center for Produce Safety	**Grant Agreement No.:** SCB14059	**Date Submitted:** December 2017
Recipient Contact: Bonnie Fernandez-Fenaroli	**Telephone:** (530) 554-9761	**Email:** bonnie@centerforproducesafety.org

Project Summary

Microbial safety of low-moisture foods is a particularly difficult challenge, as reflected in recent outbreaks and recalls associated with *Salmonella*-contaminated nuts and other low-moisture products. Therefore, processing interventions are an emerging imperative to reduce the risk of *Salmonella* in low-moisture products, including pistachios. The new Food Safety Modernization Act (FSMA) Preventive Controls for Human Food rule mandates that the low-moisture food industry implement and validate interventions against identified hazards such as *Salmonella*. Although a number of pathogen-reduction technologies are available to the pistachio industry (e.g., dry heat, steam, radio-frequency), there are several significant problems: (1) no single technology will be universally applicable, so that product-specific and scalable solutions are needed; (2) the cost of stand-alone pasteurization technologies is an impediment to small processors; and (3) robust validation protocols have not been widely tested or disseminated. Therefore, the overall goal of this project was to improve the methods for validating pathogen-reduction processes for pistachios, with particular attention to improving existing processes and enabling processors to reliably validate those processes.

Compliance dates after which food processors must meet the FSMA Preventive Controls for Human Food are August 2016, 2017, or 2018, depending on the size of the facility (e.g., very small processors are given the longest deadline for compliance). Consequently, the need for improved methods to validate both pistachio roasting and stand-alone pasteurization systems is particularly urgent. The results of this project are essential to ongoing efforts to provide the required scientific data, guidance documents, training resources, and direct assistance that the pistachio industry will need to comply with the new rules. In particular, the project team is continuing to work, beyond the end of the project, in ensuring that project results are transferred into the industry to enhance process control, monitoring, and validation, particularly for small or very small processors that might lack existing in-house expertise for process validations.

The project Co-Principal Investigator (PI) has led several recent Specialty Crop Block Grant Program (SCBGP) funded projects that directly led to and supported this current project. This project built upon the following three projects: 2009 SCBGP Project 54: *Assessing Postharvest Risks for Salmonella in Pistachios*, 2011 SCBGP Project 66: *Distribution of Salmonella in Pistachios and Development of Effective Sampling Strategies*, and 2013 SCBGP Project 59: *Assessing Postharvest Food Safety Risks and Identifying Mitigation Strategies for Foodborne Pathogens in Pistachios*. The 2009 SCBGP Project 54 resulted in a quantitative microbial risk assessment (QMRA) for pistachios. Using conservative estimates, that study concluded that an overall mean number of cases of pistachio-linked salmonellosis per year in the United States would be less than one if a uniform 4 ± 0 log (but not a 3 ± 0 log) reduction were applied to 100% of the domestic product. However, that conclusion increased to >1 case per year when variability in the pathogen-reduction step increased to a 4 ± 1 log reduction. Obviously, there is no such thing as ± 0 uncertainty in real-world processes; however, no prior study has reported direct testing of that variability and uncertainty. The lethality uncertainty values reported in the present study suggest that a 1-log uncertainty in lethality outcome is not an

unreasonable estimate of the actual results associated with real-world process validations, thereby directly supporting the analysis and assumptions of that prior study.

The 2011 SCBGP Project 66 and 2013 SCBGP Project 59 both generated preliminary data comparing the thermal resistance of *Salmonella* isolates from pistachios, and comparing thermal resistance of *Salmonella* and *Enterococcus faecium* (a non-pathogenic surrogate) on pistachios. These prior results were critically important in designing the specific treatments and selecting the *Salmonella* strain used in the present study.

Project Approach

The work plan encompassed (1) laboratory-scale experiments subjecting *Salmonella*-inoculated pistachios to a range of thermal (oven) treatments; (2) development of mathematical models to describe *Salmonella* inactivation in terms of product temperature, moisture, humidity, and time; (3) pilot-scale roasting experiments with pistachios inoculated with *E. faecium* or *Salmonella*; and (4) development of process validation guidelines.

Methods – Laboratory-Scale Experiments:
Pistachios were equilibrated to different moisture contents (or water activities, a_w), and then either directly thermally treated, or first subjected to a presoaking process (to mimic commercial brining) and then thermally treated (Figure 1 - see Attachment). Various levels of process temperatures and humidities were used. Upon completion of thermal treatment, *Salmonella* survivors, product a_w, and moisture content were all quantified, and a statistical model was applied to determine the impact of the different product and process factors evaluated.

Raw, in-shell pistachios (21/25 US#1) were obtained from a commercial processor and stored at 4°C for up to three months prior to use in the study. Pistachios were inoculated with *Salmonella* Enteritidis phage type 30 (ATCC BAA-1045), which was previously shown to be thermally resistant in almond products and to have a similar thermal resistance to strains isolated from pistachios (*S.* Montevideo and *S.* Senftenberg). Pistachios were inoculated according to previously published methods, with minor modifications.

The inoculated pistachios were held in computer-controlled humidity chambers (3+ days) to equilibrate the samples to target moisture levels (0.45 and 0.65 a_w, corresponding to 6.0%±0.2% and 8.9%±0.2% moisture content, dry basis). Initial *Salmonella* populations, immediately prior to thermal treatments, were 8.5±0.5 log CFU/g across all inoculated batches. For samples that received a presoak treatment, inoculated pistachios were immersed for 30 seconds in either deionized water or a 27% NaCl solution, drained of excess liquid, then immediately heated. This process, for the NaCl solution, matched a typical commercial brining process.

Thermal treatments were conducted in a custom, laboratory-scale, moist-air convection oven system. Treatments were divided into two categories, dry and pre-soaked, with six oven conditions per category, run in duplicate (Figure 2 – see Attachment). Samples were treated at two process temperatures (104.4 and 118.3°C), three process humidities (~3%, 15%, and 30% moisture by volume, corresponding to dew points of 24.4, 54.4, and 69.4°C, respectively) and one commercially-relevant air velocity (1.3±0.2 m/s) for a total of six treatments in duplicate for each of the two treatment categories. Treatments were randomized within each replication.

Product surface temperature, product a_w, product moisture content, process temperature, and process dew point were monitored throughout the process. For each treatment condition, samples were heated for six equally spaced durations, for a total treatment time nominally aimed to achieve a 3- to 5-log reduction of *Salmonella*. After heating, samples were analyzed for microbial survivors (on appropriate differential media), a_w, and moisture content.

Methods – Mathematical Model Development

In addition to statistical analyses, the data from the laboratory-scale trials also were used to develop/test multiple microbial inactivation models, which are mathematical equations that predict microbial inactivation as a function of process and product conditions over time. The models predicted D-value, a measure of bacterial thermal resistance defined as the time to reduce a bacterial population by 90% under specific conditions.

The five models tested were the modified Michigan State University (MSU) model:

$$D_{T,T_d}(t) = D_{ref} \times 10^{\frac{T_{ref}-T(t)}{z_T}+\frac{(T_{d,ref}-T_d)-(T_{ref}-T(t))}{z_M}} \quad (1)$$

A traditional log-linear temperature model that incorporates log-linear a_w effects:

$$D_{T,a_w}(t) = D_{ref} \times 10^{\frac{T_{ref}-T(t)}{z_T}+\frac{a_{w,ref}-a_w(t)}{z_{a_w}}} \quad (2)$$

A similar model, replacing a_w with moisture content (MC):

$$D_{T,MC}(t) = D_{ref} \times 10^{\frac{T_{ref}-T(t)}{z_T}+\frac{MC_{ref}-MC(t)}{z_{MC}}} \quad (3)$$

The modified MSU model, incorporating the log-linear form for a_w:

$$D_{T,T_d,a_w}(t) = D_{ref} \times 10^{\frac{T_{ref}-T(t)}{z_T}+\frac{(T_{d,ref}-T_d)-(T_{ref}-T(t))}{z_M}+\frac{a_{w,ref}-a_w(t)}{z_{a_w}}} \quad (4)$$

A similar model, replacing a_w with MC:

$$D_{T,T_d,MC}(t) = D_{ref} \times 10^{\frac{T_{ref}-T_s(t)}{z_T}+\frac{(T_{d,ref}-T_d)-(T_{ref}-T_s(t))}{z_M}+\frac{MC_{ref}-MC(t)}{z_{MC}}} \quad (5)$$

Each model was evaluated in terms of its accuracy and a measure of accuracy relative to complexity (i.e., simpler is better when possible.)

For each parameter, the 95% confidence interval and percent relative error were calculated. Also, each overall model fit was evaluated by the root mean squared error (RMSE) and the corrected Akaike Information Criterion (AIC_C). A lower RMSE indicated a smaller error. A lower AIC_C, when comparing two candidate models, indicates the more-likely-correct model.

Methods – Pilot-Scale Experiments

For the pilot-scale experiments, the same sample preparation, equilibration, inoculation, and enumeration procedures were followed as for the laboratory-scale treatments. A pilot-scale, moist-air impingement oven in the MSU Biosafety Level-2 Pilot Plant (Figure 3 – see Attachment) enabled simulation of commercial-scale thermal processing conditions with controlled temperature, humidity, air velocity, and conveyor speed through the oven. In-shell pistachios were inoculated *Salmonella* Enteritidis PT30 or *Enterococcus faecium* (NRRL B-2354), using methods previously reported. *E. faecium* strain NRRL B-2354 has a long history of use for validation of thermal processes for almonds and other foods. This *E. faecium* strain was chosen as the

non-pathogenic surrogate on pistachios because it was shown to have similar thermal resistances as *Salmonella* on in-shell pistachios in hot oil or hot water (previous study). The inoculated pistachios were placed in a single layer on the conveyor. Four treatments were replicated six times, nominally targeting a 4-log reduction in *Salmonella*. The four treatments (all at 118ºC air temperature) were: (1) dry/unbrined nuts in dry air (~16ºC dew point); (2) dry/unbrined nuts in humid air (69ºC dew point); (3) salt brined nuts in dry air (~16ºC dew point); and (4) salt brined nuts in humid air (69ºC dew point). The bacterial survivor data, dynamic product temperature, dynamic product moisture content, and process humidity were used to validate the models previously described, compare the surrogate and pathogen outcomes, and quantify process variability.

Methods – Guidance Documents

The project had industry cooperation from Horizon Nut, Buchanan Hollow Nut Company, and the Administrative Committee on Pistachios. Horizon Nut provided critical information, data, and materials for this project. Specifically, they provided: (1) the pistachios used for the project; (2) the range of typical brining and roasting conditions, which were used in designing the lab- and pilot-scale thermal treatments; and (3) commercial-scale validation data and reports, which the team has used to evaluate typical process parameters being measured in validation studies and the degree of variability in the reported outcomes. Horizon Nut hosted the project team for two on-site visits and tours of their processing operations, which was extremely helpful in getting the project team up-to-speed on critical factors in flat-bed roasting and pasteurization operations. Buchanan Hollow Nut also hosted the project team for two on-site visits/tours. They provided information and data on operational conditions for rotary roasters, which was helpful in assessing the potential impact of the project research results on different types of roasting systems and different scales of processing operations. The Administrative Committee on Pistachios also organized and hosted a meeting of industry representatives in July 2016, in which the project team reported preliminary project results and collected feedback from industry representatives on the relevance and application of those results.

The validation guideline documents have been prepared following the general outline and structure of multiple validation guidelines published by the Almond Board of California. Those guidelines have been in place and updated over a number of years, and are widely referenced in the low-moisture industry. However, they are designed specifically for almond processes. Therefore, the information collected from the industry partnerships in this project, and the research results that have been generated, were used to draft pistachio-specific guidance documents for carrying out validations of pathogen-reduction processes.

Results – Laboratory-Scale Experiments

The overall experimental design resulted in ~144 microbial inactivation results across all the treatments. Each treatment entailed dynamically increasing pistachio temperature, decreasing moisture pistachio moisture, and declining *Salmonella* populations (Figure 4 – see Attachment).

Overall, the results indicated that increasing temperature, humidity, and brining (presoaking) increased *Salmonella* inactivation during hot-air heating (Figure 5 – see Attachment). The statistical significance of each of these effects was confirmed through Analysis of Variance (ANOVA) tests ($P < 0.05$). Specifically, increasing process humidity from dry to ~30% moisture by volume (69ºC dew point) approximately doubled the *Salmonella* lethality (Figure 5a). In contrast, the initial water activity (or moisture content) of the pistachios did not affect the lethality outcomes within the dry roast or brined treatments (Figure 5b), suggesting that process humidity was more important than product moisture in affecting process lethality.

Additionally, brining the pistachios for 30 seconds prior to thermal treatment approximately doubled the rate of *Salmonella* reduction during heating (Figure 5c). However, there was no difference between the pure water control and the 27% salt brine (Figure 5d), indicating that the presence of salt in the presoaking treatment did not affect *Salmonella* inactivation during heating. Lastly, process lethality did increase with oven air temperature (104 vs 118ºC) (Figure 5e), although that effect (in the range of the study conditions) was smaller than the humidity or brining effects.

Results – Mathematical Models
The most appropriate secondary model for each set of data, dry or presoaked, was chosen from a selection of the five models that quantify the D-value as a function of temperature combined with process humidity, product moisture (a_w or percent moisture content, dry basis), or both (equations 1–5). A single model could not be fit for both dry and presoaked pistachios as a whole dataset; rather, the data were partitioned into dry and presoaked, and models were fit to each of those categories separately.

Based on the model fitting results (Tables 1–2 – see Attachment), all the candidate models worked reasonably well, with root-mean-square errors (RMSE) ~1.0 log or less. The MSU model (equation 1) is based on only process humidity and dynamic product temperature, but it yielded satisfactory results, with RMSE of 0.86 and 1.02 log CFU/g for the dry and presoaked pistachios, respectively. Based on the AIC_C results, the overall most-likely-correct model was equation 5, which predicts D as a function of product temperature, product moisture content, and process dew point. In dry pistachios, the AIC_c values for equation 4 (with the a_w term) and equation 5 (with a moisture content term) were similar; however, in presoaked pistachios, the AIC was lower for equation 5 than equation 4, suggesting that moisture content is a better metric for describing *Salmonella* inactivation in this type of system. For these reasons, equation 5 was determined to overall be the most likely correct model.

These models are the first published attempt to model *Salmonella* inactivation in a low-moisture food as a function of two dynamic variables (temperature and moisture). In addition, due to the nature of the high-moisture presoak condition, a_w was not the best metric for modeling *Salmonella* lethality. Within the range of conditions evaluated, the model parameters generally fell within reasonable expectations based on published data. However, due to the highly variable nature of the data gathered for presoaked pistachios, caution is advised if this model is to be used for process validations. In general, the models developed were conservative in their lethality predictions; however, some systematic process effects were observed.

Results – Pilot-Scale Experiments
The pilot-scale experiments were designed to compare the non-pathogenic surrogate (*E. faecium*) with *Salmonella*, to quantify lethality variability, and to test model performance. Overall, both the model (equation 5) and the surrogate were extremely conservative predictors of actual *Salmonella* lethality overall all the treatments (Figure 6 – see Attachment).

Specifically, *E. faecium* under-predicted actual *Salmonella* by a mean value of 2.1 logs. All but one individual test yielded conservative predictions, and that single replication was within 0.06 log. In terms of process variability, the standard deviation of actual *Salmonella* lethality was 1.5 logs, which is a large, but potentially realistic measure of actual process variability that might occur in a commercial system. In terms of the predictive model, there again was a significant conservative bias (~2.2 logs) in predicting the actual *Salmonella* lethality. This was the application of the model (and parameters) estimated from the lab-scale

experiments directly to the pilot-scale results. In a recent study by the project PI, the same overall process was followed for almond roasting/pasteurization, and that study yielded similar variability but much closer predictions of pilot-scale outcomes. It is likely that the shell on the pistachio impacts the scalability and applicability of lab-scale inactivation results to pilot- or commercial-scale processes, due to the impact on airflow, water transport, etc.

Results – Guidance Documents
Four guidance documents have been drafted and are ready for industry evaluation and testing, as follows:

Guidelines for Validation of Pistachio Pathogen Reduction Processes
1. Biological Hazard Analysis for Pistachios
2. Guidelines for using *E. faecium* in pistachio process validation
3. Guidelines for validation of pistachio dry processes
4. Example validation report

A meeting has been scheduled in the near term with food safety professionals in the pistachio industry, to solicit feedback on the format and content of these guidance documents.

Although the research term of this project is officially ended, and the proposed research tasks have been completed, the PI and the University of California, Davis (UCD) Co-PI will continue to work on pathogen reduction processes for pistachios well beyond the end of this project, in at least the following ways:

The UCD Co-PI met with pistachio industry food safety leaders in March 2017, to solicit feedback on the guidance documents, in terms of content, format, etc. The Co-PI and PI intend to carry out on-site testing of the validation guidance documents with (hopefully) two industry partners: one medium/large and one very small processor. The goal will be to “debug” the guidance documents and prepare them for industry-wide/public release.

The PI presented interim research results at the 2016 Center for Produce Safety (CPS) Research Symposium in Seattle, Washington.

The overall scope of the project only benefitted specialty crop commodities, specifically pistachios.

The project partners are the CPS and MSU. CPS managed the project while the PI and Co-PI at MSU performed the research studies in conjunction with the UCD Co-PI.

In addition the project had the support of Horizon Nut (Tulare, California), Buchanan Hollow Nut Company (Le Grand, California), and the Administrative Committee on Pistachios. Horizon Nut provided critical information, data, and materials for this project, and they hosted the project team for two on-site visits and tours of their processing operations, which was extremely helpful in getting the project team up-to-speed on critical factors in flat-bed roasting and pasteurization operations. Buchanan Hollow Nut also hosted the project team for two on-site visits/tours, and they provided information/data on operational conditions for rotary roasters, which was helpful in assessing the potential impact of the project research results on different types of roasting systems and different scales of processing operations. The Administrative Committee on

Pistachios organized and hosted a meeting of industry representatives in July 2016, in which the project team reported preliminary project results and collected feedback on the relevance and application of those results.

Goals and Outcomes Achieved

All of the laboratory-scale experiments, microbial inactivation model development, and pilot-scale experiments were completed as proposed. Additionally, draft validation guideline documents have been completed. Project results have been communicated via conference presentations, a completed Master of Science thesis, a presentation at the 2017 CPS Research Symposium, and multiple peer-reviewed journal articles.

The long-term goal of the project is to significantly increase the percentage of pistachio roasters validated for pathogen reduction outcomes. Over the course of the project, through interaction with our industry collaborators, and with other industry connections via the Administrative Committee on Pistachios, it has become clear that: (1) certain types of roasters (i.e., flat-bed) are significantly less likely to meet targeted pathogen reduction without the addition of stand-alone pasteurization units or the modification of existing roasters; and (2) there remains significant variability across the industry, in terms of capabilities to meet this goal (and to comply with the FSMA Preventive Controls rules). The project PI and UCD Co-PI remain committed to translating the project results, carrying out implementation of the validation guideline documents, and assessing the long-term impact on the pistachio industry. Although not stated in the project proposal, it is a goal to provide information, tools, and assistance that are instrumental in reducing (or hopefully eliminating) pistachio-linked salmonellosis outbreaks in the next few years.

The objectives of this project included:

1. To develop and test process modifications suitable for existing processing equipment (e.g., flat bed or rotary roasters) that could improve achievement of preventive controls (i.e., log reductions of *Salmonella*), particularly aimed at achieving lowest-cost solutions for smaller processors.
    a. To quantify the interaction of salt, product water activity, and temperature on inactivation of *Salmonella* during pistachio dry roasting.
    b. To quantify the impact of dynamic humidity control on *Salmonella* lethality during pistachio dry roasting.
    c. To validate the findings from 1a and 1b via pilot-scale, *Salmonella*-inoculated flat-bed roasting studies in the MSU Biosafety Level-2 Pilot Plant.

2. To develop, test, and disseminate a “Guidelines for Validation of Pistachio Pathogen Reduction Processes” document to help processors effectively validate various treatments, including dry roasting and thermal pasteurization, via either time-temperature calculations or the use of a non-pathogenic surrogate (*Enterococcus faecium*).
    a. To quantify, via pilot-scale and commercial-scale testing, the inherent process variability in pistachio pasteurization and roasting operations.
    b. To verify *E. faecium* as a non-pathogenic surrogate for Salmonella via inoculated pilot-scale roasting trials.
    c. To develop a science-based validation guidelines procedure that accounts for both process variability and lethality uncertainty to generate statistically-sound validation outcomes.
    d. To introduce and test the validation guidelines via a full-scale field demonstration test at one or more commercial pistachio facilities (with the industry collaborators).

Project objectives 1 (a–c) and 2 (a–c) were all achieved as proposed. However, objective 2 (d) has not yet been completed. The validation guideline documents for objective 2 were completed, but the field testing and demonstration as well as the industry-wide dissemination have not yet occurred. The PI and UCD Co-PI are committed to leveraging resources to continue working toward achieving these specific accomplishments.

The ultimate target outcome was to significantly increase the percentage of pistachio roasters validated for pathogen reduction outcomes across the industry (i.e., validation of 50 percent of the existing flat-bed roasters). The team was optimistic, at the start of the project, in the ability to directly and quantitatively assess whether this specific target was met. However, during the project period the data collected did not enable the team to quantify this metric. Nevertheless, the project team continues to work on this overall project and ultimately hopes to assess impact via future outreach activities and data collection. The project staff collected, via industry partners, some preliminary data to analyze variability across flat-bed and rotary roaster outcomes. These data have indicated that flat-bed roasters achieve lower mean lethality (i.e., less than four logs) but a much more consistent outcome. In contrast, rotary roasters (i.e., batch processes) appear much more feasible to achieve process lethality greater than four logs; however, the variability in outcomes is on the order of three times greater than with flat-bed roasters. These data support the importance of understanding process variability and uncertainty associated with process validation tools, such as the models and surrogate organisms tested in this project.

This project has generated significant new findings that are important to the pistachio industry, relative to factors affecting pathogen reduction in thermal processes. The key findings and recommendations are as follows:

1. Process humidity significantly enhances pathogen lethality. Pistachio processors should consider monitoring, and perhaps ultimately controlling and enhancing, humidity in the early stages of multi-stage roasting processes, in order to enhance the efficacy of roasting as a pathogen reduction step.
2. Brining significantly enhances pathogen reduction during roasting (by as much as double). For roasted, unsalted pistachios, a water pretreatment of some type might be considered, in order to enhance process efficacy. Dry/unbrined nuts in dry roasting conditions yielded, in several conditions, nearly negligible pathogen reduction on the time scales relevant to pistachio roasting.
3. Initial moisture content may not be a significant factor in process lethality. Although the data are not yet sufficient to preemptively exclude pistachio moisture content as a critical factor in process validations, they do suggest that, for certain hot-air treatments, it might be possible to do so (with additional supporting evidence).
4. The non-pathogenic surrogate (*E. faecium*) appears to be a very conservative tool for validating pistachio hot-air/roasting processes. Prior work by the project UCD Co-PI has shown a very close correlation between *E. faecium* and *Salmonella* thermal inactivation in water and oil; however, this study suggests that there is a significantly conservative difference in the hot-air treatments.
5. The predictive microbial inactivation model worked similarly well, with conservative predictions of lethality. Although not yet sufficient to be the sole tool for a process validation, the predictive model may be a useful tool for evaluating equipment/process modifications (e.g., to improve monitoring and control of existing roasters to support process validations) and for designing validation studies.
6. The pilot-scale data on lethality uncertainty informs the quantitative microbial risk assessment (QMRA) being published by the project UCD Co-PI. Using conservative estimates, that study concluded that an overall mean number of cases of pistachio-linked salmonellosis per year in the U.S. would be less than one if a uniform 4 ± 0 log (but not a 3 ± 0 log) reduction were applied to 100% of the domestic product.

However, that conclusion increased to >1 case per year when variability in the pathogen-reduction step increased to 4 ± 1 log reduction. Obviously, there is no such thing as ± 0 uncertainty in real-world processes. Therefore, the lethality uncertainty values reported in the present study suggest that a 1-log uncertainty in lethality outcome is not an unreasonable estimate of the actual results associated with real-world process validations. It is critically important that process controls, monitoring, and variability are properly incorporated into validation strategies for any pathogen reduction process, and that the industry continues to seek ways to maximize the reliability of those processes.

Beneficiaries

The North American pistachio industry is the primary beneficiary of the results and outcomes from this project. Specifically, this includes processors and ultimately the process authorities who provide validation services to the industry.

California produces 99% of the domestic pistachios (a record crop in 2016 of over 900 million pounds, nearly double the prior record year). There are more than 950 pistachio growers and 24 pistachio processors in the United States. The seven largest processors (all in California) account for over 97% of the total volume produced; the remaining 3% of the crop is spread over 17 much smaller processors. These processors typically need greater assistance in developing food safety plans and validating the performance of processing equipment; our novel research results (including pilot-scale validations), and forthcoming guidelines document, are particularly important to this portion of the industry.

The PI from MSU presented the final research results in June 2017 at the 8th annual CPS Research Symposium in Denver, Colorado to 325 symposium attendees. Interim results were presented previously in an oral presentation at the 2016 CPS Research Symposium in Seattle, Washington (315 attendees), and in a poster session at the 2015 CPS Research Symposium in Atlanta, Georgia (245 attendees). The symposium participants included California regional and national growers/shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provides expert panels to critique the research results after presentation by the researcher, which helps participants evaluate how the results can be used in their respective businesses.

Project results will be disseminated at industry meetings, and streamed through social media sources. Results also will be made available online as follows:

1. Final reports submitted to CPS will be posted on the CPS website: https://www.centerforproducesafety.org/grant_opportunities_awards.php.
2. CPS works with the scientists to publish results in scientific journals. Publication dates occur after the project is completed. Abstracts and awards can be found on the CPS website.
3. The Board of Directors and members of the Technical Committee of CPS distribute a series of information briefs throughout the year on the website and through presentations, meetings and webinars. An example of this would be the “CPS 2016 Research Symposium Key Learnings” on the CPS website at the following link: http://www.centerforproducesafety.org/amass/documents/document/365/CPS%202016%20Key%20Learnings.pdf.

The following websites provide additional resources on the final reports and symposium proceedings:
Center for Produce Safety: http://www.centerforproducesafety.org/resources.php
Produce Marketing Association: http://pma.com
Western Growers Association: http://www.wga.com

Lessons Learned

Overall, coordination of the project between two institutions and the industry collaborators went extremely well. The increasing ease and quality of virtual meeting tools make sharing of project results and discussion of project activities fairly seamless. Having said that, the project would have benefited from an upfront agreement or plan to hold regularly scheduled (e.g., monthly) project update briefings with the project team and collaborators (rather than the *ad hoc*/on-demand approach that was used). Although communications among the project parties was effective and responsive, pre-scheduled meetings would have enhanced progress and translation of the project results to the industry collaborators.

There were no major unexpected outcomes in the project. The research component did generate extremely novel and unique results that are significantly important to the stakeholder industry; however, they did not alter implementation of the project.

The two components of the project previously identified as incomplete will be completed by the PI and UCD Co-PI after the end of this project, via leveraging resources. One cause simply was greater time required than expected in completing pilot-scale testing and developing the guidance documents. The project team had excellent interactions with the industry collaborators; however, as noted above, regularly pre-scheduled briefings with the project partners likely would have further enhanced progress.

Additional Information

See Attachment for Figures and Tables.

Thesis, presentations, and articles resulting from this project:

1. Casulli KE. 2016. Improving pathogen-reduction validation methods for pistachio processing. M.S. thesis. Department of Biosystems and Agricultural Engineering, Michigan State University, East Lansing, MI.
2. Casulli KE, Dolan KD, Marks BP. 2016. Performance of *Enterococcus faecium* as a nonpathogenic surrogate for *Salmonella* during pistachio roasting. Abstract 17. Presented at the Conference on Food Engineering. Columbus, OH. September 12–14, 2016.
3. Casulli K, Garces-Vega F, Dolan K, Harris LJ, Marks B. 2016. Modeling the effect of product temperature, moisture, and process humidity on thermal inactivation of *Salmonella* in pistachios. Abstract P2-19. Presented at the Annual Meeting of the International Association for Food Protection. July 31 – Aug 3, 2016. St. Louis, MO.
4. Casulli, KE, Garces-Vega FJ, Dolan KD, Marks BP. 2016. Impact of temperature, moisture, and humidity on thermal inactivation of *Salmonella* in pistachios heated under dynamic processing conditions. Presented at the XIII Latin American Congress of Microbiology and Food Hygiene. September 27–30, 2016. Medellín, Colombia.
5. Harris LJ and Marks BP. 2016. The impact of water and product composition on pathogen survival and inactivation. Symposium S21. Presented at the IAFP European Symposium on Food Safety. May 11–13, 2016. Athens, Greece.

6. Marks BP. 2016. Validating legacy processing systems: application of thermal resistance data and models to predict log reductions in dynamic processes. Symposium 096. Presented at the Annual Meeting of the Institute of Food Technologists. July 19, 2016. Chicago, IL.
7. Casulli KE, Dolan KD, Marks BP. 2017. Modeling the effect of product temperature, moisture, and process humidity on thermal inactivation of *Salmonella* on pistachios during hot-air heating. *Journal of Food Protection.* To be submitted.
8. Casulli KE, Garces-Vega FJ, Dolan KD, Harris LJ, Ryser ET, Marks BP. 2017. Impact of process temperature, humidity, and initial product moisture on thermal inactivation of *Salmonella* Enteritidis PT30 on pistachios during hot-air heating. *Journal of Food Protection.* To be submitted.

/USDA Project No.:	Project Title:	
60	Improved Sampling and Analytical Methods for Testing Agricultural Water for Pathogens, Surrogates and Source Tracking Indicators	
Grant Recipient: The Center for Produce Safety	**Grant Agreement No.:** SCB14060	**Date Submitted:** December 2017
Recipient Contact: Bonnie Fernandez-Fenaroli	**Telephone:** (530) 554-9761	**Email:** bonnie@centerforproducesafety.org

Project Summary

Irrigation water must be of adequate sanitary quality prior to application to food crops in order to limit potential human health risk associated with exposure to waterborne pathogens. Currently, produce growers evaluate irrigation water quality using the fecal indicator bacteria, *Escherichia coli (E. coli)*. *E. coli* is commonly used as an indicator of fecal contamination in drinking water and recreational water because it is considered fecal-specific and can be detected and quantified using simple methods. However, *E. coli* may not be an appropriate indicator for parasites, viruses or even other bacterial pathogens in water. For example, male-specific (F+) coliphages (bacteriophages that infect *E. coli*) are often cited in the literature as more appropriate indicators for viral pathogens given similarities in size, physical and genetic characteristics and survival in the environment [1, 2]. Additionally, by relying on a single microbe, such as *E. coli*, as a determinant of water quality, produce growers may be underestimating the risk associated with use of some agricultural water sources. Current guidelines for periodic *E. coli* monitoring use a geometric mean (GM) cutoff of 126 MPN/100 mL and statistical threshold value (STV) of 410 MPN/100 mL to characterize microbial water quality. However, evidence is lacking to demonstrate whether these *E. coli* standards accurately reflect the presence of foodborne pathogens in irrigation water. Detection of generic *E. coli* also does not provide information regarding potential sources of contamination, making the development of targeted contamination prevention controls and mitigation strategies difficult. Microbial source tracking (MST) markers, which include various human- and animal-specific microbes and genetic markers, can be used to determine potential sources of contamination in a water supply. Determination of contamination inputs could help guide prevention and mitigation plans.

In addition to water quality monitoring using microbial indicators, producers and food safety investigators need sensitive testing techniques for detecting pathogens associated with disease outbreaks or identifying produce contamination. Pathogens and alternative microbial indicators can be present in low concentrations, necessitating the collection of large-volume water samples. Hollow-fiber ultrafiltration (UF) utilizes dialysis filters to concentrate bacteria, parasites, and viruses simultaneously in water samples. UF represents a cost-effective technique for co-concentrating diverse microbe types in large volume (10–100 liter) water samples. Two approaches to UF have been developed in recent years: tangential-flow and dead-end. Tangential-flow UF recirculates water samples through the ultrafilter while collecting the sample concentrate in a separate 1 liter bottle. While tangential-flow UF has been shown to effectively recover diverse microbes from water, it requires significant operator training and can be difficult to set up and perform in a field setting [3-6]. Dead-end UF (DEUF) allows water to flow straight through the ultrafilter while retaining microbes in the filter cartridge. Ultrafilters are later backflushed in a lab to recover the sample concentrate for microbial analysis. DEUF requires little operator training and is easily implemented in the field, making it an attractive option for sampling agricultural waters [7]. The laboratory team at the Centers for Disease Control and Prevention (CDC) has led the development of both of these methods.

The need for such sampling techniques was highlighted in 2013 in response to concurrent outbreaks of cyclosporiasis (reportedly associated with leafy greens and cilantro) causing more than 600 cases in 25 states. Established methods with known performance characteristics were not available for sampling and analyzing agricultural water samples for *Cyclospora cayetanensis (C. cayetanensis)*. DEUF was used to collect irrigation water samples from a farm in Mexico, but the method was not employed until weeks after the outbreaks were identified and the procedures used had not been validated for *C. cayetanensis* recovery. DEUF is routinely used for sample collection by the CDC during waterborne disease outbreak investigations and has resulted in successful detection of numerous microbes, including *Vibrio cholerae, Cryptosporidium*, *Giardia*, norovirus, hepatitis A virus, and hepatitis E virus [8-10].

Numerous analytical techniques have been verified for the detection of diverse microbe types in DEUF concentrates. Fecal indicator bacteria (e.g., *E. coli*, enterococci), pathogens (e.g., *Salmonella*) and viruses (e.g., F+ coliphages) can be directly cultured from UF concentrates. Detection of microbes by real-time quantitative polymerase chain reaction (qPCR) requires smaller final sample concentrate volumes, so secondary concentration techniques such as centrifugation and polyethylene glycol (PEG) precipitation are often used to achieve water sample concentrate volumes on the order of 1-5 milliliters prior to nucleic acid extraction [11]. By utilizing DEUF as the sampling technique for monitoring agricultural water quality, produce growers would have the capacity to obtain water quality data for a wide variety of pathogens, microbial indicators or pathogen surrogates, and MST markers from a single water concentrate.

Method recovery efficiencies for *Salmonella* have been reported for tangential-flow UF applied to tap water [12]. DEUF recovery efficiencies have been reported for *Cryptosporidium parvum* in surface water [13], but not for *C. cayetanensis*. The effectiveness of DEUF for *Cryptosporidium* oocyst recovery were reassessed in this project with irrigation water and will provide a reference point for new data on the recovery of *C. cayetanensis, Salmonella,* and MST markers in irrigation water.

In previous Center for Produce Safety projects, members of the research team studied irrigation water quality on produce farms in southern Georgia, focusing primarily on sampling strategies and testing for fecal indicators, *Salmonella*, and *E. coli* O157:H7. All study farms were located in the Southeastern Coastal Plain, an important agricultural region of the US. Farms selected for the studies were considered representative of farms across that region based on similarities in agricultural practices, water sources used for crop irrigation, and length and climate of the growing season. Most farms in this region utilize constructed farm ponds, often built by damming a nearby stream, for irrigation purposes. Irrigation ponds are typically recharged by the inflow stream, on-site wells, and precipitation runoff. By allowing ponds to be replenished by direct precipitation runoff, the potential for contamination may be high. However, results from one of these studies demonstrated the occurrence of *E. coli* O157:H7 in only 14.6% samples [14]. Preliminary results from an ongoing study have shown that *Salmonella* is commonly detected in irrigation ponds, and is also detected in irrigation water, but concentrations are often low. Both studies used low-volume sampling techniques to collect pond samples, potentially limiting their ability to detect the pathogens if present in low concentrations. Implementation of this project is both timely and relevant given recent agriculture water–related disease outbreaks and development of new water sampling and analytical tools. Large-volume sampling using DEUF and new analytical tools (such as rapid molecular testing, alternative indicators) provide new opportunities to equip produce growers and other food safety investigators with sensitive, field-portable, and user friendly tools for testing the microbial quality of agricultural water supplies.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Objective 1. Development and validation of DEUF protocols:
Key activities and tasks that were associated with objective 1 included laboratory studies to determine the effectiveness of DEUF for recovering *C. parvum, C. cayetanensis, Salmonella* spp., generic *E. coli* and two MST markers of human fecal contamination, *Bacteroides* Hf183 and human polyomaviruses (HPyVs), from irrigation water. Quantitative PCR assays have been reported for these human-specific fecal markers, but not in conjunction with DEUF [15, 16]. Irrigation water for the recovery experiments was obtained from one surface water–fed and one ground water–fed irrigation pond in the Suwannee River watershed in southern Georgia (ponds SC and LV). Five replicate experiments each were conducted using 50 liter volumes of low turbidity (LV pond) and high turbidity (SC pond) irrigation water. For parasite recovery, quantified *C. parvum* and *C. cayetanensis* stocks were obtained by flow cytometry sorting and were seeded into 50-L irrigation water samples. The bulk water was concentrated by the DEUF method as previously described, with additional concentration of the DEUF concentrate by centrifugation [7, 13]. A portion of the final concentrate was subjected to immunomagnetic separation (IMS) and fluorescent antibody (FA) microscopy to detect and quantify *C. parvum* recovery [17]. Nucleic acid extraction was performed on an additional portion of the final concentrate [18]. Recovery of *C. cayetanensis* was determined by qPCR, as there are no available IMS or FA microscopy methods for *C. cayetanensis* and the sample matrix precluded direct visualization by light microscopy [19]. Quantified stocks of *Salmonella enterica* serovar Typhimurium were seeded into 50 liter irrigation water samples. Primary settled sewage was used to seed naturally occurring *E. coli*, human *Bacteroides*, and HPyV. The bulk water was concentrated by DEUF as for the parasite recovery experiments. *Salmonella* was enumerated before and after DEUF by a three volume, three-tube most probable number (MPN) culture method, with qPCR confirmation of positive replicates [3, 20]. *E. coli* was enumerated by the Colilert-18 Quanti-Tray 2000 method (IDEXX). The remaining DEUF concentrate was further concentrated using polyethylene glycol (PEG) precipitation to simultaneously pellet bacteria and viruses. Nucleic acid extraction was performed on a portion of the PEG precipitate and gene copies of the *Bacteroides* Hf183 target and genome equivalents of the HPyV target were enumerated using qPCR standard curves [15, 16].

Key results and recommendations for objective 1 included:
Parasite recovery: Mean recovery for *C. parvum* by the DEUF method was 70% (standard deviation [SD] 82%) and 149% (SD 72%) for high and low turbidity irrigation water, respectively. *C. parvum* percent recovery was significantly higher in the low turbidity water compared to the high turbidity water (t-value = 2.53, $P = 0.04$). Mean recovery for *C. cayetanensis* could not be calculated due to the different quantification methods used for the DEUF input and output samples (oocyst count vs. qPCR, respectively). However, at the seeding levels used for this study, *C. cayetanensis* was successfully recovered by the DEUF method for all high and low turbidity replicate experiments. These results suggest that the DEUF method is effective for recovering *C. cayetanensis* from irrigation waters.

E. coli, Salmonella and MST marker recovery: Mean recovery for *E. coli* by the DEUF method was 77% (SD 26%) and 54% (SD 14%) for high and low turbidity irrigation water, respectively (Table 2). This is similar to previous recovery estimates from surface waters, indicating that the DEUF method performs as well for irrigation water as other surface water types [28]. Calculated mean recovery percentages for *Salmonella* by the DEUF method were 537% (SD 719%) and 510% (SD 735%) for high and low turbidity irrigation water, respectively. The higher than 100% recovery estimates for *Salmonella* are likely due to the imprecision of the

MPN quantification method: MPN methods are generally thought to be semi-quantitative, as the statistical calculation of MPN generates a wide confidence interval around the estimated quantity. This imprecision was compounded by using two MPN estimated quantities (pre- and post-DEUF) to calculate recovery efficiency. Future work will include running qPCR on input and output samples to refine the recovery efficiency calculations. Mean recovery for the *Bacteroides* Hf183 gene target by the DEUF method was 3.8% (SD 2%) and 9.9% (SD 5%) for high and low turbidity irrigation water, respectively. Mean recovery for HPyVs by the DEUF method was 7.8% (SD 5%) and 7.2% (SD 4%) for high and low turbidity irrigation water, respectively. Hf183 percent recovery was significantly higher in the low turbidity water compared to the high turbidity (t-value = 2.36, $P = 0.05$). *E. coli, Salmonella*, and HPyV recoveries were not significantly different between high and low turbidity irrigation water.

Objective 2. Effect of weather-related events on microorganism detection and concentration:
Water samples were collected from three irrigation ponds in the Suwannee River watershed: two ponds are surface water–fed (SC and NP) and one pond is ground water–fed (LV). Water samples were collected at least monthly during scheduled sampling events from May 2015 to May 2016. To investigate the impact of weather-related events on pathogens, indicator microorganisms, and MST markers in produce irrigation ponds, water samples were collected within 24–48 h of ≥0.5 inch of rainfall. Scheduled sampling events that occurred within 24–48 h after rainfall of ≥0.5 inch were considered rain event samples. In total, irrigation water samples were collected for 23 scheduled and rain events. To characterize irrigation water quality associated with harvest periods at the farms, water samples were collected at least twice per month during June–July and during October–November. Irrigation water samples were also collected twice per month in August–September, a period corresponding to the highest incidence of reported cases of salmonellosis and cryptosporidiosis in the U.S. [21, 22].

Water samples were collected from two locations per pond, designated as sides A and B. Fifty liters of water were filtered by DEUF and two 1 liter grab samples were collected at each sample location. *In-situ* temperature, turbidity, dissolved oxygen, conductivity, oxidation reduction potential, and pH readings were taken at the time of sampling. Ultrafilters and grab samples were transported on ice to the CDC in Atlanta on the day of collection and held at 4°C before analysis the following morning.

Ultrafilters were backflushed and the DEUF concentrate was directly analyzed for generic *E. coli*, enterococci, male-specific (F+) coliphages, *E. coli* O157:H7, and *Salmonella*. *E. coli* and enterococci were respectively enumerated by the Colilert-18 and Enterolert Quanti-Tray 2000® methods. F+ coliphages were analyzed by the USEPA Single Agar Layer (SAL) method [23]. *Salmonella* was enumerated by a three volume, three-tube MPN culture method, with qPCR confirmation of presumptive positive isolates from each MPN replicate [3, 20]. *Salmonella*-positive isolates were serotyped and subjected to pulsed-field gel electrophoresis (PFGE). The presence of *E. coli* O157:H7 was determined by enrichment, followed by IMS and plating on CT-SMAC agar and confirmation of presumptive positive samples by qPCR [5]. Grab samples were tested for generic *E. coli*, enterococci, F+ coliphages, *Salmonella*, and *E. coli* O157:H7 using the same methods described for the DEUF samples, with modifications of sample volume.

The remaining DEUF concentrate volume and 500 milliliters of the grab sample were further concentrated by PEG precipitation, and nucleic acid was extracted from a portion of the PEG precipitates. Nucleic acid extracts were assayed for the presence of *Cryptosporidium* [24] and MST markers by end-point real-time PCR. The MST marker gene targets representing human sources of contamination included *Bacteroides* Hf183, HpYVs,

and *Methanobrevibacter smithii* [15, 16, 25]. Animal-specific qPCR assays targeted mitochondrial DNA of cows, chickens, pigs, and birds [26]. All real-time PCR assays were performed with an internal control to monitor method performance and potential PCR inhibition. Molecular assays were considered positive if duplicate reactions resulted in crossing threshold (CT) values <45. The remaining volume from the grab sample was used to determine total suspended solids (TSS) according to Standard Method 2540 D [27]. Statistical analyses were performed to determine if rain events affected the occurrence or concentration of pathogens, indicators, or MST markers in irrigation ponds.

Key results and recommendations from objective 2 included:
In total, the team collected 19, 15, and 17 baseline samples (<0.50 inch of rain 24–48 hours before sampling event) from ponds SC, LV, and NP, respectively, and 3, 8, and 5 rain events from the three ponds, respectively. The differences in number of baseline and rain events for each pond were related to spatial differences in rainfall amounts, with some sampling events qualifying as rain events for some ponds but baseline for others. Physical water quality parameters showed that rain events were associated with higher solids loading (e.g., TSS and turbidity) and lower pH in the irrigation ponds, especially for surface water–fed ponds SC and NP. Other microbial studies have shown that enteric pathogens in surface water are more likely to be associated with solid particles than be free-floating [29].

Of the molecular analytes, including *Cryptosporidium* and the MST markers, only the human-specific *Bacteroides* (Hf183) detection was significantly associated with sampling after a rain event ($\beta = 1.17$, $P = 0.003$), corresponding to a 3.2-fold increased odds of detection after a rain event. Sampling method had a significant effect ($P < 0.0001$) on the model, while pond, water source, and sample location did not ($P > 0.05$). F+ coliphage detection was also significantly associated with sampling after a rain event ($\beta = 1.01$, $P = 0.02$), corresponding to a 2.8-fold increased odds of detection after a rain event. Sampling method ($P = 0.0003$) and water source ($P = 0.02$) had a significant effect on the model, while pond and sample location did not ($P > 0.05$). Neither *E. coli* nor enterococci or *Salmonella* were detected significantly more frequently after rain events compared to non-rain events. There were too few detections of *E. coli* O157:H7 for any statistical analyses to be performed.

F+ coliphage, *E. coli*, and enterococci concentrations were positively associated with a water sample being collected after a rain event (versus a baseline event) ($\beta = 0.17$, $P = 0.02$; $\beta = 0.86$, $P < 0.001$; and $\beta = 0.56$, $P < 0.001$, respectively), meaning that these analyte concentrations were 1.48 to 3.63 plaque-forming units [PFU] or MPN/100 milliliters higher after rain events compared to baseline sampling events. *Salmonella* concentrations were not significantly associated with rain events. *E. coli* concentration exceeding the geometric mean threshold (126 MPN/100 milliliters) was significantly associated with rain events ($\beta = 1.59$, $P = 0.002$), equivalent to an approximate 5-fold increased odds of a water sample being above the geometric mean after a rain event. Pond and water source had a significant effect on the model, while sample location and sampling method did not ($P > 0.05$). *E. coli* concentration exceeding the STV (410 MPN/100mL=milliliters) was not significantly associated with rain events when controlling for pond variables.

Due to a high prevalence of the fecal indicator bacteria, *E. coli* and enterococci, in the irrigation ponds, it is unsurprising that increased detection of these microbes was not observed after rain events. However, it is notable that the concentration of both organisms, but not *Salmonella*, were positively correlated with sampling after a rain event, meaning that *E. coli* monitoring occurring after rainfall resulted in significantly higher

concentration measurements, but this increase was not associated with increased *Salmonella* detection or concentration. The increased detection of Hf183 and increased detection and concentration of F+ coliphage following rain events suggest a human contamination source related to runoff to these ponds. This could potentially suggest an increased risk of viral contamination of these surface water sources.

Objective 3. Assessment of large-volume sample collection:
Qualitative detection results (positive versus negative) from objective 2 were used to determine if large-volume DEUF sampling allowed for increased detection rates of F+ coliphages or *Salmonella* compared to small-volume grab sampling. Statistical comparisons for *E. coli* and enterococci could not be performed because there were too few non-detects of these indicators during the study.

Key results and recommendation from objective 3 included:
DEUF samples were associated with an increased probability of detecting *Salmonella* compared to grab samples ($\beta = 1.04$, $P = 0.00006$), equivalent to an approximate 3-fold increased odds of detecting *Salmonella* in a sample if the DEUF was used. DEUF samples were associated with an increased probability of detecting F+ coliphages compared to grab samples ($\beta = 2.46$, $P < 0.0001$), equivalent to an approximate 12-fold increased odds of detecting F+ coliphage when DEUF is used. Sample location did not have a significant effect on either model ($P > 0.05$), but pond and water source did have a significant effect.

Salmonella concentration was negatively associated with a sample processed by DEUF filtration ($\beta = -0.7268$, $P < 0.0001$), equivalent to an average 6.1 MPN/100 milliliters lower *Salmonella* concentration in DEUF samples versus grab samples. *E. coli* concentration was negatively associated with a sample processed by DEUF filtration ($\beta = -0.1210$, $P = 0.0039$), equivalent to an average 1.3 CFU/100 milliliters lower *E. coli* concentration in DEUF samples versus grab samples. F+ coliphage concentration was also negatively associated with a sample processed by DEUF filtration ($\beta = -0.2626$, $P = 0.0014$), equivalent to an average 1.8 PFU/100 milliliters lower F+ coliphage concentration in DEUF samples versus grab. These results are not surprising because there is a likelihood of some irreversible microbial attachment to DEUF filter media, but this "recovery efficiency" factor differs between microbes. For example, enterococci concentrations were not associated with a sample processed by DEUF filtration, meaning there was no significant difference in the concentration in DEUF samples versus grab. For *Salmonella*, F+ coliphage, and *E. coli* models, pond and water source had a significant effect on the model while sample location did not.

For detection of lower-level indicators or pathogens (coliphage and *Salmonella*), DEUF increased the detection rates and gave a better estimation of water quality than grab sampling for these analytes. Even with loss during DEUF processing, the concentration estimates between DEUF and grab sampling were only different by a small amount (<10 MPN or PFU/100 milliliters), so the concentrations were not meaningfully underestimated when DEUF was used. DEUF would not be necessary for quantification of *E. coli* or enterococci in irrigation water because both indicators are present at sufficiently high concentrations to be effectively detected by grab sampling. However, DEUF can improve detection rates for low concentration pathogens or indicators during more advanced monitoring.

Objective 4. Evaluation of indicator and *E. coli* microbial water quality thresholds:
Activities included evaluating indicator and pathogen data obtained from objective 2 to determine whether the *E. coli* was associated with pathogen presence in irrigation water. Detection of *Salmonella* was compared to *E. coli* concentration data to specifically examine how well the *E. coli* thresholds represent the presence of this

common foodborne pathogen. Logistic regression (controlling for pond variables) was used to evaluate whether *Salmonella* presence (detected in DEUF samples) was associated with *E. coli* concentrations exceeding the geometric mean value (126 MPN/100 milliliters) or the STV (410 MPN/100 milliliters). The utility of *E. coli*, enterococci, F+ coliphages, and the MST markers were evaluated as tools for predicting the presence of pathogens in irrigation water.

Key results and recommendation from objective 4 included:
Salmonella presence was not significantly associated with *E. coli* concentrations above the geometric mean (β = 0.17, P = 0.07) or the STV (β = -1.21, P = 0.31). This result suggests that microbial water quality thresholds (geometric mean and STV) for *E. coli* were not predictive of *Salmonella* presence in these irrigation ponds.

E. coli concentrations in DEUF and grab samples were positively associated with the probability of detecting *Salmonella* in the samples (β = 0.900, P = 0.0008 and β = 0.852, P = 0.0016, respectively), equivalent to a 1-$\log_{10}$ increase in *E. coli* concentration, increasing the odds of detecting *Salmonella* by 2.5-fold. *E. coli* concentrations were not associated with *Salmonella* presence in grab samples. Enterococci concentrations in DEUF and grab samples were also positively associated with the probability of detecting *Salmonella* in DEUF samples (β = 1.17, P = 0.0015 and β = 1.10, P = 0.0013, respectively), equivalent to a 1-$\log_{10}$ increase in enterococci concentration, increasing the odds of detecting *Salmonella* by 3.2-fold. Enterococci concentrations were not associated with *Salmonella* presence in grab samples. Neither F+ coliphage detection nor concentration in DEUF or grab samples was associated with *Salmonella* DEUF presence ($P > 0.05$). The association between *Salmonella* detection and the detection of *E. coli* or enterococci could not be evaluated due to the high prevalence of both microbes in all three irrigation ponds. Neither F+ coliphage detection nor concentration was associated with *Salmonella* presence in DEUF or grab samples.

Cryptosporidium, *Bacteroides* Hf183, HPyVs, and *M. smithii* were not associated with *Salmonella* presence in DEUF samples when controlling for pond variables ($P > 0.05$). None of the animal MST markers (bird, chicken, cow, pig) were significantly associated with *Salmonella* presence in DEUF samples ($P > 0.05$), likely due to the low detection rate of the MST markers.

E. coli concentrations in DEUF and grab samples were positively associated with *Salmonella* concentration in DEUF samples (β = 0.18, $P < 0.0001$ and β = 0.18, P = 0.0003, respectively), equivalent to a 1-$\log_{10}$ increase in *E. coli* concentration being associated with a 0.18-$\log_{10}$ increase in *Salmonella* concentration in DEUF samples. *E. coli* concentrations were not associated with *Salmonella* concentrations in grab samples. Enterococci concentrations in DEUF and grab samples were also positively associated with *Salmonella* concentration in DEUF samples (β = 0.15, P = 0.013 and β = 0.19, P = 0.0008, respectively), equivalent to a 1-$\log_{10}$ increase in enterococci concentration being associated with a 0.15- or 0.19-$\log_{10}$ increase in *Salmonella* concentration, depending on which sample method was used. Grab sample enterococci concentrations were not associated with *Salmonella* concentrations in grab samples. F+ coliphage concentration was positively associated with *Salmonella* concentration in DEUF samples (β = 0.16, P = 0.036), equivalent to a 1-$\log_{10}$ increase in coliphage concentration being associated with a 0.16-$\log_{10}$ increase in *Salmonella* concentration. Grab sample F+ coliphage concentrations were not associated with *Salmonella* concentrations in grab or DEUF samples.

E. coli and enterococci concentrations, measured by either grab or DEUF methods, correlated with *Salmonella* detection and concentration in DEUF samples but not in grab samples. This suggests that monitoring for fecal

indicator bacteria, such as *E. coli* and enterococci, by grab sampling is appropriate, but that when indicator levels trigger further monitoring, large-volume sampling would be more effective for determining the extent of low-concentration pathogen contamination. Current *E. coli* standards were not found to be associated with *Salmonella* presence in southern Georgia produce-farm irrigation ponds. Therefore future research is needed to determine risk-based thresholds for indictor monitoring in irrigation water. While enterococci were not found to have a stronger association with *Salmonella* in this study, future work should consider other microbial alternative indicators and standards for each.

Objective 5. Utility of DEUF to facilitate detection of *Cryptosporidium* and MST markers:
Activities and tasks associated with Objective 5 included analysis of the data obtained from objective 2 to demonstrate the utility of DEUF to facilitate detection of MST indicators in agricultural water.

Key results and recommendation from objective 5 included:
DEUF versus grab: The prevalence of *Cryptosporidium* and the MST markers in each pond using the two sampling methods is described in Table 4. *Cryptosporidium* ($\beta = 2.05$, $P < 0.0001$) and *Bacteroides* Hf183 ($\beta = 2.78$, $P < 0.0001$) detections were significantly associated with a sample being collected with DEUF compared to grab sampling, meaning testing was significantly more likely to detect one of these analytes if the DEUF method was used instead of grab sampling. Sample location did not significantly affect either analyte's model ($P > 0.05$), but sample event and pond significantly affected both models. Water source significantly affected the *Cryptosporidium* detection model (the ground water–fed pond was less likely to have detects than the surface water–fed ponds) but not the Hf183 model. No other MST markers were significantly associated with the sampling method after controlling for pond variables ($P > 0.05$). *Cryptosporidium* subtyping was not possible for this study because the sensitivity of the genotyping PCR assay was not high enough to detect the low concentrations of *Cryptosporidium* found in the irrigation pond samples. The *Cryptosporidium* and Hf183 results provide evidence for the benefits of large-volume sample for the detection of low-concentration MST markers and pathogens. This work also demonstrates the utility and feasibility of performing MST analyses on irrigation water samples using DEUF despite low recovery efficiencies measured for these analytes.

Salmonella antigen-based serotyping:
Salmonella was detected in at least one of the three irrigation ponds for 20 out of the 23 sampling events that occurred over the course of one year (SC = 19 positive events, LV = 7 positive events, and NP = 14 positive events). For three sampling events, *Salmonella* was not detected in any of the three ponds. Only one isolate from each positive MPN dilution was selected for typing, meaning up to nine isolates per sample could be typed.

A total of 131 isolates were serotyped, representing 71 unique water samples ($N = 48$ positive DEUF samples and 23 positive grab samples out of the 276 total grab and DEUF samples collected during the study period). Eighteen different *Salmonella* serotypes were detected among the 131 typed isolates. Overall, serotypes Muenchen and Rubislaw were most frequently detected in the three ponds over the 23 sampling events, being detected in 23% and 20% of samples, respectively. Up to five different serotypes were detected in a pond at a single sampling event (either in the grab or DEUF sample from either collection site), and up to two serotypes were detected within a single water sample (a sample collected with one sampling method from one sampling site on one pond). In total, 11 different *Salmonella* serotypes were detected in SC, 11 in LV, and 12 in NP. Figure 6 shows the proportion of *Salmonella* serotypes detected in positive samples for each of the three irrigation ponds. All of the *Salmonella* serotypes detected are considered potentially pathogenic to humans,

and none of the serotypes detected were those commonly associated with animals (e.g., serotypes Kentucky [chickens], certain strains of Typhimurium [birds], Gallinarum [chickens], Dublin [cows], Choleraesuis [pigs]). Three of the serotypes detected in the ponds, Javiana, Muenchen, and Saintpaul, were among the top 10 serotypes causing human *Salmonella* cases in the United States in 2015 [30].

Salmonella isolate subtyping was conducted using pulsed-field gel electrophoresis (PFGE). PFGE using the XbaI enzyme was performed on all *Salmonella* isolates ($N = 131$), and the resulting patterns were queried against the CDC PulseNet database of clinical *Salmonella* isolates submitted in 2015 and 2016 [31]. Pattern analysis and dendrogram generation were performed using BioNumerics software (Applied Maths, Saint-Martens-Latem, Belgium) with the Dice coefficient and tolerance of 1.5% (Figure 7). A matching PulseNet pattern was identified for 65 out of the 131 isolates from the irrigation pond samples (Table 6). In total, 21 different PulseNet patterns were matched to the 65 isolates, some with multiple patterns matching to different isolates of the same serotype (e.g., PulsoTypes JN6X01.0044 and JN6X01.0092 are both antigen-based serotype Saintpaul).

Because all *Salmonella* isolates detected in the study samples were identified as potentially pathogenic serotypes to humans, and no association was found between the presence of *Salmonella spp.* and human MST markers, it was not possible to evaluate any association between pathogenic *Salmonella* presence and the human MST markers. The association between animal MST markers and *Salmonella* serotypes could not be determined because no animal-associated serotypes were detected.

In June 2016, interim research results were presented at the Center for Produce Safety Research Symposium in Seattle, Washington to 315 attendees.

The project did not benefit commodities other than California specialty crops; water sampling was carried out from irrigation ponds located on produce farms.

The project partners were the Centers for Disease Control and Prevention (CDC). The Center for Produce Safety (CPS) managed the project and the CDC team, including the University of Georgia (UGA) and Emory University (EU) collaborators, performed the research studies.

The CDC team members were the primary planners, organizers, and analysts for this project. All laboratory water sample testing was performed in the CDC Environmental Microbiology Laboratory. The project Principal Investigator (PI) administered the project, planned and supervised experiments and field studies, analyzed data, and communicated research progress and findings to CPS. The Emory team assisted in the analysis of samples for *Salmonella*, providing input on statistical issues related to study design and sample collection, and assisted with analysis of project data. The EU Co-PI advised collaborators on study design and statistical analysis of data and assisted in preparation of reports and manuscripts; the Co-PI also supervised and oversaw the work of the EU postdoctoral researcher working on the project. The UGA Co-PI supervised the selection of precipitation events for collecting precipitation-affected water samples and assisted in data analysis and preparation of reports and manuscripts. UGA technicians, under the supervision of the UGA Co-PI and a UGA postdoctoral researcher, collected water samples, measured field water quality parameters (e.g., temperature, pH), and transported samples to CDC and Emory staff. During the field study, UGA staff visited the three irrigation ponds at least every month for one year.

Goals and Outcomes Achieved

Activities completed included the following: (i) determination of the effectiveness of DEUF for the recovery of *C. parvum*, *C. cayetanensis*, *E. coli*, *Salmonella*, *Bacteroides* Hf183 marker, and human polyomaviruses (HPyVs) from irrigation water; (ii) establishment of effective DEUF and analytical protocols for the recovery of these diverse microbe classes from irrigation water of varying quality; (iii) collection of baseline and rain event water samples and use of DEUF to determine whether weather-related events affect the occurrence or concentration of the microbe classes; (iv) assessment of improved detection and quantitation of target pathogens and pathogen surrogates by large-volume water sampling (DEUF) versus small-volume (1-L) grab samples; (v) determination of the correlation between the presence and/or concentration of pathogen surrogates and the occurrence and/or concentration of pathogens in the irrigation ponds; (vi) demonstration of the utility of DEUF to facilitate detection of MST indicators in agricultural water; and (vii) serotyping of *Salmonella* isolates from collected water samples.

The project PI anticipates that at least four peer-review manuscripts will result from this project. The first manuscript will compare the two sample collection methods used in the study: ultrafiltration and grab sampling, using data from Objectives 1, 3 and 5. The second manuscript will evaluate the ability of *E. coli* and alternative indicators to predict *Salmonella* presence in irrigation water. The third manuscript will evaluate whether seasonality or weather-related events affect the occurrence or concentrations of pathogens, indicators, and MST markers in irrigation water. The fourth manuscript will analyze the PFGE and whole genome sequence data obtained for the *Salmonella* isolates detected in this study. In addition, performance on the project will be assessed in conjunction with presentations at the CPS Research Symposium.

The original proposal set out to determine the feasibility of using DEUF and molecular testing as tools for monitoring agricultural water quality and to provide an evidence base supporting the implementation of ultrafiltration-associated testing protocols by crop producers as part of site-specific and product-specific risk-based sampling programs. The five project objectives were all achieved as proposed.

DEUF procedures were established for agricultural irrigation water applications, and recovery efficiencies for the DEUF method were determined for pathogenic bacteria, human parasites, and human-specific fecal bacteria and viruses from irrigation water. The DEUF method had higher detection rates of the low-level microbes, *Salmonella* and F+ coliphage, compared to grab samples, but minimal impact on concentration estimates. The DEUF method did not adversely affect detection of *E. coli* and enterococci compared to grab sampling. The DEUF method also increased detection rates of the molecular analytes *Cryptosporidium* and the *Bacteroides* Hf183 human-associated microbial source tracking marker. DEUF is recommended for advanced monitoring of irrigation water when target analytes are suspected to be present at low concentrations, as with pathogens or alternative indicators such as fecal source tracking markers.

The *Bacteroides* Hf183 human-associated marker and F+ coliphage were detected more frequently after rain events, suggesting a runoff-related human contamination source. *E. coli* concentration increased after a rain event and was more likely to exceed the geometric mean standard, but this increase was not associated with an increase in *Salmonella* detection or concentration.

Overall, *Salmonella* detections were not associated with *E. coli* concentrations above the geometric mean or STV levels, indicating that these *E. coli* thresholds were not predictive of *Salmonella* presence in irrigation ponds during this study in southern Georgia. However, increased *E. coli* and enterococci concentrations (by

either grab or DEUF sampling) were associated with increased *Salmonella* detection and concentration (by DEUF only). Neither *Cryptosporidium* nor any of the MST markers were associated with *Salmonella* detection.

Of the 131 subtyped *Salmonella* isolates collected from the irrigation ponds, approximately half matched PFGE patterns of clinical *Salmonella* isolates in the PulseNet database, and all isolates cultured from the ponds were serotypes potentially pathogenic to humans.

Key baseline data that have been gathered include: (i) the recovery efficiencies by the DEUF method for *Cryptosporidium parvum*, *E. coli*, *Salmonella* and microbial source tracking (MST) markers in high and low turbidity irrigation water samples (as part of Objective 1); (ii) the association between detection and/or concentration of *E. coli*, enterococci, F+ coliphages, and *Salmonella* in water samples after a rain event compared to a non-rain event (as part of Objective 2); (iii) qualitative detection results to determine if large-volume DEUF sampling allowed for increased detection rates of F+ coliphages or *Salmonella* compared to small-volume grab sampling (as part of Objective 3); (iv) association between the concentration of *E. coli* in DEUF and grab samples and the probability of detection and/or concentration of *Salmonella* in irrigation water (as part of Objective 4); (v) the prevalence of *Cryptosporidium* and the MST markers in irrigation ponds using the DEUF and grab sampling methods (as part of Objective 5); and (vi) the identification and number of *Salmonella* serotypes detected in the irrigation water samples over the 23 sampling events.

Major successful outcomes for the project include: (i) the collection of quantitative data on pathogens, indicator microorganisms and microbial source tracking (MST) markers in a total of 276 grab (1-L) and DEUF (50-L) irrigation water samples from two surface water–fed ponds and one ground water–fed pond in southern Georgia during the study period (which included 23 scheduled sampling and rain events); and (ii) validation of CDC's DEUF large-volume collection method for enabling reliable detection of low-level pathogen and indicator concentrations, making it a valuable tool for advanced irrigation water monitoring.

The project staff were not able to meet the target to conduct a survey at the Southeast Regional Fruit and Vegetable Conference as planned during the project period. The project was not far enough along to generate survey questions for the 2016 Southeast Regional Fruit and Vegetable Conference in January 2016. As an alternative, the team intended to conduct the survey at the annual CPS Research Symposium in June 2016, but was not aware that any survey needed to be reviewed and cleared by CPS prior to the meeting. As a result, the survey was not distributed at that meeting either. Unfortunately, project staff were not able to secure a presentation slot at the 2017 Southeast Regional Fruit and Vegetable Conference. Despite the challenges that occurred during this multifaceted research project, project staff met the approved work plan timeline for all other activities and the established objectives and goals.

Beneficiaries

The main beneficiaries of this project include all U.S. fresh produce farms that must monitor the quality of their irrigation water supplies. Given the known issues with fecal indicator organisms, it is anticipated that many growers may be interested in proactively expanding their irrigation water quality monitoring programs to include alternative water quality parameters, including pathogens, alternative pathogen surrogates, and fecal source identification tools (e.g., MST). Presently, growers rely on testing small-volume grab samples to determine water quality because no user-friendly, field portable, large-volume sampling method has been demonstrated for agricultural water. The dead-end ultrafiltration (DEUF) method has now been shown to be

effective for streamlining water monitoring for diverse microbial parameters and will be beneficial to growers as part of risk-based sampling programs. Additionally, the relatively low cost of the DEUF method compared to the high costs associated with recalls or destruction of potentially contaminated product demonstrates a pronounced economic impact of the method.

The California leafy greens industry and associated commodity boards will benefit from the findings of this project. For example, this project will benefit the over 90 member companies of the California Leafy Green Products Marketing Agreement that work with hundreds of farmers in the state to produce and handle lettuce, spinach and other leafy greens products. According to the California Agricultural Statistics Review 2015–2016, the lettuce production alone is valued at over $2.2 billion annually.
Final research results were presented in June 2017 at the 8th annual CPS Research Symposium in Denver, Colorado, to 325 symposium attendees. Interim results were presented previously in an oral presentation at the 2016 CPS Research Symposium in Seattle, Washington to 315 attendees, and in a poster session at the 2015 CPS Research Symposium in Atlanta, Georgia to 245 attendees. The symposium participants included California regional and national growers/shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provides expert panels to critique the research results after presentation by the researcher, which helps participants evaluate how the results can be used in their respective businesses.

Project results will be disseminated at industry meetings, and streamed through social media sources. Results will also be made available online as follows:

1. Final reports submitted to CPS will be posted on the CPS website: http://www.centerforproducesafety.org/grant_opportunities_awards.php.
2. CPS works with the scientists to publish results in scientific journals. Publication dates occur after the project is completed. Abstracts and awards can be found on the CPS website.
3. The Board of Directors and members of the Technical Committee of CPS distribute a series of information briefs throughout the year on the website and through presentations, meetings and webinars. An example of this would be the "CPS 2016 Research Symposium Key Learnings" on the CPS website at the following link: http://www.centerforproducesafety.org/amass/documents/document/365/CPS%202016%20Key%20Learnings.pdf.

The following websites provide additional resources on the final reports and symposium proceedings:
Center for Produce Safety: http://www.centerforproducesafety.org/resources.php
Produce Marketing Association: http://pma.com
Western Growers Association: http://www.wga.com/

Lessons Learned

The partnership between CDC, Emory University and the University of Georgia resulted in a successful laboratory and field-based study that will provide timely and useful scientific data to the fresh produce industry. The team was able to utilize and validate CDC's DEUF large-volume water collection method, used extensively for drinking and recreational water, for agricultural water types such as irrigation water. The project team did encounter a number of obstacles, ranging from the application of new and complex analytical methods for irrigation water to the logistical constraints of collecting samples after rain events and transporting

them to the laboratory for immediate analysis. For example, the use of MPN quantification for calculating the recovery efficiency of *Salmonella* by the DEUF method resulted in imprecise estimates due to large confidence intervals. Quantification by quantitative PCR may have resulted in more precise recovery calculations. Also, sequencing and subtyping of *Cryptosporidium*-positive samples was desired, as it would have assisted the research team in identifying animal and human sources of fecal contamination for the study irrigation ponds. However, the level of *Cryptosporidium* in the ponds was too low for sequencing and subtyping to be performed, as these molecular testing assays are designed for clinical samples and have a lower sensitivity than methods developed for environmental testing.

A broad range of molecular source tracking (MST) target analytes were chosen for investigating potential sources of fecal contamination for the study irrigation ponds. However, one unexpected outcome was that there were too few detections of most of these analytes for any trends to emerge or for statistical analyses to be performed.

The team was not able to conduct a survey at the Southeast Regional Fruit and Vegetable Conference as planned during the project period. The project was not far enough along to generate survey questions for the 2016 Southeast Regional Fruit and Vegetable Conference in January 2016. As an alternative, the team intended to conduct the survey at the annual CPS Research Symposium in June 2016, but was not aware that any survey needed to be reviewed and cleared by CPS prior to the meeting. As a result, the survey was not distributed at that meeting either. Unfortunately, the team was not able to secure a presentation slot at the 2017 Southeast Regional Fruit and Vegetable Conference. Despite the challenges that occurred during this multifaceted research project, the team met the approved work plan timeline for all other activities and the established objectives and goals, and maximized the use of the funding provided.

Additional Information

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CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
61	Addition of 10 Specialty Crops into the COMET- Farm Tool	
Grant Recipient: California Department of Food and Agriculture	**Grant Agreement No.:** SCB14061	**Date Submitted:** December 2017
Recipient Contact: Amrith Gunasekara	**Telephone:** (916)-654-0433	**Email:** amrith.gunasekara@cdfa.ca.gov

Project Summary

Specialty crops are grown on a significant portion of the cropland acreage in California, however prior to this project there had been relatively little capacity in tools and methods to assess the role specialty crops play in greenhouse gas emissions (GHG) in California, or their role in climate change mitigation. Through this project, a collaborative team of scientists, extension specialists, and agency personnel located and summarized previous and ongoing specialty crop research datasets on plant growth, yield, soil carbon and nitrous oxide emissions, and leveraged those existing data for the following crops for use in the COMET-Farm tool, per the California Department of Food and Agriculture's (CDFA) initiative on *Fertilization Guidelines for Major Crops Grown in California:* almonds, strawberries, walnuts, pistachios, tomatoes, grapes, lettuce, broccoli, cauliflower and citrus. There are no existing tools specific to specialty crops for quantifying the reduction of GHGs from management practices.

The specialty crop agriculture sector in California can benefit from reduced atmospheric GHGs by improving the farmer's overall performance, contribution to the environment and long-term sustainability, while at the same time providing multiple benefits to the environment. Also, being able to evaluate the GHG reductions of specialty crop management practices is increasingly important for a farmers overall marketing strategy. This project provided specialty crop farmers with a user-friendly, yet highly quantitative GHG accounting tool that will help them manage their farms consistent with environmental stewardship principles resulting in potential economic benefits to California specialty crop farmers. COMET-Farm is one of the most promising tools for on-farm GHG quantification and estimation.

In the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment 2014, researchers assessed opportunities to mitigate climate change and reduce the accumulation of GHG in the atmosphere, and concluded that significant GHG reductions must be achieved through improved land use and management in the agricultural and forestry sectors. This is in order to prevent the world's mean annual temperature from rising more than 2° C and keep atmospheric GHG concentrations from accumulating beyond a threshold supporting that goal. Achieving those goals requires the capacity to assess the relative benefits of agricultural conservation practices with GHG mitigation potential, and prioritize those practices according to their benefits and practicality. The United States Department of Agriculture (USDA)/National Resource Conservation Services (NRCS) has supported the development of the COMET-Farm tool for this purpose. USDA has endorsed the tool for use in the agricultural sector.

California has the largest agricultural economy in the United States, and has significant opportunities for GHG mitigation in the agricultural sector. At the time this project was proposed, the COMET-Farm tool had the capacity to assess crops covering approximately 65% of the cropland in California, but did not have the capacity to model orchard and vineyard crops as well as important specialty crops grown in annual crop rotations such as lettuce, broccoli, cauliflower and strawberries. Adding orchard and vineyard crops as well as

these annual crops to the tool increases the COMET-Farm tool's capacity to assess crops grown on approximately 85% of the cropland acreage in California.

This project was proposed to help fill that gap by adding crops that were currently in California's Fertilizer Research and Education Program (FREP). This project helps improve the infrastructure to support California's efforts to reduce GHG emissions by helping quantify the capacity of the agricultural sector to engage in climate change mitigation. This project also supports improvements in the COMET-Planner tool by broadening the scope and capacity of the COMET-Farm tool and the GHG models used therein to assess the potential of GHG mitigation in the agricultural sector in California.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The work under this project was divided into several tasks:
Task 1: The current extension and NRCS literature on recommended/common management practices for the specialty crops being added or improved in the tool was collected. Colorado State University (CSU), USDA-Agricultural Research Services (ARS), University of California (UC)-Davis and NRCS staff conducted a literature review, identifying and utilizing more than three dozen extension bulletins, enterprise budgets, and related types of literature for use in the modeling efforts for this project.

Task 2: Visits at the study sites and with growers, extension specialists and NRCS conservationists to interview growers on management practices for the specialty crops, focusing on filling gaps in the understanding of management practices was completed. Project personnel from CSU, ARS, UC-Davis and NRCS conducted four site surveys, visiting growers, extension personnel, and researchers in agricultural regions throughout the state. Additional, informal meetings, email dialogue, and telephone conversations occurred with growers and commodity group representatives to assess specific questions about regional cropping practices. Grape growers provided detailed management and crop yield data for model verification efforts. The Almond Board provided the results of research studies to aid in modeling almond crop dynamics and resource partitioning.

Task 3: Collection of at least two and up to four study datasets for each crop, and entered into the data into the GRACENET format (regardless of whether trace gas data are available). These studies included information on economic crop yield, plant production, biomass, detailed management information, and soil physical properties, soil carbon stocks, and/or trace gas measurements. CSU, ARS, and UC-Davis staff identified more than 100 studies in the peer-reviewed literature that described the results of experiments assessing aspects of plant production, plant resource partitioning, soil organic carbon, and trace gas response to cropping practices in the related specialty crops. ARS scientists provided research data from multiple studies on wine grape production in the Central Valley, Central Coast, and North Coast. Data on wine grape production were entered into the GRACENET format. They also acted as liaison to other research studies, including the CAL-CORE study on the Central Coast, which provided important research findings from their work on lettuce, broccoli, and strawberries. Of the more than 100 studies initially identified, 41 could be utilized in parameterizing the DayCent model. Between two and five research datasets were identified for each of the specialty crops in this project. Wine grapes and almonds each had the most datasets available (five).

Task 4: Parameterize of the crops for the DayCent model based on the study datasets, were added to the COMET-Farm crops database. All of the crops were parameterized for the DayCent model, and several of the

crops were expanded to include several crop classes. Yield data, combined with extension information on growing practices, allowed the team to subdivide some of the crops into additional classes where applicable.

These include:
- Wine grapes were subdivided into four classes based on their growing degree day classifications.
- Grapes were further subdivided into raisin grapes and table grapes.
- Lettuce was classified into head lettuce, leaf lettuce, and romaine.
- Citrus was classified into grapefruit, oranges, lemons & limes, and mandarins & tangerines.

Where possible, the crop parameterization effort was validated against regional crop production information. County-level National Agricultural Statistics Service (NASS) crop yields were used to verify and improve the DayCent plant production coefficients developed from experimental data. Grape crop production could not be verified effectively against regional yield measurements because of a combination of factors, including 1) the extent of crop manipulation done to influence the quality of grapes; and 2) the types of crop yield data collected for reporting in the NASS dataset.

Task 5: Modify the COMET-Farm system to account for crop management practices unique to these specialty crops and which are necessary to drive the GHG models described in the USDA Greenhouse Gas Methods for Entity-Level Inventory. Both the DayCent model and the COMET-Farm Graphical User Interface (GUI) required modifications were completed to support adding these specialty crops to the COMET-Farm system. Besides developing new crop input parameters for DayCent, new crop management parameters were developed to address differences in pruning and tillage in these systems. Several new carbon pools describing woody plant systems were added to the DayCent model in support of this effort.

This project does not enhance the competiveness of non-specialty crops.

Project partners from four institutions made up the research team of this project:
The research team at CSU contributed to the literature reviews, attended site visits, accomplished the DayCent model parameterization efforts, verified the model results, improved the COMET-Farm system to support specialty crops and added the specialty crops to the COMET-Farm tool, and conducted the final quality assurance and quality control review with the COMET-Farm graphical user interface, and wrote the final report.

The ARS office in Davis, Calfornia provided invaluable support for this project. ARS staff supported the project by providing research measurements of plant production, resource partitioning, biomass accumulation, soil carbon stocks and trace gas measurements from five wine grape research plots in the Central Coast, Central Valley, and North Coast. Networking relationships with ARS researchers throughout the state were made, wine grape growers in several regions to aid in the CSU team's research and understanding of wine grape production, and support with data entry and literature review were made. Without the support and collaboration the ARS leadership at Davis, it is unlikely that the project team could have successfully completed the work to add wine, table and raisin grapes in this project. ARS facilitated dialogue with the USDA Climate Change Program Office, successfully raising funding to support the research for and writing of an addendum to the USDA Entity Level Greenhouse Gas Inventory Methods (Eve, *et al.* 2014. *Quantifying*

Greenhouse Gas Fluxes in Agriculture and Forestry) (Methods Document). UC-Davis staff also supported this effort.

Invaluable support at the national level was provided from the NRCS, and also from the NRCS State Office. The NRCS State Office facilitated liaison services to NRCS field offices throughout California. NRCS assistance made it possible to meet with growers, extension and NRCS field office staff throughout the state on each of the specialty crops. NRCS supported the project's goals by providing separate funding for outreach and analysis.

The Horwath lab at UC-Davis Department of Land, Air and Water Resources led a critically important effort to complete a literature review and compile an addendum to the Methods Document, focusing on updating findings related to specialty crops and GHG emissions. This addendum was necessary to update the findings of the scientific committee who initially developed the GHG inventory methods. UC-Davis leveraged work completed within the UC system as well an extensive literature review to update the Methods Document's findings regarding specialty crops in California. UC-Davis supported the parameterization efforts for the DayCent model improvements, providing research datasets from their own work and acting as a liaison to other researchers within the UC-Davis system to facilitate use of their research findings in the development of tomato and lettuce input parameters.

Goals and Outcomes Achieved

The core objective of this project was to add specialty crops to the COMET-Farm tool. The following activities were accomplished to meet this goal:

1. Literature reviews to identify research studies with useful measurements and crop management descriptions that may be used to parameterize the DayCent model.
2. Literature reviews, grower interviews, and extension service consultations to identify common crop management practices for the different specialty crops.
3. An intensive DayCent model parameterization effort involving multiple research studies and a final model verification process against regional measurements of crop production.
4. Modifications to the COMET-Farm system to account for the new crops and changes supporting the unique management processes for some specialty crops.

The project team achieved the objective for all of the specialty crops described in this project and are in the final stages of quality assurance and quality control testing for the COMET-Farm GUI. An updated version of COMET-Farm was released on August 7, 2017 and included the specialty crops under this project (broccoli, cauliflower, head lettuce, leaf lettuce, romaine lettuce, strawberries, fresh tomatoes, and processed tomatoes). An additional update was released in December 2017, which included the woody crops under this project (almonds, grapefruit, lemons & limes, mandarins & tangerines, oranges, wine grapes, raisin grapes, table grapes, pistachios, walnuts).

The benefits of this project to California's specialty crop industry will continue after the completion of the grant. The addition of the specialty crops to COMET-Farm will be a valuable tool to specialty crop farmers as they will be able assess the environmental benefits, including quantifiable GHG reductions, of various farming practices. Specialty crop farmers can benefit from the on-farm energy audit provided by COMET-Farm, be eligible for financial incentives for practices that reduce GHG emissions, and validate their environmental

stewardship activities for potential marketing purposes. The COMET-Farm tool was added to the Climate Change list found on the CDFA website https://www.cdfa.ca.gov/oefi/ in December 2017. Since the update of the tool occurred in December 2017, the webpage was not able to be monitored for the number of hits and geographic location of the hits using Google Analytics as a quantitative metric of use.

All of the tasks described in the initial proposal and project goals and objectives have been completed and met. The final quality assurance and quality control processes for this project have taken longer than initially anticipated, due to staff and resource scheduling issues combined with a more extensive and lengthy model verification process. Hence the brief delay for the final release of the specialty crops into the COMET-Farm tool. Consequently, the evaluation of early innovators ranging from 5 to 10% of all specialty crop farmers in California to utilize the COMET-Farm tool was not determined during the grant term. The project will continue to evaluate this outcome in the future.

Currently, given the lack of a user-friendly GHG quantification tool for specialty crop farms in California, the baseline number of projects with GHG reductions is zero.

The project's goals were to add ten specialty crops to the COMET-Farm tool. The project team has achieved this objective, adding all of the originally-specified crops to the COMET-Farm system. It became clear during the model verification process that the ability to assess different classes of some crops (lettuce, citrus, grapes), due to differences in crop management techniques and plant growth characteristics, in order to facilitate a more precise use of the tool for COMET-Farm users with must be provide. Grapes were divided into six classes (four wine grapes according to different growing degree day classes, raisin grapes, and table grapes). Head lettuce was divided into three classes (head lettuce, leaf lettuce, and romaine lettuce). Citrus was divided into four classes sharing common management and crop production characteristics (grapefruit, lemons & limes, mandarins and tangerines, and oranges). In the end, the project team is adding twenty-one new crops to the COMET-Farm system.

Beneficiaries

The goal of this project was to integrate specialty crops into the COMET-Farm tool, in which there was none. The tool was updated and posted to the website in December 2017. This updated tool is available to the California specialty crop industry.

The beneficiaries of this project are California growers of almonds, walnuts, pistachios, lettuce, tomatoes, cauliflower and broccoli, grapes, strawberries, and citrus. These crops rank among the highest economic value agricultural commodities produced in the state.

The CDFA will similarly benefit from this project, through connections to the agency's FREP program. The Almond Board and the Farm Bureau worked collaboratively with the research team during this project, providing research data and facilitating connections with growers and extension specialists. Organizations and individuals involved in agriculture throughout the state provided input to the CSU team during this process and regarding practices that should be reflected in the COMET-Farm tool. It is anticipated these interested parties will benefit from the additions of these specialty crops to the states.

There are approximately nine million irrigated acres of cropland in California. As a result of this project, conservation and GHG mitigation practices on approximately 65% of the cropland dedicated to specialty crops,

and 85% of the total cropland in California, can be modeled in the COM ET-Farm system. This equates to approximately 5.85 to 7.65 million acres of total cropland. The COMET-Planner tool will be able to include specialty crops in its next update cycle. This allows growers throughout the state of California to effectively assess the GHG mitigation benefits of conservation activities on their crop enterprises.

Lessons Learned

Several critical lessons learned from this project follow:
Modeling intensive crop production on irrigated, desert soils presents some core challenges. The interaction between soil nitrogen dynamics and irrigation systems are tightly coupled in an ecosystem with very high transpiration demands, and connecting the processes effectively can be particularly challenging when soils are routinely flooded to flush accumulated salts from the rooting zones. The response for this challenge by separating lettuce and broccoli into different variants according to the cropping region and growing season, with coastal (seasonal/year-round) and desert (winter) versions of the crops. The project team believe this to be a positive improvement to the COMET-Farm system.

Additional, unanticipated modifications to the DayCent model were required to support this effort, which led to the need to repeat lengthy and labor-intensive model spinup/initialization processes and quality assurance and quality control steps to ensure accurate results were represented in the COMET-Farm tool. The project team anticipate scheduling these efforts differently in the future in order to meet the project objectives on schedule.

Previous portions of this report described how crops were partitioned into different classes reflecting differences in crop varieties, or differences in growing techniques, or both. Originally when the project was envisioned such divisions might be required, however the extent of the divisions and amount of additional verification work required was not anticipated. Despite the extra effort that ensued, the project team believe these additions are a very positive improvement to the COMET-Farm system.

There is tremendous amount of variation in how grapes are grown, and how crop yields are manipulated to influence the quality of the fruit. These include variations in cordon systems, fruit pruning objectives, irrigation systems, intentional water stresses, intentional nutrient stresses, harvest timing, vine density and row spacing, and other factors. These issues, in combination, contribute to a great deal of variation in crop yield and quality as well as plant growth characteristics. There is a great deal of additional work that can still be done to improve how grapes are modeled and how managing vineyards can contribute to climate change mitigation. These issues are reflected in some orchard crops as well.

Relatively little work has been done on vineyard and orchard cover crop (“floor”) management, however research findings indicate that the type of floor vegetation and how it is managed may have the greatest potential climate change mitigation impact. There is a great deal of additional work that can be done to improve the understanding how floor management affects crop growth and nutrient dynamics as well as climate change mitigation potential.

An unexpected outcome was that the project team did not anticipate needing to develop separate leafy crops and brassica crops for the desert regions.

The overall goals of this grant were achieved.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
62	Promotion of California Grown Specialty Crops in Mexico	
Grant Recipient: California Department of Food and Agriculture	**Grant Agreement No.:** SCB14062	**Date Submitted:** December 2017
Recipient Contact: Josh Eddy	**Telephone:** (916) 654-0433	**Email:** josh.eddy@cdfa.ca.gov

Project Summary

Mexico is a growing export destination for California's specialty crop sector. Over the last 10 years, overall exports to the market have almost doubled (2005 - $591 million; 2015 - $1.059 billion). Eighty four percent of California's agricultural exports to the market represent the specialty crop sector. This project enhanced the competitiveness of California specialty crops through trade and consumer promotions that increased the purchase of specialty crop products in Mexico. While Mexico is a fast growing market for U.S. agricultural products, local production and regional competition represents a challenge for California specialty crop producers to expand exports and market share. This project addressed this issue by developing generic promotions of California specialty crops at the consumer and trade (buyer) level, this project increased the visibility and awareness of these products to targeted demographics. Local production and regional competition is a specific issue this project addressed.

This project was important and timely, because of the continuing growth within the retail and foodservice sectors and the need to keep California specialty crops visible and competitive in relation to domestic (Mexico) and regional producers. By participating at an annual foodservice tradeshow (Abastur) and conducting retail promotions, this project provided increased visibility and promotion for California specialty crops.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The overall promotion program consisted of the following elements:

Trade Mission:
A trade mission to Mexico occurred August 27-30, 2017). The mission consisted of five representations of California's specialty crop marketing associations and businesses and two California Department of Agriculture (CDFA) staff. While in Mexico, the delegation met with government officials, Mexico trade associations, and representatives for the retail/foodservice sector to promote specialty crop products and develop future opportunities for promotions and education opportunities such as, seminars on produce handling, to increase the competitiveness of the specialty crop sector.

Results of the trade mission element included (Delegation in Mexico for two days): Media Press Conference targeting 15 media outlets; four promotional meetings in Walmart, Vidimport, Grupo PM, a visit to California/Global Marketing and Sales, Inc.; and two policy/government meetings with Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) and United States Department of Agriculture (USDA) Agricultural Trade Office. Each of these meeting provided the opportunity for California specialty crop representatives to better understand market dynamics, leverage in-market activities

for the promotion of specialty crops and provide visibility to key trade entities. These meetings have allowed for follow-up discussion and planning to conduct future specialty crop promotions with Walmart and a visit to California/Global Marketing and Sales, Inc.

Trade Show/Seminar:
CDFA along with project partners participated at the ABASTUR trade show, which occurred August 29 - September 1, 2017 in Mexico City, which is the largest food service trade show in Latin America. Also during ABASTUR, as part of the show's educational program, project partners conducted an educational seminar demonstrating the diversity, quality, and nutritional elements of California specialty crops and how they can be showcased in food offerings at restaurants and hotels.

Results of the trade show/seminar element included: Participation in the ABASTUR trade show which led to 267 direct company inquires (booth badge scans/cards) on California specialty crop products and 1,495 indirect inquires on U.S. agricultural products (provided by U.S. trade show organizer to all exhibitors). The one hour California specialty crop seminar at ABASTUR highlighted three California specialty crop dishes and had approximately 25-30 trade attendees.

Retail/Supermarket Promotions:
CDFA along with project partners conducted retail promotions in August and September for California specialty crops in selected supermarket chains. The promotion included in-store demonstrations/tastings and associated promotional/merchandising material. In addition, advertising was conducted to further the exposure and visibility of this promotional activity.

As part of the project’s goals and outcomes, CDFA and project partners conducted a variety of activities from planning, development and implementation associated with program deliverables. This required significant coordination among program partners in relation to contracting, individual program oversight, and subcontractor management.

Results of the promotional program included: Produce tasting/sampling at 32 stores in the Mexico City area, representing 393 sampling days. Five California specialty crop products were sampled during this period: peaches, pears, nectarines, almonds and pistachios.

One unusual development was the catastrophic earthquake that occurred on Mexico City on September 21, 2017. As a result of this crisis, promotional activities (retail promotions) were postponed for an appropriate period.

This project focused specifically on California specialty crops and did not benefit other commodities. Project staff and project partners worked in collaboration to ensure that funds were focused on solely enhancing the competitiveness of specialty crops.

This project would not have been possible without the contributions and role of the project partners. Project partners coordinated the activity, contracting, program organization/design, recruitment, trade show participation, staffing for promotional activities, and overall oversight.

Goals and Outcomes Achieved

Performance goals and measurable outcomes associated with conducted promotional elements are as follows:

Retail/Supermarket Promotions:
As part of the retail promotions, the project had the goal of increasing California specialty crop sales in Mexico. This goal was evaluated through a performance metric that tracked sales information with the participating retail chain in which promotions were held. As a result of the promotions more than 57,000 tastings/samples were conducted and resulted in the sales of 903 bags of pistachios; 822 bags of almonds; 4,986 kilos of pears; 5,610 kilos of peaches/nectarines; and 926 kilos of plums. Estimated total sales were approximately: $40,000-$50,000 ($682,644 MXD). This was below targeted sales goal of $250,000 (USD).

Trade Mission/Trade Show:
As part of the trade mission/tradeshow activity, the goal was to increase the knowledge of a set number of buyers (200) on specialty crop attributes. In addition, 80 buyers would report the intention to access/produce/prepare/preserve specialty crops. As a result of the trade mission/trade show, 267 direct inquires occurred, meeting the overall metrics identified.

Initial outcome measures for this activity were not established as being long term.

As a short term project, baseline data was not established for this activity. With the completion of the promotional program in Mexico, future activities can rely on the following benchmark metrics:

2017 Retail Sales Benchmark: - $50,000 (five week promotional period). 2017 Trade Show Benchmark: 267 direct inquires on California specialty crop products with the intention to access/produce/prepare/preserve specialty crops.

Overall, the promotional program provided the opportunity to highlight California specialty crop products in the retail and foodservice sectors. This activity brought specialty crop representatives to the market to directly meet with the trade sector; highlighted the diversity of California specialty crops in a leading food service trade show; and conducted in-store promotions of specialty crops. These activities were supplemented with consumer advertising and educational seminars directed towards the foodservice trade.

Quantifiable results of the program were less than anticipated, primarily with the retail promotion element. Timing of the promotions (August/September) and the earthquake can be partially attributed to the unsuccessful results. The promotional efforts however, further highlighted the challenges within the market related to local production and regional competition representing a challenge for California specialty crop producers in expanding exports and market share.

Beneficiaries

On average, approximately 26 percent of California's agricultural production is exported and agricultural exports to Mexico is valued at $1.059 billion - a majority of which is specialty crop production representing approximately 84% of overall exports. These activities have the potential to increase overall consumer and trade awareness of promoted California specialty crops. Estimated reach of the developed activities include 17,000 trade show visitors and two million consumers through advertisement.

Promotional activities directly benefited the following commodities/products on a generic basis: almonds, pistachios, raisins (trade show), peaches/nectarines, olive oil (trade show), plums, wine (trade show) and pears.

Lessons Learned

Overall, the implementation and development of programs by project staff and subcontractors met with overall expectations. The retail/supermarket promotion activity experienced challenges based on increased expectations of project leads and estimated exposure/deliverables the project would achieve. Project staff also experienced logistical challenges in communication between corporate offices and individual stores in which the promotions occurred. It is recommended that future retail/supermarket promotions focus on 3-5 flagship/high-volume stores and the promotional footprint should be expanded in those store to provide higher visibility and attract more consumer exposure.

In regards to the trade show/education component, the activity performed as expected. Tradeshows provide an opportunity to connect with potential buyers, education on specialty crop products, and increase overall awareness and market visibility. The tradeshow activity met with expectations of this promotional project.

In terms of implementing the program, the promotional activities occurred as anticipated. The unexpected aspect to the programs, which was the earthquake that impacted the region and led to a postponement of retail promotional activities. Outside of this occurrence, no other unexpected outcomes occurred.

Other results included general metrics from the retail promotions which indicated that 94% of consumers bought California specialty crop products after sampling during the store tastings; 84% of consumer were women between the age of 36-45; and that 55% of surveyed consumers had previously purchased California specialty crop products. In addition, 53% of surveyed consumers were aware of nutritional benefits of products and quality was the highest rated category for purchasing specialty crop products.

The primary challenge was the development of appropriate metrics and baselines for identified measurable outcomes. As a first year, short term project, without baselines it was difficult to determine an appropriate metric. It is advised that when conducting first year activities, without baselines, to work closely with program partners and subcontracts to identify and determine appropriate metrics.

Additional Information

See attachment 1.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 63	**Project Title:** Using Transmission Electron Microscope and Digital Camera for the Detection of Plant Virus Pathogens at the Plant Pest Diagnostics Center	
Grant Recipient: California Department of Food and Agriculture, Plant Pest Diagnostics Center	**Grant Agreement No.:** SCB14063	**Date Submitted:** December 2017
Recipient Contact: Tongyan Tian	**Telephone:** (916) 738-6717	**Email:** Tongyan.tian@cdfa.ca.gov

Project Summary

Plant viruses are important pathogens on specialty crops. Timely and accurate diagnostics of these viruses are critical both for the protection of specialty crops and providing support for phytosanitary certification for specialty crop export in trade. At the Plant Pest Diagnostics Center (PPDC) of the California Department of Food and Agriculture, the transmission electron microscope (TEM) played an important role by allowing the PPDC to quickly assess plant samples for the presence of virus particles. However, the PPDC did not have a way of preserving the images for what had been detected with the TEM. Without a digital CCD camera, the PPDC was unable to measure the sizes of virus particles and observations under the TEM could not be documented. Purchasing a digital CCD camera, BIOSPRINT12M-B, for the TEM would allow the PPDC to use this system to serve the vital role of plant virus detection on specialty crops.

The focus of this project was the purchase of a specialized digital CCD camera, BIOSPRINT12M-B, to enable the PPDC to record images from the TEM. The PPDC already had the TEM, Hitachi 7500, however, lacking an image recording system for virus detections. The BIOSPRINT12M-B digital camera would enhance the PPDC's ability to detect viruses by providing more detailed high quality images. Virus particle sizes could also be measured using the software provided with the camera. These functions are critical for virus particle analysis during screening of virus pathogens on specialty crops. Therefore, the PPDC proposed to purchase the BIOSPRINT12M-B for virus detection.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Following the procurement process, the CCD Camera was ordered in September 2017. The CCD Camera, BIOSPRINT12M-B, was installed and training was completed from December 4, 2017 through December 8, 2017.

This equipment will be used to provide initial diagnostics of viruses potentially infecting specialty crops. The usage of the CCD camera and other specific diagnostic methods will enable staff to determine virus identities and the specialty crop hosts that are likely to be affected. The PPDC works with all plants grown in California for pest diagnostics. However, approximately 95 percent of the plant samples are specialty crop. This equipment will be marked “For Specialty Crops Only” and lab staff will be made aware of this use restriction.

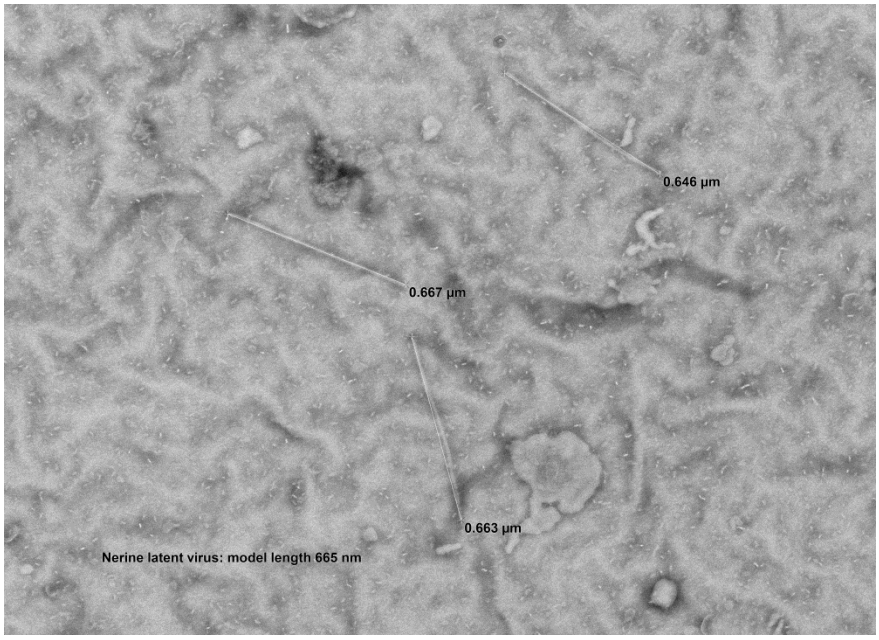
Goals and Outcomes Achieved

While the original project was approved on August 16, 2017, the procurement process took longer than anticipated due to the new statewide accounting and procurement system. The procurement process to acquire

the equipment was completed on September 26, 2017. Due to unforeseen shipping delays, the installation and training of the equipment was not completed until December 4, 2017 through December 8, 2017.

After the installation and training, staff members at the PPDC were able to record the images from the TEM and were able to measure the sizes of virus particles using the CCD Camera, BIOSPRINT12M-B.

Below is a photo of Nerine latent virus from a specialty crop, flower bulb-amaryllis, taken with the CCD Camera, BIOSPRINT 12M-B:



The use of the CCD digital camera will enable staff to record the virus particle size and compare with the sizes of known virus groups; thus, reducing the amount of uncertainty during sample assessment. This will help in accurate and timely identification of viruses and will serve to protect specialty crops from the spread of virus diseases and promote the export of specialty crop products. Since the completion of the installation and training on the CCD Camera, BIOSPRINT12M-B, staff have had the capability to perform the task.

The PPDC processed approximately 7,000 phytosanitary samples last year and anticipated an increase of one percent or 70 samples. This will be in addition to samples from materials intercepted at the border inspection stations and county agricultural inspections. Due to the delay in receiving and training staff on the equipment, the projects performance goals and outcomes have not been achieved.

Beneficiaries

The PPDC services for the improvement of plant quality and for export of agricultural products by providing accurate and timely diagnostics of plant viruses. Ninety-five percent of the samples submitted for virus diagnosis were specialty crops. The specialty crop growers will benefit from the new camera due to the enhancement of the labs ability to perform virus diagnostics.

The PPDC is responsible for plant virus disease detection for regulatory and phytosanitary purposes. *Cucumber green mottle mosaic virus* on cucurbit crops, *Lettuce mosaic virus* on lettuce, and *Celery mosaic virus* on celery are just a few examples that the PPDC tests to support specialty crops in California. Per California Agricultural Statistics Review (https://www.cdfa.ca.gov/statistics/PDFs/2016Report.pdf), in California for 2015 there were:

- 3,500 acres of cucumbers with a total value of $21,253,000
- 190,500 acres of lettuce (head, leaf, and romaine) with a total value of $2,255,391,000
- 28,800 acres of celery with a total value of $437,441,000

As previously stated, the lab has processed about 7,000 phytosanitary samples last year and anticipated about the same number of samples in 2018. This will be in addition to samples from materials intercepted at border inspection stations and county agricultural inspectors. A majority of these samples must be tested for viruses, in addition to fungi and bacteria, and the CCD digital camera will be used for virus identifications. California grows over 350 different kinds of specialty crops worth several billion dollars, and it is important to keep exotic viruses from entering the state and establishing here. The virus diagnostics conducted at the PPDC lab also helps certify California specialty crop products for export as free of viruses, thereby enabling specialty crop trade worth several hundreds of millions of dollars.

At this time the lab does not have an adequate mechanism to estimate the amount of savings due to the increase in number of phytosanitary samples processed each year.

Lessons Learned

The California Department of Food and Agriculture transitioned to a new accounting and procurement system. Procurement staff were being trained on the new procurement process when the camera was being ordered. Ordering the equipment took longer than expected due to the transition to the new system.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
64	Increasing the Capacity of the Plant Pathology Laboratory for Testing of Specialty Crops	
Grant Recipient: California Department of Food and Agriculture, Plant Pest Diagnostics Center	**Grant Agreement No.:** SCB14064	**Date Submitted:** December 2017
Recipient Contact: Cheryl Blomquist	**Telephone:** (916) 738-6707	**Email:** Cheryl.Blomquist@cdfa.ca.gov

Project Summary

Field inspections, fungal or bacterial isolations and pathogenicity tests allow nursery stock produced in California to be cleared for export to foreign markets. The agricultural economy of specialty crops produced in California was worth $44.7 billion dollars with agricultural products sold to foreign markets being the most rapidly growing segment. The number of phytosanitary certificates written for specialty crop product export has increased. New diseases are found in nursery crops during inspection that must also be confirmed. The Plant Pathology Laboratory sought to increase capacity of growth chambers used to conduct laboratory testing related to the movement of specialty crops in commerce. If a disease is detected in the inspections, it is necessary to prove the fungal or bacterial organism caused the disease. This is reproducibly done in a dew chamber and followed by grow out in an environmentally-controlled growth chamber. Once inoculated, plants need to be maintained under a controlled environment with high humidity in order for disease to be confirmed. The lack of controlled environmental conditions makes it difficult to simulate disease-causing conditions. State and Federal permits for diagnostic testing required the laboratory to perform pathogenicity tests in a growth chamber and will not permit use of a greenhouse facility.

A new environmentally contained growth chamber would enhance the accuracy of the detection and identification of plant pathogens for specialty crop fruit and nursery stock and improve California growers' ability to access international markets. Without confirmation of a new disease by pathogenicity tests, there is always a lingering doubt that the isolated fungus or bacterium may not actually be the cause of the disease symptoms.

The focus of the project was the purchase of a piece of scientific equipment, an environmentally controlled growth chamber. This chamber had lights to promote plant growth, temperature and humidity regulation, which could be adjusted to provide the environmental conditions required for most plant pathogens to cause disease in their host plants. The Plant Pathology Laboratory needed to increase the capacity of growth chambers used to conduct laboratory testing related to the movement of specialty crops in commerce. Without these growth chambers, diseases confirmations would be delayed.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Following the procurement process, the growth chamber was ordered on September 29, 2017. However, the equipment had not yet been received.

This project solely enhanced the competitiveness of specialty crops. Only specialty crops will benefit from the use of the equipment. The vast majority of work in any of the current growth chambers was done on specialty crops. In the small number of cases where a crop from another category would be inoculated, another growth chamber not purchased with Specialty Crop Block Grant Program funds would be used. The new growth chamber will be designated and used for specialty crops only, with a sign “For specialty crops use only” on the growth chamber.

Goals and Outcomes Achieved

The focus of the project was the purchase of a piece of scientific equipment, an environmentally controlled growth chamber. This chamber had lights to promote plant growth, temperature and humidity regulation, which could be adjusted to provide the environmental conditions required for most plant pathogens to cause disease in their host plants.

While the original project was approved on August 16, 2017, the procurement process took longer than anticipated due to the new statewide accounting and procurement system. The procurement process to acquire the growth chamber was completed on September 29, 2017. The equipment has not yet been received so performance goals and outcomes have not been achieved. There was a delay in the shipping, and shipment is expected in late January 2018. After installation of the equipment has been completed, training on use of the new chamber will be conducted, and then use of the new equipment will begin.

Beneficiaries

A new environmentally contained growth chamber will enhance the consistency and reproducibility of the detection and identification of plant pathogens for specialty crop fruit, nursery stock, and vegetable seed crops, and improve California growers' ability to access international markets. This project benefited the nursery industry and specialty crop fruit growers. The Agricultural Council of California had more than 15,000 grower members, and this project will potentially benefit these members. In addition, there were 4,139 farms in the nursery, greenhouse and floriculture category in California which will potentially benefit from this project (United States Department of Agriculture, National Agriculture Statistics Service 2012 Census of Agriculture, Specialty Crops).

This equipment will be a onetime purchase and will not require continued funding. Once installed, this equipment will continue to benefit the California specialty crop industry for many years beyond the grant period.

Lessons Learned

The California Department of Food and Agriculture transitioned to a new accounting and procurement system. Procurement staff were being trained on the new procurement process when the growth chamber was being ordered. Ordering the equipment took longer than expected due to the transition to the new system. Additionally, the growth chamber will be built individually, which caused delays in shipment of the equipment.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 65	**Project Title:** Improving the Pesticide Residues Analysis Process of Specialty Crops	
Grant Recipient: California Department of Food and Agriculture, Center for Analytical Chemistry	**Grant Agreement No.:** SCB14065	**Date Submitted:** December 2017
Recipient Contact: Tiffany Tu	**Telephone:** (916) 228-6830	**Email:** Tiffany.tu@cdfa.ca.gov

Project Summary

The Food Safety (FS) laboratories at the Center for Analytical Chemistry, California Department of Agriculture (CDFA), screen domestic and imported specialty crop produce for all classes of pesticides and herbicides and in cooperation with enforcement agencies, assure the quality and safety of California's food supply. Pureeing fruits and vegetables is the important first step in extracting agrochemicals such as pesticides from produce samples. Some crops are difficult to pulverize en masse such as lemons or pineapples.
The goal of this project was to equip the Sacramento FS laboratory with blenders, milling apparatus of different capacities and supplies for proper homogenization of different types of samples for effective pesticides extraction process ultimately assure data accuracy and relevant surveillance work.

As the Food Safety Modernization Act (FSMA) passed, laboratories performing food and feed testing are mandated or encouraged to provide data to governmental agencies working to protect the food supply. Regulatory agencies, including the Food and Drug Administration, have mandates such as Partnership for Food Safety Protection and the FSMA, and need laboratories' food and feed data to evaluate anomalies as part of an early warning system to detect food born outbreaks. For these governmental agencies to be effective in their task, data submitted must be accurate and timely.

This project equips the FS laboratory with proper process apparatus thus enhances programmatic efficiency and improves data quality ultimately.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Pesticide Residue (PR) staff started the purchase of the supplies immediately after the award was announced. Staff started to use the blenders and millers and lab supplies as soon as they arrived. The benefit was immediate as staff was able to homogenize many samples that were difficult to process previously. The added benefit was the availability of more supplies so the work flow was more efficient. Up to date, 265 small volume samples were pureed using the tube mill in addition to numerous hard to blend samples such as lemons or sweet corn. Safety was improved with the use safety shield as many samples were processed with dry ice which could cause pressure build-up.

Results from the Pesticide Residue program will be reported in the 2017 California Department of Pesticide Regulation Annual Summary which will be available December 2018. Access to these reports can be found at: http://www.cdpr.ca.gov/docs/enforce/residue/rsmonmnu.htm.

Goals and Outcomes Achieved

As stated, immediate benefit was observed as PR staff started implementing the use of the new supplies purchased by funds from this project. New operating procedures were written specifically for the use of the tube mill. New assignments were instituted as more supplies were available. Staff no longer need to wait for their turn to use apparatus.

As stated, PR staff has been able to process 265 small volume samples and many difficult to blend produce samples (30% increase). Turn-around time for projects was reduced because of effective workflow. The goal of improving process efficiency and results has been accomplished. A report will be made by FS laboratories in the CDFA Center for Analytical Chemistry 2017 annual report which will be released in late 2018. A copy of the current report can be found at: https://www.cdfa.ca.gov/is/pdfs/Reports/ISDAnnualReport2015.pdf.

Beneficiaries

The immediate beneficiary of increased sample analysis capacity, speed, and accuracy is the California specialty crop industry and consumers. California has strict guidelines for pesticide use. The ability to more quickly and accurately test specialty crops will substantially decrease the potential for quarantines and public safety incidents that may result in loss of revenue for specialty crop farmers. The knowledge and assurance that California quickly and accurately tests specialty crops also influences the potential of revenue growth on a national and global market scale. Additionally, laboratory staff performing samples preparation benefited from the appropriate apparatus purchased.

PR laboratories process approximately 3,700 samples representing 150 different specialty crops. Apples, grapes, sweet corn, broccoli, and tomatoes are just a few examples that the lab tests to support specialty crops in California. Per California Agricultural Statistics Review (https://www.cdfa.ca.gov/statistics/PDFs/2016Report.pdf), in California for 2015 there were:

- 14,000 acres of apples with a total value of $40,363,000
- 115,000 acres of broccoli with a total value of $866,464,000
- 29,900 acres of sweet corn with a total value of $159,068,000
- 112,000 acres of table grapes with a total value of $1,741,729,000
- 30,400 acres of tomatoes with a total value of $328,898,000

Lessons Learned

A major positive result was staff's ability to process samples quickly and more efficiently than previously possible. Staff no longer have to wait for their "turn" to process specialty crops. This has caused the FS laboratories output to increase.

An unexpected result has come in the form of increased staff morale. Staff are no longer waiting for an opportunity to use the equipment and this helps them progress through the work day.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
Karen Ross, Secretary

2014
Specialty Crop Block Grant Program – Farm Bill (SCBGP-FB)
FINAL REPORT
APPENDIX

USDA, AMS Agreement No:
Specialty Crop Agreement No. 14-SCBGP-CA-0006

State of California
Department of Food and Agriculture
1220 N Street
Sacramento, CA 95814

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Date Submitted:
March 5, 2018

APPENDIX
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CALIFORNIA
always in season
PART 4: Second-generation California farmer Bill Smitcamp of Wawona Ranch wants the whole country to enjoy his peaches.
watch the accompanying video at visitcalifornia.com/californiagrown
CALIFORNIA PEACHES
fresher than fresh
Q&A
WITH BRETT WILLIAMS, THE BREWMASTER AT THE FAMILY-OWNED AND -OPERATED 168 LOCAL BREWERY, AND HIS PARENTS AND BUSINESS PARTNERS, CHERYL AND RANDY.
CA GROWN
California


CALIFORNIA
always in season
PART 5: Casey Houweling is a farmer who has mastered the art of growing tomatoes using cutting-edge technology at his sustainable greenhouse.
watch the accompanying video at visitcalifornia.com/californiagrown
GREENHOUSE FARMING
HOUWELING'S
it's always summer for our tomatoes
Q&A
WITH JON SHOOK AND VINNY DOTOLO, THE CO-OWNERS AND CO-CHEFS BEHIND ANIMAL, SON OF A GUN AND JON & VINNY'S.
CA GROWN
California


CALIFORNIA
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PART 5: Vincent Ricchiuti and his father, Patrick, are farmers who are changing the way we think about olives by growing and pressing the freshest organic olive oil on the market.
watch the accompanying video at visitcalifornia.com/californiagrown
CALIFORNIA OLIVES
quality of freshness
Q&A
WITH JON SHOOK AND VINNY DUFRESNE, THE CO-OWNERS AND CO-CHEFS BEHIND ANIMAL, SON OF A GUN AND JON & VINNY'S
CA GROWN


CALIFORNIA
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PART 4: Third-generation California farmer Jeff Colombini of Lodi Farming Co. is on a mission to turn out the best cherries you can buy: fresh, plump and sweet.
watch the accompanying video at visitcalifornia.com/californiagrown
CALIFORNIA SWEET CHERRIES
CHEFS SARAH & EVAN RICH
Rich Table, San Francisco
Q&A
WITH CALIFORNIA CHERRY FARMER JEFF COLOMBINI, LODI FARMING CO.
CA GROWN
California
dream big


CALIFORNIA
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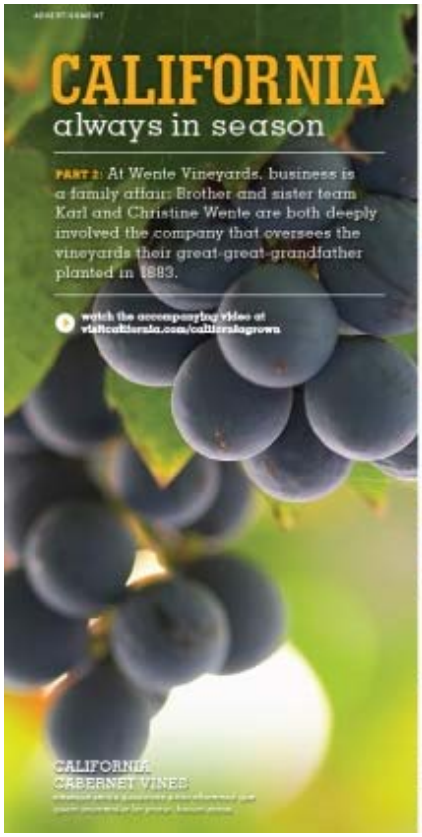
PART 1: California farmers Joe Turkovich and Nick Michels grow dried plums that are coveted both all over the world, and in local restaurants, like Rich Table in San Francisco.
watch the accompanying video at visitcalifornia.com/californiagrown
CALIFORNIA
DRIED PLUMS
Generations of California farmers bringing you the sweetest natural sensation — California dried plums.


generations
synergy
CHEFS:
SARAH & EVAN RICH
Rich Table, San Francisco


Q&A
WITH CALIFORNIA DRIED PLUM FARMERS
JOE TURKOVICH AND NICK MICHELS
CA GROWN
California
dream
Big
FOR MORE INFORMATION AND FEATURED RECIPES, GO TO
visitcalifornia.com/californiagrown


CALIFORNIA
always in season
PART 2: At Wente Vineyards, business is a family affair: Brother and sister team Karl and Christine Wente are both deeply involved the company that oversees the vineyards their great-great-grandfather planted in 1883.
watch the accompanying video at visitcalifornia.com/californiagrown
CALIFORNIA
CABERNET VINES


WENTE


from the ground up
Q&A
WITH FIFTH GENERATION
WINEGROWERS CHRISTINE AND KARL
WENTE, OF WENTE VINEYARDS
CA GROWN
California
dream
Big

Social and Run of Site Extensions of Always in Season and audience relevant CA GROWN content samples below:














CALIFORNIA
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FOOD & WINE
CALIFORNIA
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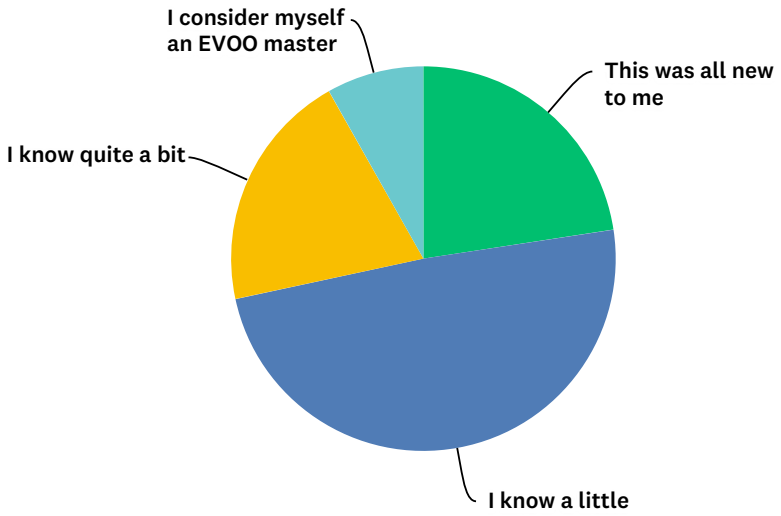
Food & Wine
Always In Season
California Grown


Food & Wine magazine
Follow
The Northern California climate creates the perfect environment for Dried Plums to develop and be harvested. #CAGROWN #VisitCalifornia #spon
Food & Wine magazine
Follow
Ad: Did you know California is home to 600 Cherry growers farming over 26,000 acres? Learn more at bit.ly/1KsRvqc. #CAGROWN

Q1 How would you rate your knowledge about Extra Virgin Olive Oil before seeing our exhibit?

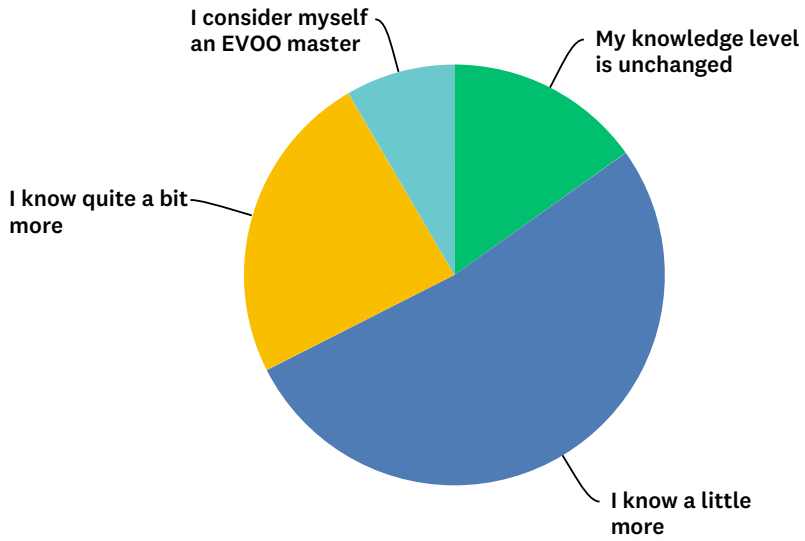
Answered: 416 Skipped: 0



Answer Choices	Responses	
This was all new to me	22.60%	94
I know a little	49.04%	204
I know quite a bit	20.19%	84
I consider myself an EVOO master	8.17%	34
TOTAL		416

Q2 After seeing our exhibit, how would you rate your knowledge of Extra Virgin Olive Oil?

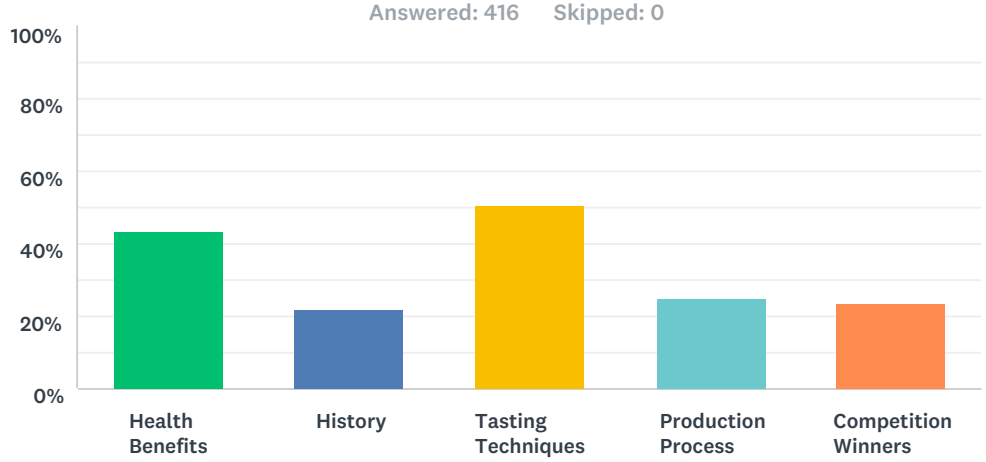
Answered: 416 Skipped: 0



Answer Choices	Responses	
My knowledge level is unchanged	15.14%	63
I know a little more	52.40%	218
I know quite a bit more	24.04%	100
I consider myself an EVOO master	8.41%	35
TOTAL		416

Q3 What interested you most in the exhibit? (Check all that apply)

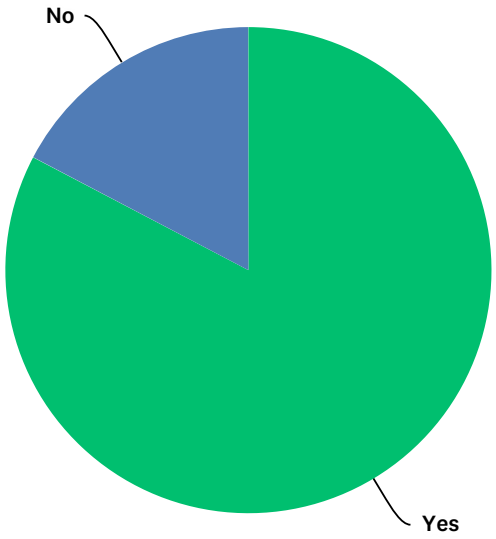
Answered: 416 Skipped: 0



Answer Choices	Responses	
Health Benefits	43.27%	180
History	21.88%	91
Tasting Techniques	50.48%	210
Production Process	25.00%	104
Competition Winners	23.56%	98
Total Respondents: 416		

Q4 Have you purchased Extra Virgin Olive Oil in the past?

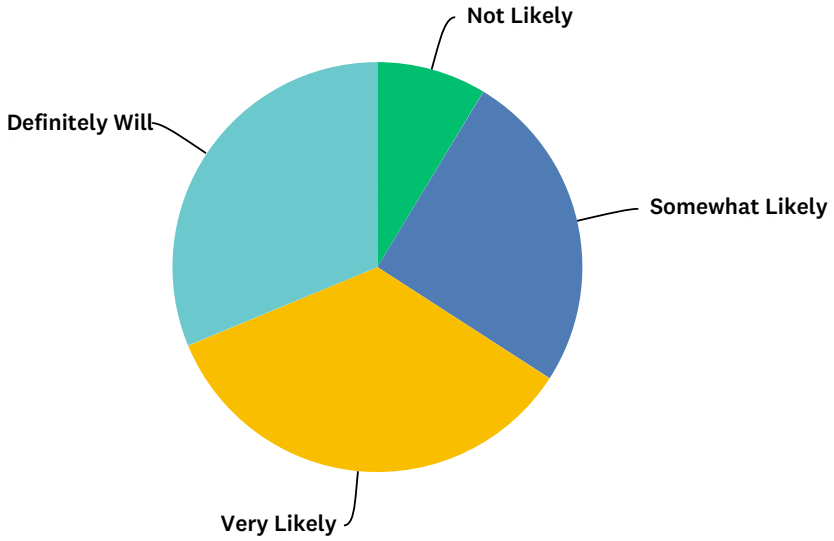
Answered: 416 Skipped: 0



Answer Choices	Responses	
Yes	82.69%	344
No	17.31%	72
TOTAL		416

Q5 After seeing our exhibit, how likely are you to purchase California Extra Virgin Olive Oil as compared to other grades of olive oil?

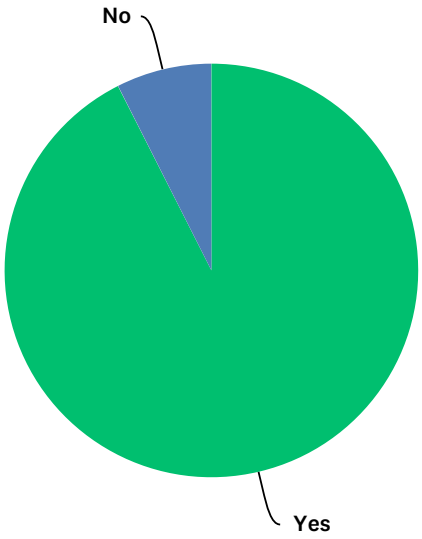
Answered: 416 Skipped: 0



Answer Choices	Responses	
Not Likely	8.65%	36
Somewhat Likely	25.48%	106
Very Likely	34.62%	144
Definitely Will	31.25%	130
TOTAL		416

Q6 Do you feel California State Fair exhibits provide valuable information, in an entertaining way?

Answered: 416 Skipped: 0



Answer Choices	Responses	
Yes	92.55%	385
No	7.45%	31
TOTAL		416

Q7 Comments:

Answered: 77 Skipped: 339

American Farmland Trust

Stewardship Practices Case Studies Matrix

Stewardship Challenges	**Crop**									
	Tree fruits and Nuts	Berries	Grapes	Leafy greens and cole crops	Root crops	Citrus and Avocado	Tomatoes	Cucurbits and melons	Other produce	Nursery and Flowers
Water conservation/efficiency	x	x	x	x	x	x	x	x		x
Water supply	x	x	x	x						
Groundwater quality		x	x	x			x			
Surface water quality		x	x	x			x	x		
Air quality	x	x	x	x		x	x			
Greenhouse gas reduction/carbon sequestration	x	x	x	x	x	x		x		
Biodiversity/wildlife habitat/pollinators	x	x	x	x	x		x		x	x
Energy conservation/renewables	x	x	x	x	x	x	x	x		x
Erosion/soil health/quality	x		x	x	x		x	x		x
Nutrient management	x	x	x	x	x		x	x		x
Pest management	x	x	x	x	x	x	x	x		x

Geography										
Sacramento Valley	x			x	x		x	x	x	x
San Joaquin Valley	x		x	x	x	x	x	x	x	
North Coast			x	x	x			x		x
Bay Area		x	x	x						
Central Coast	x	x	x	x						x
Southern California		x			x	x				x
Inland Empire										

x indicates a completed profile contains elements

University of California Agriculture and Natural Resources
UCDAVIS AGRICULTURAL SUSTAINABILITY INSTITUTE

Additional Resources on Marketing and Selling Your Produce

Many resources on marketing and selling your produce can be found on the UC SAREP "Breaking into Wholesale" webpage http://asi.ucdavis.edu/programs/sarep/research-initiatives/fs/supply/breaking-into-selling-wholesale

FOOD SAFETY

- Food Safety Begins at the Farm: http://www.gaps.cornell.edu/documents/edumat/FSBFEngLOW.pdf
- Small Farm Digest: Food Safety for Small Farmers: http://nifa.usda.gov/sites/default/files/resources/Small%20Farm%20Digest%202013.pdf
- California Small Farm Food Safety Guidelines (available in multiple languages): https://www.cdfa.ca.gov/is/i_&_c/sffsg.html
- Good Agricultural Practices & Harmonized GAP Food Safety Manual: https://ag.umass.edu/vegetable/food-safety-for-farmers/gap-online-manual

PACK AND GRADE (Packing Standards)

- http://asi.ucdavis.edu/programs/sarep/publications/food-and-society/infosheet-producepackguide.pdf
- California Department of Food and Agriculture (CDFA) Standardization: https://www.cdfa.ca.gov/is/i_&_c/standardization.html

PRICING

- Rodale Institute's Organic Price Report: http://rodaleinstitute.org/farm/organic-price-report-tool/
- USDA Market News Report: http://www.ams.usda.gov/market-news/fruits-vegetables

BUYER INTRODCTIONS

- UC Small Farm Program's Marketing Through Wholesalers and Shippers: http://sfp.ucdavis.edu/pubs/SFNews/archives/92091/
- UC Small Farm Program's Time to Call a Wholesaler-Distributor? http://sfp.ucdavis.edu/pubs/SFNews/archives/93052/
- Scaling Up - Perspectives from Growers and Buyers on Barriers and Benefits to Wholesale Marketing of Local Fruits and Vegetables: http://www.leopold.iastate.edu/sites/default/files/pubs-and-papers/2012-10-scaling-perspectives-growers-and-buyers-barriers-and-benefits-wholesale-marketing-local-fruits-and-v.pdf

INSURANCE

- Drake Agricultural Law Center Legal Guide for Direct Farm Marketing: http://directmarketersforum.org/direct-farm-marketing-checklists/
- Campbells Risk Management Small Farm Insurance: http://www.campbellriskmanagement.com/small-farm-insurance
- USDA Risk Management: https://newfarmers.usda.gov/risk-management

DELIVERY

- Siskiyou Sustainable Cooperative Case Study: A Model for Cooperative Farming & Marketing http://smallfarms.oregonstate.edu/sfn/spg09cooperative
- Resources on starting an Agricultural Cooperative: http://cccd.coop/publications/general_resources/ag_resources
- Collaborative Marketing for Small Farms: http://smallfarms.cornell.edu/files/2012/05/Collaborative-Marketing-for-Small-Farms-10385vc.pdf

Directory of California Farmer Education & Support Services Organizations

Acknowledgements: Many thanks to all who have contributed to the development of this directory! The online survey to collect organization data was first created and promoted by the Information-Sharing Workgroup of the Farm Education Network (FEN), which convenes each year at the EcoFarm Conference. UC SAREP compiled and formatted the FEN survey responses, and FarmsReach compiled and formatted the Ecosystem Chart & Map that serve as companions to this Directory. Generous funding was provided by the California Department of Agriculture (CDFA) and by Rabobank. This project was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

Alameda County RCD

3585 Greenville Road, Suite 2
Livermore, CA 94550-6710
(925) 371-0154
www.acrcd.org

Mission: The Alameda County RCD provides technical and educational services to promote natural resource conservation and agriculture enhancement in Alameda County and the region.

Activities & Programming: Provide support, technical assistance and educational opportunities to promote resource conservation and sustainable agriculture. Additional work focuses specifically on enhancing food system infrastructure and supporting beginning farmers.

Regions Served: Alameda County and East Bay

Agricultural Land Based Training Association (ALBA)

P.O. Box 6264
Salinas, California 93912
(831) 758-1469
www.albafarmer.org

Mission: Our overall goal is to create greater economic opportunities for small farms while promoting ecological land management and healthy local foods. Objectives accomplished in pursuit of this goal include training in organic farm production, marketing, record-keeping, labor law, pest management and numerous other topics related to operating a small farm business.

Activities & Programming: Farmer Education Course, Farmer Incubator, and Food Hub. 2016 Goals: Organic Careers Development. Services include: business consulting, marketing consulting, production consulting. Delivery Format: consulting, advising, 1-1 assistance.

Regions Served: Central Coast

Community Alliance with Farmers (CAFF)

PO Box 363
Davis, California 95617
(530) 756-8518
www.caff.org

Mission: CAFF's mission is to build sustainable food and farming systems through policy advocacy and on- the-ground programs that create more resilient family farms, communities and ecosystems.

Activities & Programming: CAFF helps farmers by 1) Policy Advocacy by creating and changing state and national legislation; 2) Providing Farmer Services, working directly with farmers to get access to new markets (food safety planning, access to direct markets and farm to cafeteria) and improve their growing practices. 3) Climate Smart Ag Workshops coming in 2016. Delivery format: consulting, advising, 1-1 assistance.

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California

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California Center for Cooperative Development (CCCD)

979 F Street, Suite A-1
Davis, CA 95616
(530) 297-1032
www.cccd.coop

Mission: The mission of the California Center for Cooperative Development is to promote cooperatives as a vibrant business model to address the economic and social needs of our communities.

Activities & Programming: Education and technical support for farmers looking to create grower-owned businesses for marketing, supply purchasing, and equipment sharing. Group GAP coming in 2016. Delivery Format: consulting, advising, 1-1 assistance.

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California

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California FarmLink

303 Potrero Street, Suite 29-201
Santa Cruz, CA 95060
www.californiafarmlink.org

Mission: The mission of California FarmLink is to link independent farmers and ranchers to the land and financing they need for a sustainable future.

Activities & Programming: Our Land Access Program maintains a FarmLand Listing database of land available for lease or sale connecting farmers and landowners, and supports them through various types of technical assistance. The Farm Opportunities Loan Program provides flexibly structured financing to underserved, low-income, immigrant and beginning farmers across the state for operating, equipment and infrastructure loans. Delivery Format: Consulting, advising, 1-on-1 assistance, printed and online educational materials.

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California

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California Certified Organic Farmers (CCOF)

2155 Delaware Avenue, Suite 150
Santa Cruz, CA 95060
(831) 423-2263
www.CCOF.org

Mission: CCOF is a nonprofit organization that advances organic agriculture for a healthy world through organic certification, education, advocacy, and promotion. We envision a world where organic is the norm.

Activities & Programming: The CCOF Foundation envisions a world where organic is the norm. We advance organic agriculture for a healthy world through education and hardship grants, technical assistance, and consumer education. We are proud to build upon more than 40 years of CCOF's commitment to growing organic. Our two major offerings for beginner farmers are The Future Organic Farmer Grant Fund and the Organic Training Institute. The Future Organic Farmer Grant Fund is the only fund in the nation that provides educational grants exclusively to students and teachers of organic agriculture. Grant recipients (are made to) include K-8th grade teachers, high school, and vocational and higher education students, and works with teachers in low-income communities and students from disadvantaged backgrounds. Since 2013, the fund has disbursed nearly $150,000 and impacted more than 6,000 students, teachers and their families. The Organic Training Institute educates and connects farmers, processors and ranchers with resources to be successful in organic production. Over the last two years, the CCOF Foundation. educated more than 1,000 people through workshops, webinars and field days.

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California, National (US), Mexico

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Center for Agroecology and Sustainable Food Systems (CASFS)

1156 High St
Santa Cruz, CA 95064
(831) 459 -3240
www.casfs.ucsc.edu

Mission: The mission of the Center for Agroecology & Sustainable Food Systems (CASFS or the Center) is to research, develop, and advance sustainable food and agricultural systems that are environmentally sound, economically viable, socially responsible, nonexploitative, and that serve as a foundation for future generations.

Activities & Programming: The Center for Agroecology and Sustainable Food Systems (CASFS) is a research, education, and public service program based at the 30-acre organic farm and 3-acre organic garden at UC Santa Cruz. CASFS trains organic farmers through its 6- and 12-month Apprenticeship programs (scholarships available), offers free and low-cost beginning farmer workshops, and teaches other audiences from undergraduates to home gardeners. CASFS shares its training materials online for free, including the revised and expanded Teaching Organic Farming and Gardening: Resources for Instructors, and Teaching Direct Marketing and Small Farm Viability: Resources for Instructors. See casfs.ucsc.edu for more information. Delivery Format: Consulting, advising, 1-on-1 assistance, data & analytics about the sector overall, program evaluation, in person events, online and printed educational materials.

Regions Served: Regional, national, international

Center for Land Based Learning (CLBL), Farm Academy

5265 Putah Creek Rd
Winters, CA 95694
(530) 795-1520
www.landbasedlearning.org

Mission: The Center for Land-Based Learning exists to cultivate opportunity. For the land. For youth. For the environment. For business. For the future of agriculture.

Activities & Programming: The California Farm Academy offers a 7-month training program for beginning farmers, as well as the opportunity for new farmers to start their businesses with staff and infrastructure support on multiple sites in West Sacramento, Davis, and Winters as part of the incubator program. Additionally, other programs through the Center for Land-Based Learning offer hands-on learning experiences on farms in Sacramento, Solano, and Yolo Counties for high school students. Efforts in 2016: Launch of the Sacramento Valley Beginning Farmer Apprenticeship Program - an accredited agricultural apprenticeship program in collaboration with the Department of Apprenticeship Standards and Soil Born Farms. Delivery Format: Consulting, advising, 1-1 assistance.

Regions Served: Sacramento Valley

Center for Sustainability (CFS), Cal Poly SLO

California Polytechnic State University
San Luis Obispo, CA 93407-0250
(805) 756-5086
www.cfs.calpoly.edu

Mission: Using a holistic approach to today's challenges and opportunities in agriculture and the management of natural resources, the Center seeks to strengthen synergistic linkages across disciplines to provide a robust framework supporting 'Agriculture for Tomorrow.'

Activities & Programming: The Center for Sustainability is an auxiliary unit within the College of Agriculture that provides coordination of and outreach for sustainable agricultural activity on campus and in the community. This primarily involves hosting educational events, providing professional development and supporting special projects. It has also involved development of curricula (such as for organic agriculture) and fostering relationships within the regional food system. Efforts in 2016: We are currently developing an online resource for assessing and cultivating soil health and also a potential extended education training program for Veterans entering agriculture. Delivery Format: In-person events.

Regions Served: Central Coast

Center for the Study of the Americas-International Agroecology Program (SOCLA)

2288 Fulton St. Suite 103
Berkeley, CA 94704
www.socla.co or www.socla.co/en

Mission: The main goal of this program is to promote agroecological initiatives that exert a positive impact on the livelihoods and food sovereignty of small farming communities in various Latin American countries.

Activities & Programming: Research, training and publications on agroecology, urban agriculture, ecologically based pest management and seeding of climate change resilient farming systems, International Agroecology Conference every two years (2017, 2018) and online courses. Efforts in 2016: Short course on urban agroecology June 2016 Delivery Format: Printed or online educational materials, references, etc.

Regions Served: Global, Latin America, Emphasis on exchanges with California/Latin American Agroecologists

Central Coast Grown

246 S Higuera St.
San Luis Obispo, CA 93401
(805)769-8344
www.centralcoastgrown.org

Mission: Central Coast Grown creates strong connections among farmers, the public and the land to nourish our community, support local agriculture, and make local food products accessible for all.

Activities & Programming: We manage 20 acres of city-owned land on which 4 beginning farmer tenants lease acreage. we also offer educational programs to the continuation high school and our local PREPARE program (18-22 year olds with disabilities) Efforts in 2016: Providing educational workshops, farmer organizing through Farmers Guild. Delivery Format: Consulting, advising, 1-on-1 assistance, in person events, printed and online education materials.

Regions Served: Central Coast

Ecological Farming Association

2901 Park Avenue, Suite D-2
Soquel, CA 95073
(831) 763-2111
www.eco-farm.org

Mission: The mission of the Ecological Farming Association (EcoFarm) is to nurture healthy, just, and ecologically sustainable farms, food systems, and communities by bringing people together for education, alliance building, advocacy, and celebration.

Activities & Programming: EcoFarm provides events and resources that bring together farmers and food system stakeholders to learn and explore ecological farming, business practices and policies influencing the entire food system.Since its 1981 inception, the annual Ecological Farming Conference has been crucial to the sustainable and organic agriculture movement on the West Coast. Over 1800 farmers and food-system stakeholders convene at conference, a networking hub and incubator of initiatives around beginning farmers, climate change, conservation, and marketing.
Thousands more are participating in Capay Valley's HoesDown Festival and the Organic Stonefruit Jubilee in San Joaquin Valley. The farmer-led Ecological Farmers & Ranchers Alliance (EFRA) furthers the success of farmers and ranchers pursuing triple-bottom- line businesses (honoring the planet, people and profit) through collaborative programs.

Nationwide, people rely on consistent and timely information from EcoFarm, including Genetic Engineering News Service, and EcoFarm provides a bi-weekly Sustainable Ag Jobs List service with over 12,000 subscribers. Efforts in 2016:Current Ecological Farmers & Ranchers Alliance (EFRA) Initiatives: Livestock Producers -The Livestock Producers Committee is working on the creation of collaborative services for Central Coast meat producers and other regional meat producers. The group is currently exploring a "Plant in a Box" (PIB) that could be an alternative to a full production USDA inspected meat processing facility. Food Safety Clearinghouse- This online tool helps farmers understand how food safety affects them and how to determine their action plans and next steps in order to be compliant with current regulations.Seed Growers Network - The Seed Growers Network is currently working with Seed Revolution Now! and the Organic Seed Alliance to conduct variety trials and data collection of locally-adapted, public domain seed varieties for commercial use.Grain Growers Group- The goal of this newly formed group is to support local and heritage grain growing, milling and processing.Food Justice Certification - AJP is offering EFRA

guidance in triple bottom line standards and how to support farmers towards food justice certification.Delivery Format: In-person events.

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California

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Elkhorn Slough Estuarine Research Reserve (ESERR)

1700 Elkhorn Road
Watsonville, CA 95076
(831) 274-8700
www.elkhornsloughctp.org

Mission: The goal of the Coastal Training Program is to improve decision-making related to coastal resources management at local and regional levels. The program aims to provide coastal decision makers with knowledge and tools they need to address critical resource management issues.

Activities & Programming: Water quality expertise and information related to the Elkhorn Slough Delivery Format: Consulting, advising, 1-on-1 assistance.

Regions Served: Central Coast

Farmer Veteran Coalition

4614 2nd Street, Suite 4
Davis, CA 95618
(530) 756-1395
farmvetco.org

Mission: The mission of the Farmer Veteran Coalition is mobilizing veterans to feed America. We help veterans launch their farm careers, build their farm businesses and find viable employment in the agricultural industry.

Activities & Programming: In the coming months we will be expanding our efforts in California to help veterans get training and education at California schools and farm training programs, expand our efforts to get veterans internships on successful farm operations, support veteran farms through our Homegrown Heroes. Delivery Format: Consulting, advising, 1-on-1 assistance.

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California, National

FarmsReach

PO Box 7488
Berkeley, CA 94707
(415) 658-5405
www.farmsreach.com

Mission: The FarmsReach online platform and strategic community events help family farmers and agriculture organizations to connect, learn, and be more successful.

Activities & Programming: Through our online platform, farmers share information with each other, connect with farm advisors and service providers, access practical toolkits, and source inputs and supplies. By partnering with agriculture organizations, we offer an evolving mix of farm services and develop sector events to bolster our collective impact. FarmsReach's ultimate goal is to help farmers help each other and to help organizational partners expand their reach in the farming community.

Before switching our focus to farm education and support services, FarmsReach operated several farm-to-chef and farm-to-institution programs and developed software for regional distribution. In 2011, we published a popular white paper, "Building Regional Produce Supply Chains," that highlights the obstacles and opportunities in local food distribution.

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California

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Grange School of Adaptive Agiculture

16200 North HWY 101
Willits, CA 95490
www.school-of-adaptive-agriculture.org

Mission: The GSAA is an educational training center that equips the current and next generation of farmers and advocates with essential skills in the science, art and business of food. Through vocational workshops and its flagship program, an intensive 14 week, residential agriculture course, the GSAA has gained a reputation for being one the premier agriculture schools in Northern California.

Activities & Programming: We offer immersive training for adults in animal husbandry, crop production, business management, and industrial arts in a 14 week residential program. The education is split between guided field work on a demonstration farm, over 30 field trips, classroom lessons and workshops. Every Winter and early Spring we offer a series of continuing education workshops for farmers and ranchers. Efforts in 2016: The program is in its' first three years of capacity building, with opportunities springing up each year and an approach that takes in feedback to adapt our programs. Delivery Format: in-person events

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California

Holistic Management International (HMI)

5941 Jefferson St. NE, Suite B
Albuquerque, NM 87109
(505) 842-5252
www.holisticmanagment.org

Mission: Our mission is to educate people in regenerative agriculture for healthy land and thriving communities.

Activities & Programming: Place-based and online classes in Whole Farm/Ranch Business Planning, Whole Farm/Ranch Land Management, and Beginning Farmer/Rancher Training

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California

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Kitchen Table Advisors

405 14th Street, Suite 164
Oakland, CA 94612
www.kitchentableadvisors.org

Mission: Kitchen Table Advisors fuels the economic viability of sustainable small farms and ranches through practical business advising and trusted relationships.

Activities & Programming: Practical and personalized business advising over a three year period with small scale organic farms or pasture-based livestock ranches. Efforts in 2016: We will be on boarding 10-15 farms per year. Terms begin in November. Delivery Format: Consulting, advising, 1-1 assistance.

Regions Served: Central Coast, North Coast, Sacramento Valley, San Joaquin Valley

Multinational Exchange for Sustainable Agriculture (MESA)

2362 Bancroft Way
Berkeley, CA 94704
(510) 654-8858
www.mesaprogram.org

Mission: MESA cultivates a global grassroots network of food and farming leaders to revive community food systems, linking ancestral knowledge with innovation rooted in earth stewardship, equitable economies and multicultural alliances worldwide.

Activities & Programming: MESA is a global grassroots network that connects farmers, researchers and organizers to share heritage and innovation on behalf of resilient community food systems and advancing the next generation of farmers. MESA's network and programs offer: farmer-to-farmer exchange, experiential education, mentorship support, bilingual online curriculum in Applied Agroecology, and a Bay Area Urban Farmer Training Program to primarily serve immigrants and formerly incarcerated individuals. Delivery Format: in-person and online events, printed or online educational materials, references, etc.

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California

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NCAT/ATTRA

36355 Russell Blvd.
PO Box 2218
Davis, CA 95617
(530) 792-7338
Toll free Sustainable Agriculture Hotline
1-800-436-9140 (English) and
1-800-411-3222 (Spanish)
www.ncat.org/california and www.attra.ncat.org

Mission: Helping people by championing small-scale, local, and sustainable solutions to reduce poverty, promote healthy communities, and protect natural resources

Activities & Programming: NCAT/ATTRA provides in-person workshops for farmers, webinars, 1 on 1 technical assistance and training and publications (see website) on a wide variety of topics related to sustainable agriculture production. Efforts in 2016: NCAT/ATTRA is currently working with the Growing Roots Project (https://growingroots.berkeley.edu/) and will be teaching workshops on farm business planning, marketing,ecological soil management, ecological pest management, and beneficial habitat management, food safety, urban farming and pastured pork and poultry for beginning farmers. NCAT/ATTRA is also planning the second annual Latino Farmer Conference, to be held in November. http://www.latinofarmerconference.ncat.org/

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California

Organic Farming Research Foundation (OFRF)

P.O. Box 440
Santa Cruz, CA 95061
(831) 426-6606
www.ofrf.org

Mission: To foster the widespread adoption and improvement of organic farming systems.

Activities & Programming: At OFRF, we build the vital infrastructure that supports the success of organic farmers. Our four areas of focus are: POLICY, where we grow champions in Congress and federal agencies; EDUCATION, where we work to integrate organic farming programs into all agricultural universities; GRANTMAKING that expands the adoption of organic farming and practices while addressing urgent issues faced by many organic farmers in America; and building COMMUNITY to cultivate a broader and deeper connection among organic supporters.

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California, U.S.

Organic Seed Alliance (OSA)

PO Box 772
Port Townsend, WA 98368
(360) 385-7192
www.seedalliance.org

Mission: Organic Seed Alliance advances the ethical development and stewardship of the genetic resources of agricultural seed. We believe seed is part of our common cultural heritage – a living, natural resource that demands careful management to meet food needs now and into the future. We accomplish our mission through research, education, and advocacy.

Activities & Programming: We support farmers interested in producing seed commercially, as well as farmers who are interested in finding or developing the best crop varieties for their needs. We do this by:
- Providing in-person, print-based and on-line training in seed production and plant breeding
- Conducting variety trials and plant breeding projects in conjunction with farmers
- Providing appropriate seed production equipment
- Providing networking opportunities for current and prospective seed growers

Regions Served: Central Coast, North Coast, Northeast Mountain, Sacramento Valley, Sierra Nevada, Southern California

Pacific Coast Farmers' Market Association (PCFMA)

5060 Commercial Circle, Suite A
Concord, CA 94520
(925) 825-9090 or (800) 949-FARM
www.pcfma.org

Mission: Our mission is to empower California farmers to be enormously successful in Bay Area communities. You'll see us pursuing our mission every time you shop at one of our farmers' markets where local farms gather to sell their delicious products.

Activities & Programming: PCFMA creates economic opportunities through thriving certified farmers' markets. We organize over 65 weekly certified farmers' markets in more than 35 Bay Area communities. We're also happy to help our growers and non-agricultural producers take advantage of other opportunities to sell their product directly to consumers, including larger scale buyers such as restaurants and institutions. In addition, PCFMA helps its sister organization, Fresh Approach, to source from PCFMA farmers' market producers for their famers' market on wheels, Freshest Cargo, which drives into underserved communities, making local food more accessible.

Regions Served: Central Coast

Pie Ranch

PO Box 363
Pescadero, CA 94060
(650) 879-0995
www.pieranch.org

Mission: Pie Ranch cultivates a healthy and just food system from seed to table through food education, farmer training, and regional partnerships.

Activities & Programming: Workshops, tours, apprenticeships, internships, developing research on integrated animal crop production system, monthly community gatherings & barn dances, sharing information/knowledge/learnings. Efforts in 2016: Holding a workshop on blacklivesmatter, white people showing up for racial justice and how this connects to dismantling racism in food & farming systems

Regions Served: Central Coast

PUENTES - Bridging Sustainable Communities

4719 Quail Lakes Dr, Ste. G
Stockton, CA 95207
www.puentesca.org

Mission: PUENTES' mission is to spread the knowledge and the development of sustainable technology and stimulate a critical cooperative and positive attitude in at-risk communities throughout the Americas.

Activities & Programming: PUENTES is a 501 c (3) community service organization that operates the Boggs Tract Community Farm, the PUENTES CSA, the Stockton Fairgrounds Family Gardens and sponsors the Black Urban Farmer Association (BUFA), all in San Joaquin County. PUENTES CSA markets fresh produce and serves special needs families (the Community Divident Program) and operates a food hub that is supplying a growing network of urban food outlets (liquor and convenience stores). Our Nurbaculture (natural urban agriculture) Apprentice Training Program prepares new farmers to become urban agricultural entrepreneurs, and we are developing a partnership with San Joaquin Delta College to integrate the NATP into their academic offerings in horticulture and related fields. Each year more than a thousand community volunteers come out to engage in farmisthenics in support of our free range poultry, beekeeping, food forest, school garden, hyacinth composting, and other sustainable agriculture projects. Efforts in 2016: We hope to increase our food hub operations in more of the food desert areas in our community and will need to partner with more independent producers who meet our high standards (non-chemical), and we are always working on expanding our CSA sales. The third class of our two semester apprentice training program will begin later this fall and will provide an intensive and comprehensive training program to prepare wanta be urban agriculture entrepreneurs. Delivery Format: Business services, production services, marketing services

Regions Served: San Joaquin Valley

Rogue Farm Corps

PO Box 533
Ashland, OR
(541) 951-5105
www.roguefarmcorps.org

Mission: Rogue Farm Corps exists to train the next generation of farmers and ranchers through hands-on educational programs. We support our local agricultural economy and serves as a model for other communities.

Activities & Programming: Our farm training programs offer hands-on experience on a diverse network of commercial family farms in Oregon. We provide real world opportunities for beginners and advanced students of agriculture. Delivery Format: in person events

Regions Served: Oregon (active in the CA farming community as well)

San Benito Working Landscapes Group

P.O. Box 2080
Hollister, CA 95024
(831) 389-4486
www.pinnaclespartnership.org/working-landscapes

Mission: Finding common ground for ranching and conservation

Activities & Programming: In recognition of the vital role that ranchers play in caring for San Benito County's unique and valuable rangelands, the SBWLG connects local and regional land owners and managers to tools, events, and opportunities to support the economic viability of family ranches. The SBWLG also connects willing landowners and conservation partners for on-the-ground range management or wildlife habitat improvement projects, and seeks to document and share local success stories related to ranching and conservation. The SBWLG provides monthly e-mail updates to ranch owners/managers and other partners on available tools, resources, events, and opportunities related to the protection and enhancement of working ranches and farms in San Benito County and adjacent areas. SBWLG partners convene two or three times per year in San Benito County to share individual and organizational updates related to rangeland conservation in our area. Ranchers are invited to contact the SBWLG coordinator any time to request customized information about available resources (including peer-to-peer, rancher-to-rancher connections) to support the family's specific goals for range management, economic viability, or conservation. All information is kept confidential.

Regions Served: Central Coast

Santa Rosa Junior College, Shone Farm

7450 Steve Olson Ln
Forestville, CA 95436
(707) 535-3707
www.shonefarm.com

Mission: Shone Farm serves primarily as an outdoor laboratory site for agriculture and natural resource classes. A full complement of farm equipment and facilities exist on the farm for use by the students and staff. Students gain hands-on practices on the 365 acres which consist of forest, pasture, sustainable agriculture and vineyard, and also learn how to make important business management decisions through direct sales at various locations. Some of the products include vegetables, olive oil, wine, lamb, beef and eggs. Shone Farm also serves as a community resource by supporting events, short courses and industry meetings each year.

Activities & Programming: Associate's degree and/or certificate in Sustainable Ag, along with stand-alone courses in Ag Business, Ag Mechanics and other horticultural subjects. Shone Farm also offers an Incubator-like program where participants take responsibility for one half-acre and grow in collaboration with our CSA and other markets. Efforts in 2016: Our incubator-like program: Independent Ag Enterprise Program - IAEP is still expanding and being refined. 2016 is our first year with participants. We hope to seek grant funding to help enrich the program with more staff time to support participants and provide training in business planning and record-keeping tools.

Regions Served: North Coast

Soil Born Farms, Urban Agriculture and Education Project

PO Box 661175
Sacramento, CA 95866
(916) 363-9685
www.soilborn.org

Mission: Our mission is to create an urban agriculture and education project that empowers youth and adults to discover and participate in a local food system that encourages healthy living, nurtures the environment and grows a sustainable community.

Activities & Programming: Soil Born Farms offers a stipend-based, living on-site 8-month beginner farmer apprenticeship training program. We also have second and third year opportunities. Most of our apprenticeship classes and farm tours are open to the public and regional farmers. Delivery Format: On site training and printed or online educational materials, references, etc.

Regions Served: Sacramento Valley

Sustainable Agriculture Education (SAGE)

David Brower Center
2150 Allston Way, Suite 320
Berkeley, CA 94704
(510) 526-1793
www.sagecenter.org

Mission: SAGE revitalizes agricultural places near cities where farming and local food culture can thrive and be celebrated.

Activities & Programming: SAGE develops and manages Urban Edge AgParks which facilitate land access for beginning and immigrant farmers; provides or facilitates business planning and agronomic technical assistance to beginning farmers; works in multi-stakeholder collaborations at the regional and sub-regional scale to facilitate urban-rural connections and to revitalize agricultural places near cities. Efforts in 2016: SAGE is collaborating on the BFRDP grant led by UC Berkeley, that focuses on increasing the effectiveness of learning hubs for beginning farmers. A pending project will increase production of specialty crops aimed at serving the growing San Jose market. Delivery Format: Consulting, advising, 1-on-1 assistance, data & analytics about the sector overall, in person events.

Regions Served: Central Coast

Sustainable Agriculture Education Association (SAEA)

www.sustainableaged.org

Mission: The SAEA exists to serve and connect educators, teachers, students, staff, and administrators who focus on the teaching and learning of sustainable agriculture at the adult level.

Activities & Programming: Provide opportunities (workshops, symposia, conferences, short courses, etc.) to learn about and develop sustainable agriculture education programs. Maintain a bibliography and/or library of sustainable agriculture education curriculum materials. Publish a newsletter to share information about sustainable agricultural education information. Host national conferences to provide forums for professional development, networking, advocacy activities and publishing of proceedings.

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California, nation

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The Farmers Guild

www.farmersguild.org

Mission: To establish an integrated network of social and professional hubs across California where farmers connect, collaborate and find the resources they need to thrive within local food webs that stimulate stronger local economies, create social equity and sustain our natural resources.

Activities & Programming: We are a network of local, grassroots hubs where farmers and food system advocates gather to share resources, exchange best practices and organize on behalf of family farms, sustainable agriculture and new farmers in their region. The wider, statewide Farmers Guild organization works to support these local hubs, cross-pollinate between them, compile and share resources to ensure farmer success, and give collective voice to a new generation of agriculture. Efforts in 2016: Continued gatherings of local Farmers Guild chapters, the Entrepreneurial Intensive offered throughout the state, online resources, policy advocacy and more. Delivery Format: In-person events.

Regions Served: Central Valley, North Coast, Sacramento Valley, Sierra Nevada, Southern California, Bay Area

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UC Berkeley, Growing Roots Project

www.growingroots.berkeley.edu

Mission: To support the economic and ecological viability of California beginning farmers and ranchers from diverse communities – whether urban, rural or peri-urban, or Latino, Southeast Asian, African or Caucasian.

Activities & Programming: Our Growing Roots Project (a partnership with NCAT, SAGE, UCCE and ACRCD) offers in-depth, culturally and regionally

appropriate workshops, technical assistance and educational materials to beginning farmers and ranchers in urban, peri-urban and rural regions of 10 counties. We aim to strengthen farmer to farmer and agricultural learning hub networking through retreats, field days, and farm tours. Efforts in 2016: We offer workshops, technical assistance and referrals and are developing educational materials (tip sheets, videos, webinars) related to farm business planning and marketing, ecological production, pastured poultry, rangeland management, food safety, cottage foods, and collaborative farming. Delivery Format: Printed and online education materials, references, etc.

Regions Served: Central Coast, Central Valley, North Coast, Sacramento Valley, San Joaquin Valley

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UC Cooperative Extension – Fresno County

550 E. Shaw Avenue, Suite 210-B
Fresno, CA 93710
(559) 241-7515
www.cefresno.ucanr.edu

Mission: We are stewards, problem-solvers, catalysts, collaborators and educators.

Activities & Programming: We conduct research and extension programs to improve production and marketing for small-scale farming operations. Topics include integrated pest management, irrigation, crop nutrition, marketing, and regulatory compliance (food safety, pesticide safety, nitrogen and groundwater management, etc.). Efforts in 2016: We are planning workshops on integrated pest management, food safety, and drip irrigation. Delivery Format: Printed and online educational materials, references, etc, in-person events

Regions Served: Central Valley

UC Cooperative Extension – Los Angeles County

700 W. Main Street
Alhambra, CA 91801
(626) 586-1971
www.celosangeles.ucanr.edu

Mission: The University of California Cooperative Extension in Los Angeles County develops and implements community-based educational programs that address the critical needs of the county's diverse and multiethnic population. Staff and volunteers provide and encourage the use of current research-based information in the areas of nutrition, family and consumer science; youth development; urban gardening; commercial horticulture; agriculture; and natural resources.

Activities & Programming: We connect urban farmers with training, technical resources, and policy information. Efforts in 2016: We are developing a series of urban agriculture workshops that will be offered around the state in 2017-2018. Delivery format: Consulting, advising, 1-on-1 assistance, printed and online education materials.

Regions Served: Southern California

UC Cooperative Extension – Marin County

1682 Novato Blvd., Suite 150B
Novato, CA 94947
(415) 473-4204
www.cemarin.ucanr.edu

Mission: We are stewards, problem-solvers, catalysts, collaborators and educators.

Activities & Programming: We offer education materials and in person workshops to all farming practices, as well as a webpage with fact sheets, and other helpful resources. Efforts in 2016: Food safety, succession planning, dairy calf health, beef industry concepts. Delivery Format: In-person events, workshops, printed or online educational materials, references.

Regions Served: North Coast

UC Cooperative Extension – San Diego County

9335 Hazard Way, Suite 201
San Diego, CA 92123
(858) 822-7711
www.cesandiego.ucanr.edu

Mission: We are stewards, problem-solvers, catalysts, collaborators and educators.

Activities & Programming: Our organization provides research based information and technical know how on all areas of agriculture, from production to marketing to consumption. The San Diego specific program supports the agricultural industry by providing research based information on business and risk management education, marketing and market development, new or specialty crop research and education, new grower education, IPM and pesticide safety education and food safety education. Efforts in 2016: New or Specialty Crops Research and Education Program - ongoing program focusing primarily on finding profitable, water efficient crop alternatives for agricultural producers in Southern California. As part of this program we plan to have seminars and field days focusing on Pitahaya or Dragon Fruit and possibly coffee in San Diego, Ventura and Riverside Counties over the next few months. In addition, we plan to offer a specialty crops conference in the Spring of 2017. Business and Risk Management Education Program - In an effort to improve the management skills of farm owners and farm labor supervisors, we will collaborate with Zenith Insurance and the California Farm Labor Contractor Association to organize an annual Farm Labor Management Seminar in San Diego County in December 2016.

Regions Served: Southern California

UC Cooperative Extension – Santa Clara County

1553 Berger Drive, Bldg. 1
San Jose, CA 95112
(408) 282-3110
www.cesantaclara.ucanr.edu

Mission: We are stewards, problem-solvers, catalysts, collaborators and educators.

Activities & Programming: The Small Farms Program (SFP) develops, implements, and evaluates education and applied research programs on critical issues

and problems faced by small-scale, limited resource, family farmers, and specialty crop producers in the county. The SFP also provides production and marketing information to small-scale farmers. Applied research on improved production practices as well as variety tests are aimed at helping small-scale farmers reduce costs, produce safe and wholesome food, and find new varieties that might flourish under local growing conditions.

Regions Served: Central Coast

UC Cooperative Extension – Santa Cruz County

1430 Freedom Boulevard, Suite E
Watsonville, CA 95076-2796
(831) 763-8040
www.cesantacruz.ucanr.edu

Mission: The University of California Cooperative Extension is dedicated to protecting and improving the resources and quality of life in Santa Cruz County by providing research-generated knowledge and techniques related to agriculture, natural resources and youth development.

Activities & Programming: Research and education related to livestock and rangeland management. Topics include livestock health, weed management, pasture management, water quality, etc. Delivery Format: Printed or online educational materials, references, etc.

Regions Served: Central Coast

UC Cooperative Extension – Sonoma County

133 Aviation Blvd Suite 109
Santa Rosa, CA 95403
(707) 565-2621
www.cesonoma.ucanr.edu

Mission: In Sonoma County, the UC Cooperative Extension academic staff is at the forefront of change, working to preserve agriculture, helping communities shape wise public policy, and strengthening community development and leadership in our youth and adults.

Activities & Programming: Workshops on specialty crops, regulatory/permitting, other valuable tools for farmers - i.e. irrigation, equipment, marketing, etc. As well as one-on-one if needed. Provide research based information to ag community. Efforts for 2016: Starting a Mentoring program that has opportunity to be regional model. Business services, marketing services, production services. Delivery format: Consulting, advising, 1-1 assistance, print and on-line publications

Regions Served: North Coast

UC Cooperative Extension – Yolo County

70 Cottonwood Street
Woodland, CA 95695
(530) 666-8143
www.ceyolo.ucanr.edu

Mission: Yolo County Cooperative Extension provides a broad range of educational programs that are of benefit to farmers, rural and urban residents, community leaders, homemakers, parents, and youth. Extension programs focus on traditional and changing needs in the areas of agriculture, home

economics, community and rural development, nutrition, environmental horticulture and 4-H and youth.

Activities & Programming: CE's many teaching tools include meetings, conferences, workshops, demonstrations, field days, video programs, newsletters and manuals.

Regions Served: North Coast

UC Food Observer

www.ucfoodobserver.com

UCFOODOBSERVER

Mission: UC Food Observer is your daily selection of must-read news on food policy, nutrition, agriculture and more, curated by the University of California as part of its UC Global Food Initiative.

Activities & Programming: We are a UC website/social platform(s) that provides original and curated content/news relating to a broad range of food and agricultural issues. @ucfoodobserver and find us on Facebook. Delivery Format: online educational materials and references

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California, national/international

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UC Small Farm Program

2116 Social Science & Humanities, UC Davis
Davis, CA 95616
(530) 752-7779
www.sfp.ucdavis.edu



Mission: We are guided and motivated by a vision of a thriving, viable California agriculture that has a diversity of small- and moderate-scale farms that remain profitable, enhance the environment, enrich our culture, and improve the quality of life for both producers and consumers. Our mission is to promote such a community by conducting applied research and outreach programs for the successful adoption, management and marketing of potentially profitable crops and enterprises.

Activities & Programming: We develop field and market research aimed at the needs of small- and moderate-scale farmers, and provide that information to farmers who are often not reached by traditional extension programs. In addition to our website, newsletters and research reports, we also offer webinars, workshops, field days, and one-on-one consultations. Our clients include farmers of many different cultures who operate a wide variety of farming operations, often with limited resources. Efforts in 2016: We expect to begin offering workshops regarding the Food Safety Modernization Act during Fall 2016. Delivery Format: In-person events, printed or online educational materials, references, etc.

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California

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UC Sustainable Agriculture Research and Education Program (SAREP)

Agricultural Sustainability Institute at UC Davis
One Shields Avenue
Davis, CA 95616
(530) 752-3915
www.asi.ucdavis.edu/programs/sarep

Mission: SAREP provides leadership and support for scientific research and education in agricultural and food systems that are economically viable, conserve natural resources and biodiversity, and enhance the quality of life in the state's communities. SAREP serves farmers, farmworkers, ranchers, researchers, educators, regulators, policy makers, industry professionals, consumers, and community organizations across the state.

Activities & Programming: The UC Sustainable Agriculture Research and Education Program (SAREP) is a statewide program within UC Agriculture and Natural Resources and is a unit of the Agricultural Sustainability Institute at UC Davis. SAREP provides leadership and support for scientific research, outreach, and education in agriculture and food systems that are economically viable, conserve natural resources and biodiversity, and enhance the quality of life in the state's communities. SAREP has several program areas under its dual initiatives: Food & Society and Agriculture, Resources & the Environment.
1) Our farm to school and farm to institution programs partner with communities to assess the effectiveness of local food programs and recommend steps to improve them.
2) Our Values-based Supply Chain programs work to build markets for farmers and inform consumers of the values of sustainability in agriculture. We coordinate technical assistance to support players along the food chain (farmers, buyers and consumers), and facilitate connections between food systems partners. Resources on our website provide information for farmers interested in selling produce to wholesale markets and diversifying markets.
3) We work to build and strengthen networks of food systems players through communications and convenings such as the Collaborative Food Hub Learning Network, supporting the business viability of food hubs, and in turn, the farmers who sell to them.
4) We conduct county-level Food System Assessments throughout California in partnership with governmental, public health, social service, environmental, and agricultural experts to serve as a foundation for strengthening regional food systems.
5) The Solution Center for Nutrient Management is a website w/ resources for growers and agriculture professionals on nutrient management.
6) The California Nitrogen Assessment is the first comprehensive account of nitrogen flows, practices, and policies for California, and their impacts on ecosystem services and human wellbeing. The California Nitrogen Assessment is a book available online, with summary materials available online.
7) The Cover Crop Database contains detailed entries for over 40 commonly used cover crop species, including: Seed, seedling and mature plant descriptions and pictures, ideal temperature and geographic range, soil, water and nutrient considerations, Management details including planting and termination dates, maintenance issues, mowing, incorporation, harvesting and recommended equipment.
8) SAREP's Energy and Climate Foot-printing work assesses the entirety of the food production and supply chain to identify energy and emissions ""hotspots"", evaluates the impacts of new practices and technologies, and assesses trade-offs between interventions at different stages of the supply chain for selected foods.

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California

USDA - Natural Resources Conservation Services (NRCS)

430 G St
Davis, CA 95616
(530) 792-5600
www.nrcs.usda.gov

Mission: NRCS provides America's farmers and ranchers with financial and technical assistance to voluntarily put conservation on the ground, not only helping the environment, but agricultural operations too.

Activities & Programming: NRCS offers free technical assistance for conservation planning on agricultural lands. Various financial incentive programs are available on a competitive basis. Efforts in 2016: Environmental Quality Incentive Program (EQIP) is offered on an annual basis. Delivery Format: Consulting, advising, 1-on-1 assistance.

Regions Served: Central Coast, Central Valley, North Coast, North Mountain, Northeast Mountain, Sacramento Valley, San Joaquin Valley, Sierra Nevada, Southern California

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Wild Willow Farm & Education Center

PO Box 33285
San Diego, CA 92163
www.sandiegoroots.org

Mission: Educating, cultivating and empowering sustainable food communities in San Diego county.

Activities & Programming: Wild Willow Farm is a 6 acre farm located south of San Diego, on the border with Tijuana. Our Farm School program educates students on the basics of building soil, low-till and no till farming practices, and how to grow vegetables in our Farming 101 and 102 courses. Our farm is also a community center, hosting volunteer days, corporate outings, school field trips, and monthly parties and networking events.

Regions Served: Southern California

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SERVES NORTH COAST

CA Center for Cooperative Development
CAFF
California FarmLink
CCOF
Ecological Farming Association
Farmer Veteran Coalition
Farmers Guild
FarmsReach
FSA
Grange School of Adaptive Agriculture
Multinational Exchange for Sustainable Agriculture (MESA)
NCAT/ATTRA
North Coast Opportunities
Organic Farming Research Foundation (OFRF)
Organic Seed Alliance (OSA)
SAFE-BIDCO
Shone Farm, Santa Rosa Junior College
UC Berkeley, Growing Roots Project
UC Cooperative Extension
UC Food Observer
UC SAREP
UC Small Farm Program
USDA NRCS

SERVES NORTH MOUNTAIN

CA Center for Cooperative Development
CAFF
California FarmLink
CCOF
Ecological Farming Association
Farmer Veteran Coalition
FarmsReach
FSA
Multinational Exchange for Sustainable Agriculture (MESA)
NCAT/ATTRA
Organic Farming Research Foundation (OFRF)
Organic Seed Alliance (OSA)
UC Cooperative Extension
UC Food Observer
UC SAREP
UC Small Farm Program
USDA NRCS

SERVES NORTHEAST MOUNTAIN

CA Center for Cooperative Development
CAFF
California FarmLink
CCOF
Ecological Farming Association
Farmer Veteran Coalition
FarmsReach
FSA
Multinational Exchange for Sustainable Agriculture (MESA)
NCAT/ATTRA
Organic Farming Research Foundation (OFRF)
Organic Seed Alliance (OSA)
UC Cooperative Extension
UC Food Observer
UC SAREP
UC Small Farm Program
USDA NRCS

SERVES SACRAMENTO VALLEY

CA Center for Cooperative Development
CAFF
California Farm Academy, Center for Land-Based Learning (CLBL)
California FarmLink
CCOF
Ecological Farming Association
Farmer Veteran Coalition
Farmers Guild
FarmsReach
FSA
Multinational Exchange for Sustainable Agriculture (MESA)
NCAT/ATTRA
Organic Farming Research Foundation (OFRF)
Organic Seed Alliance (OSA)
SAFE-BIDCO
Soil Born Farms
UC Berkeley, Growing Roots Project
UC Cooperative Extension
UC Food Observer
UC SAREP
UC Small Farm Program
USDA NRCS

SERVES SIERRA NEVADA

CA Center for Cooperative Development
CAFF
California FarmLink
CCOF
Ecological Farming Association
Farmer Veteran Coalition
Farmers Guild
FarmsReach
FSA
Multinational Exchange for Sustainable Agriculture (MESA)
NCAT/ATTRA
Organic Farming Research Foundation (OFRF)
Organic Seed Alliance (OSA)
UC Cooperative Extension
UC Food Observer
UC SAREP
UC Small Farm Program

SERVES SAN JOAQUIN VALLEY

CA Center for Cooperative Development
CAFF
California FarmLink
CCOF
Ecological Farming Association
Farmer Veteran Coalition
Farmers Guild
FarmsReach
FSA
Multinational Exchange for Sustainable Agriculture (MESA)
NCAT/ATTRA
Organic Farming Research Foundation (OFRF)
Organic Seed Alliance (OSA)
UC Berkeley, Growing Roots Project
UC Cooperative Extension
UC Food Observer
UC SAREP
UC Small Farm Program
USDA NRCS
Valley Small Business Development Corp.

SERVES CENTRAL COAST

Alameda County Resource Conservation District (RCD)
ALBA
CA Center for Cooperative Development
CAFF
Cal Coastal Rural Development Corp.
California FarmLink
CCOF
Center for Agroecology & Sustainable Food Systems (CASFS)
Center for Sustainability, Cal Poly SLO
Central Coast Grown
Ecological Farming Association
Elkhorn Slough Estuarine Research Reserve (ESERR)
Farmer Veteran Coalition
Farmers Guild
FarmsReach
FSA
Holistic Management International (HMI)
Kitchen Table Advisors (KTA)
Multinational Exchange for Sustainable Agriculture (MESA)
NCAT/ATTRA
Farming Research Foundation (OFRF)
Organic Seed Alliance (OSA)
Pie Ranch
SAFE-BIDCO
San Benito Working Landscapes Group
Sustainable Agriculture Education (SAGE)
UC Berkeley, Growing Roots Project
UC Cooperative Extension
UC Food Observer
UC SAREP
UC Small Farm Program
USDA NRCS

SERVES SOUTHERN CALIFORNIA

CA Center for Cooperative Development
CAFF
Cal Coastal Rural Development Corp.
California FarmLink
CCOF
Ecological Farming Association
Farmer Veteran Coalition
Farmers Guild
FarmsReach
FSA
Multinational Exchange for Sustainable Agriculture (MESA)
NCAT/ATTRA
Organic Farming Research Foundation (OFRF)
Organic Seed Alliance (OSA)
UC Cooperative Extension
UC Food Observer
UC SAREP
UC Small Farm Program
USDA NRCS
Wild Willow Farm & Education Center

Ecosystem Map of CA Farmer Education & Support Organizations

FarmsReach · UC SAREP

Map design funded by Rabobank

Revised 9/30/16

Boldfaced or logo in region = organization based in that region.
Note: Logos placed alphabetically within each region.

Ecosystem Chart of CA Farmer Education & Support Services Organizations

	Business, Operations & Finance	Labor & HR	Marketing & Sales	Production	Conservation & Nature	Policy & Regulations	Consumer Education	Culture, Spirit & the Movement
Online Events & Webinars	Farmer Veteran Coalition FarmLink	CCOF UC Small Farm Program	MESA UC Small Farm Program	Farmer Veteran Coalition Organic Seed Alliance	Organic Seed Alliance	North Coast Opps. Organic Seed Alliance		
In-Person Events & Workshops	Ecological Farming Assoc Farm Academy, CLBL Farmer Veteran Coalition Farmers Guild FarmLink Grange School MESA NCAT/ATTRA North Coast Opps Organic Seed Alliance Puentes San Benito Wrkg Lands Shone Farm UC Small Farm Program UCB, Growing Roots	ALBA Central Coast Grown Ecological Farming Assoc Farm Academy, CLBL Grange School North Coast Opps UC Small Farm Program	CAFF CCOF Ecological Farming Assoc Farm Academy, CLBL Farmer Veteran Coalition Farmers Guild Grange School NCAT/ATTRA Organic Seed Alliance Puentes San Benito Wrkg Lands Shone Farm Soil Born Farms UC SAREP UC Small Farm Program UCB, Growing Roots Wild Willow Educ Ctr	Alameda County RCD CAFF CalPoly, CFS CASFS CA Center for Coop Dev Central Coast Grown CCOF Ecological Farming Assoc Farm Academy, CLBL Farmer Veteran Coalition Farmers Guild Grange School MESA Organic Seed Alliance Puentes SAGE Shone Farm Soil Born Farms UC SAREP UC Small Farm Program UCB, Growing Roots	Alameda County RCD CalPoly, CFS CCOF Ecological Farming Assoc Farm Academy, CLBL Farmers Guild Grange School Organic Seed Alliance Pie Ranch Puentes San Benito Wrkg Lands Shone Farm Soil Born Farms UC SAREP UC Small Farm Program	CAFF CalPoly, CFS CA Center for Coop Dev Central Coast Grown CCOF Ecological Farming Assoc Farm Academy, CLBL Farmers Guild Grange School Organic Seed Alliance Puentes San Benito Wrkg Lands UC SAREP UC Small Farm Program UCB, Growing Roots	CalPoly, CFS CASFS CA Center for Coop Dev CCOF Ecological Farming Assoc Farmers Guild Grange School Kitchen Table Advisors MESA Pie Ranch Wild Willow Educ Ctr	CalPoly, CFS CCOF Ecological Farming Assoc Farm Academy, CLBL Farmer Veteran Coalition Farmers Guild FarmsReach Grange School Kitchen Table Advisors MESA Organic Seed Alliance NCAT/ATTRA Pie Ranch Puentes Soil Born Farms Wild Willow Educ Ctr
Printed & Online Information	CASFS Farm Academy, CLBL FarmLink FarmsReach Shone Farm UC Food Observer UC Small Farm Program UCB, Growing Roots	Ecological Farming Assoc FarmLink FarmsReach MESA NCAT/ATTRA UC Food Observer UC Small Farm Program	CAFF CASFS Farm Academy, CLBL FarmsReach Shone Farm UC Food Observer UC SAREP UC Small Farm Program UCB, Growing Roots	Alameda County RCD CAFF Farm Academy, CLBL FarmsReach Shone Farm Organic Seed Alliance UC Food Observer UC SAREP UC Small Farm Program UCB, Growing Roots	Alameda County RCD Farm Academy, CLBL FarmsReach MESA NCAT/ATTRA Organic Seed Alliance San Benito Wrkg Lands Shone Farm UC Food Observer UC SAREP UC Small Farm Program	CAFF Farm Academy, CLBL Farmer Veteran Coalition FarmLink MESA NCAT/ATTRA OFRF Organic Seed Alliance UC Food Observer UC SAREP UC Small Farm Program UCB, Growing Roots	Central Coast Grown NCAT/ATTRA North Coast Opps OFRF Soil Born Farms UC Food Observer UC SAREP UC Small Farm Program	Farm Academy, CLBL Farmer Veteran Coalition FarmsReach OFRF UC Food Observer UC Small Farm Program
TA & Advisors	Alameda County RCD ALBA CA Center for Coop Dev Central Coast Grown Ecological Farming Assoc Farm Academy, CLBL Farmer Veteran Coalition FarmLink Kitchen Table Advisors Pie Ranch Puentes SAGE Shone Farm UCB, Growing Roots	Ecological Farming Assoc Farm Academy, CLBL Kitchen Table Advisors Pie Ranch SAGE	Alameda County RCD ALBA CAFF CA Center for Coop Dev Central Coast Grown Ecological Farming Assoc Farm Academy, CLBL FarmLink Kitchen Table Advisors Organic Seed Alliance Pie Ranch Puentes Shone Farm UC SAREP UCB, Growing Roots	Alameda County RCD ALBA CAFF Ecological Farming Assoc Farm Academy, CLBL Farmer Veteran Coalition NCAT/ATTRA North Coast Opps Organic Seed Alliance Pie Ranch Puentes Shone Farm UC SAREP UC Small Farm Program UCB, Growing Roots Wild Willow Educ Ctr	Alameda County RCD ALBA Elkhorn Slough Estuarine Farm Academy, CLBL Farmer Veteran Coalition FarmLink Puentes San Benito Wrkg Lands UC SAREP USDA NRCS Wild Willow Educ Ctr	Alameda County RCD ALBA CASFS Farm Academy, CLBL FarmLink Kitchen Table Advisors Puentes UCB, Growing Roots USDA NRCS	UC SAREP	Farm Academy, CLBL Farmer Veteran Coalition Puentes

	Business, Operations & Finance	Labor & HR	Marketing & Sales	Production	Conservation & Nature	Policy & Regulations	Consumer Education	Culture, Spirit & the Movement
Equipment & Supplies	Farmer Veteran Coalition FarmLink Holistic Mgmt Inst Puentes	Puentes	Farmer Veteran Coalition Puentes	Farmer Veteran Coalition Organic Seed Alliance Puentes	Alameda County RCD	Puentes		
Other Services	Farm Academy, CLBL FarmLink FarmsReach Puentes	Farm Academy, CLBL Holistic Mgmt Inst Puentes	Farm Academy, CLBL North Coast Opps Organic Seed Alliance Puentes UCB, Growing Roots	Alameda County RCD Farm Academy, CLBL Organic Seed Alliance Puentes	Alameda County RCD Farm Academy, CLBL Puentes San Benito Wrkg Lands	Alameda County RCD Farm Academy, CLBL FarmLink Puentes UCB, Growing Roots	ALBA	ALBA Farm Academy, CLBL Farmer Veteran Coalition FarmsReach Puentes
Grants & Loans	Cal Coastal Rural Dev FarmLink FSA KivaZip MESA Puentes SAFE-BIDCO Valley Small Business DC	Cal Coastal Rural Dev FarmLink FSA KivaZip SAFE-BIDCO Valley Small Business DC	Cal Coastal Rural Dev FSA KivaZip SAFE-BIDCO Valley Small Business DC	Cal Coastal Rural Dev Farmer Veteran Coalition FarmLink FSA KivaZip SAFE-BIDCO Valley Small Business DC	Alameda County RCD Cal Coastal Rural Dev FarmLink FSA KivaZip SAFE-BIDCO San Benito Wrkg Lands USDA NRCS Valley Small Business DC			
Sector Analytics & Reports	CCOF FarmLink		Organic Seed Alliance SAGE	Alameda County RCD Organic Seed Alliance	Alameda County RCD CASFS SAGE	Organic Seed Alliance	SAGE	Farmer Veteran Coalition FarmsReach SAGE

Refer to the *Directory of Organizations* for details about each organization.

Revised 9/30/16. To add your organization or update your info, go to http://bit.ly/2bG47RB

California Farmer Education & Support Services Summit

PRIORITY FOCUS AREAS

Hosted September 9, 2016 by
UC Sustainable Agriculture Research and Education Program & FarmsReach

University of California Agriculture and Natural Resources

FarmsReach Growing Farmer Networks

15 Priority Focus Areas determined at the Summit to advance collective work of farmer educator organizations:

Objective: Build capacity for the collective movement
Top 3 Priority Areas:

- Create a "backbone" team to coordinate strategies identified as priorities by the group
- Broaden stakeholders within the movement and bring NEW and minority voices to the table and/or go to them directly.
- Strategically communicate/translate our diverse values (and impact metrics) to funders, policy makers and farmers themselves.

Objective: Build capacity for measuring collective impact
Top 3 Priority Areas:

- Explore common metrics of impact that balance economics, ecological, cultural, social, and political factors.
- Share data collection online tools.
- Establish participant-driven metrics of success.

Objective: Foster relationships, communication, collaboration
Top 3 Priority Areas:

- Coordinate more in-person regional meetings among orgs.
- Continue state-wide strategy sessions, possibly:
    - Expand current 2-hour FEN meeting @ EcoFarm.
    - Schedule meeting pre/post CA Small Farm Conference Nov 2017.
    - Continue annual meetings like the Sept 2016 Summit.
- Include funders in future discussions.

PRIORITY FOCUS AREAS

Objective: Build capacity for organizations' INTERNAL operations

Top 3 Priority Areas:

- Get training in cultural competency and outreach.
- Share organizational personnel for operations that can be done remotely (e.g., accounting, bookkeeping, etc.).
- Take time to hire and train more diverse staff and boards of directors.

Objective: Build capacity for organizations' EXTERNAL operations (strategic, high impact farm education & support services)

Top 3 Priority Areas:

- Create more/better programs for non-English speaking farmers.
- Share best practices in delivering technical assistance, especially *culturally appropriate* assistance.
- Establish a shared online platform to connect geographically isolated farmers and to post/archive farmer training materials for CA.

Workshop on Wheels

"Meet the Buyer" tours for small, beginning and underserved farmers

Gail Feenstra, UC SAREP
Gwenaël Engelskirchen, UC SAREP
Rebecca Campbell, UC SAREP
Thomas Nelson, UC SAREP
Scott Cosca, UC SAREP
David Visher, UC SAREP
Ruth Dahlquist-Willard, UCCE Fresno
Ramiro Lobo, UCCE San Diego
Jennifer Sowerwine, UC Berkeley
Rachel Surls, UCCE Los Angeles
Julia Van Soelen Kim, UCCE North Bay
Michael Yang, UCCE Fresno

Introduction

Urban consumer demand for specialty crops that authentically communicate values of local, regional, or sustainable is creating a new market niche for the produce industry. To meet demand, wholesalers are seeking wholesale ready farmers who can reliably provide safe, quality products.

Similarly, small, beginning and underserved farmers are looking beyond direct sales channels and seeking to expand their market access. UC SAREP's "Meet the Buyer" bus tours provide a potent educational experience, offering an opportunity for farmers to meet face-to-face with wholesale buyers and learn first-hand and in person about standards for receiving, packaging, labeling, and other required procedures. Getting a grasp of these procedures can be daunting for many small farms, and presents a barrier to entry for selling into wholesale market channels. The tours address this barrier directly by demystifying processes and regulations and giving farmers a chance to build relationships with buyers.

What We Did

- Organized 6 bus tours for farmers to visit wholesale produce buyers from 2013-2015.
- Built collaborative relationships between UC SAREP and Cooperative Extension farm advisors to identify market stops and recruit farmer participants.
- Covered 6 geographic regions in California: Sacramento Valley, Central Coast, Fresno, North Coast/Bay Area, Los Angeles, and San Diego.
- Visited 4 to 5 different wholesale or values-based market buyers on each of the one day tours.
- Presented educational material based on grower needs (e.g. food safety, pack and grade standards).
- Conducted 6 follow-up workshops on food safety and marketing to promote grower readiness in accessing the wholesale channels they were exposed to on the tour.
- Provided one-on-one consultation and technical assistance to farmers as needed.

Impacts

- From 2013 – 2015, the "Meet the Buyer" bus tours served 170 farmers and 22 food system partners. Farmers made an average of six new contacts on the tours, and 90% of tour participants said they planned to follow up with these buyers after the tour.
- 93% of tour participants said that learned about a new way to market their produce from the tour.
- Farmers reported an average of 4 on a confidence scale of 0-5 for finding new markets post tour.
- 75% of farmers interviewed after the 2013 tours said networking with other farmers on the tours was valuable; 50% made positive changes to their farm business from these connections.
- 70% of farmers who participated in 2 food safety workshops said they planned to adopt one or more practices learned at the workshop.



Success Stories

2013 tours: A Fairfield-based farmer veteran sold his tomatoes to Cooks Company, a distributor visited on the tour, and used some of the lessons learned to diversify his marketing channels and begin supplying small grocery stores in Marin and Sonoma County.

2015 tours: A North Bay farmer started selling seaweed to Three Stone Hearth, a community supported kitchen, after leaving a sample with the produce buyer on the tour. They developed new packaging for her product that worked better for the Three Stone Hearth retail shop.

"I can't begin to tell you how valuable the tour was for me, on countless levels. It opened my eyes wide and gave me a huge boost of confidence and a lot of direction. When we moved to this property all these apple trees I had no idea what to do with them, I didn't know the first thing about marketing then and I had very little confidence that I could succeed. But after the tour I feel completely different. And now with this follow up support you are offering I feel even more confidence."

– North Bay tour participant

UC DAVIS AGRICULTURAL SUSTAINABILITY INSTITUTE

University of California Sustainable Agriculture Research and Education Program

University of California Agriculture and Natural Resources

FARM CREDIT

This project was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

California Farmer Education & Support Services Summit

AGENDA

Friday, September 9, 2016 - 8:00 AM to 5:30 PM
Sierra 2 Center for the Arts and Community - 2791 24th St, Sacramento, CA 95818
Hosted by the UC Sustainable Agriculture Research and Education Program & FarmsReach

University of California Agriculture and Natural Resources

FarmsReach Growing Farmer Networks

8:00 am	***Registration Opens***
8:30 am	***Welcome!*** Gwenaël Engelskirchen & Rebecca Campbell, UC SAREP Melanie Cheng, FarmsReach
	How Did We Get Here! Gwenaël Engelskirchen, UC SAREP
9:00 am	***Interactive Part 1: Ecosystem Map & Discussions*** Introduction: Melanie Cheng, FarmsReach Facilitated by Kas Neteler and Nancy Roberts, Gigantic Idea Studio
10:45 am	***Morning Break***
11 am	***Interactive Part 2: Collaborative Fundraising*** Introduction: Gail Feenstra, UC SAREP Facilitated by Kas Neteler and Nancy Roberts, Gigantic Idea Studio
12:00 pm	***Buffet Lunch***
12:45 pm	***Communications Survey & Tips*** Nancy Roberts, Gigantic Idea Studio
	Interactive Part 3: Priorities & Strategic Action Facilitated by Kas Neteler and Nancy Roberts, Gigantic Idea Studio
3:00 pm	***Evaluation & Conclusion*** Facilitated by Kas Neteler and Nancy Roberts, Gigantic Idea Studio
3:30 pm	***Networking Reception***

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Tell Your Story, Sell Your Produce: Tour of Produce Markets

	Thomas Nelson	(530) 867-4926
	Julia Van Soelen Kim	(530) 400-7254
Tour guide mobile phone numbers:	Jennifer Sowerwine	(510) 207-2692
Buyer contact information:	It's up to you! Ask for a card, make notes, and follow through.	

5:00	**Sebastopol, FEED Sonoma, 6780 Depot St #120**	February 24, 2015
7:00	**San Francisco Wholesale Produce Market, 2095 Jerrold, SF** The **San Francisco Wholesale Produce Market** is the bustling home to over 30 produce distribution businesses. We will visit three companies there: **Cooks Company Produce**: Distributor of fruits and vegetables to hundreds of restaurants in the Bay Area. **Vegiworks**: Serving the Bay Area since 1992, they offer a full line of organic and conventional fruits, culinary herbs and vegetables as well as floral leaves, organic microgreens, assorted dried chiles. **Washington Vegetable**: Family owned business serving the Bay Area since 1931, they offer a full line of vegetables and supply major chains, independent grocery stores, restaurants, jobbers and Government facilities.	Michael Janis, Director SF Wholesale Produce Market Ric Tombari, Owner
10:30	**The Fruit Guys, 490 Eccles, South SF** The Fruit Guys are the #1 provider of farm-fresh fruit to businesses and schools. They are family owned and operated and serve thousands of companies through regional hubs in San Francisco, Chicago, Los Angeles, Philadelphia, and Phoenix.	Chris Mittelstaedt, CEO
12:30	**Cal Dining, UC Berkeley, 2415 Bowditch St, Berkeley** Cal Dining provides food service for the UC Berkeley campus, serving approximately 30,000 meals-per-day. They are dedicated to sustainability and currently source 38% of their food locally.	Shawn LaPean, Director
3:00	**Three Stone Hearth, 1581 University Ave, Berkeley** Three Stone Hearth is a cooperatively-owned, community supported kitchen. They sell a wide range of prepared products and meals, emphasizing local produce and farmers. Additionally, they do education and outreach.	Mud Hut, Purchaser
4:15	**Bus Departs for Novato to Rohnert Park to Sebastopol**	

This tour is funded by grants from CoBank, Farm Credit West, American AgCredit, Fresno Madera Farm Credit, Farm Credit Services of Colusa-Glenn, and California Department of Food and Agriculture. It is a project of the University of California Cooperative Extension, UC Sustainable Agricultural Research and Education Program (SAREP), and UC Davis Agricultural Sustainability Institute (ASI).

Tell Your Story, Sell Your Produce: Tour of Produce Markets

	Thomas Nelson	(530) 867-4926
	Michael Yang	(559) 241-7523
Tour guide mobile phone numbers:	Ruth Dahlquist-Willard	(559) 241-7513

Buyer contact information: It's up to you! Ask for a card, make notes, and follow through.

3:15	**UCCE Fresno, 550 E. Shaw Avenue** Meet in North parking lot.	**February 18, 2015**
7:00	**Pacific Rim Produce, Oakland** A large produce distributor based in Oakland that serves supermarkets, restaurants, food processors, food service delivery companies, hotels, and casinos. They offer over two hundred produce items including a complete line of fresh fruits and vegetables with a special emphasis in Asian produce.	John Wong, Owner
9:00	**SF & LA Specialty, Union City** A wholesale distributor supplying food service and fine dining establishments in California, Nevada, Arizona and Hawaii. With a diverse customer base, they distribute a wide variety of produce grades, labels, sizes, shapes, ripeness, appearance, relative quality levels, and price points.	Chris Charlesworth, SF Director
11:15	**Cal Dining, UC Berkeley** Cal Dining provides food service for the UC Berkeley campus, serving approximately 30,000 meals-per-day. They are dedicated to sustainability and currently source 38% of their food locally.	Shawn LaPean, Director
2:30	**TW Burmese Gourmet, San Ramon** William Lue owns and operates 5 Burmese dining establishments in the East Bay and also plans to sell some specialty produce. He is actively looking to improve the local supply chain for specialty vegetable and herbs used in South East Asian cooking.	William Lue, Owner
6:30	**Return to UCCE Fresno**	

The tour is funded by grants from CoBank, Farm Credit West, American AgCredit, Fresno Madera Farm Credit, Farm Credit Services of Colusa-Glenn, and California Department of Food and Agriculture. It is a project of the University of California Cooperative Extension, UC Sustainable Agricultural Research and Education Program (SAREP), and UC Davis Agricultural Sustainability Institute (ASI).

SCB14007 Attachment 10

Meet the Buyer: LA Market Tour for Southern California Growers

December 2nd, 2015
5:00 am-6:30 pm

SIGN IN, COFFEE & BOARD BUS — **5:00 – 5:15 am**

DEPART — **5:15 am**
I-15 and SR-76 Park and Ride

TRAVEL (2 HRS)
- Introduction from UCCE Ramiro Lobo
- Grower Introductions

HARVEST SENSATIONS — **8:00 am**
3030 E Washington Boulevard, Los Angeles
- Doug Ranno - Harvest Sensations - President

MELISSA'S/WORLD VARIETY PRODUCE — **10:00 am**
5325 Soto Street, Vernon
- Bill Gerlach - Melissa's - Research and Development

WHOLE FOODS MARKET DISTRIBUTION CENTER — **12:00 pm**
2307 E 49th Street, Vernon
- Jeff Biddle - Whole Foods Market - Executive Coordinator of Purchasing

HEATH & LEJEUNE — **2:30 pm**
1417 S Eastman Avenue, Comerce
- David Weinstein - Heath & LeJeune - Grower and Buyer

RETURN TO SAN DIEGO — **6:30 pm**

University of California Agriculture and Natural Resources | UCDAVIS AGRICULTURAL SUSTAINABILITY INSTITUTE | FARM CREDIT

This project was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

THANK YOU TO OUR GENEROUS HOSTS!

Harvest Sensations - http://www.harvestsensations.com

Harvest Sensations is an industry leader in fresh produce innovation. The famous Harvest Sensations brand stands for premium quality, great tasting core conventionally grown products, amazing organically grown producats, specialties and herbs rom around the world, and services from our state-of-the-art facilities in both Los Angeles, CA and Miami, FL.

We are able to ship by truck or air cargo and all of our facilities undergo strict 3rd party audits, daily shelf life testing, and HACCP training to ensure excellence in service.

Melissa's/World Variety Produce - http://www.melissas.com

Think tasty, creamy, tangy, aromatic, tart, sweet, crunchy and delectable. Within the 280,000 square feet of the Melissa's/World Variety Produce, Inc. warehouse, one is sure to find the freshest fruits and vegetables -- quality products with exceptional value and first-class service. Melissa's/World Variety Produce, Inc. is currently the largest distributor of specialty produce in the United States.

Over the years the company's Food Service Division has become a full-service operation that supplies culinary professionals with staples, exotics and Melissa's full line of organic produce.

Whole Foods Market Distribution Center - http://www.wholefoodsmarket.com

Who are we? Well, we seek out the finest natural and organic foods available, maintain the strictest standards in the industry, and have an unshakeable commitment to sustainable agriculture. Add to that the excitement and fun we bring to shopping for groceries, and you start to get a sense of what we're all about. Oh yeah, we're a mission-driven company too.

Heath & Lejeune - http://www.soullyorganic.com

As a CCOF certified organic wholesaler, we provide distribution, storage, logistics and consolidation services to trading partners throughout the U.S. and Canada. Working with many of the original pioneers of organic farming we've been privileged to help bring organics to the doorstep of the mass market.

Our mission is rooted in the proposition that "organic" is more than just a product to be marketed. We are dedicated to the development of a sustainable food system, incorporating green alternatives in packaging, transportation, composting and recycling, and higher standards for workplace welfare and justice. We are committed to serving the farmers who are creating a new agricultural model that promotes a balanced, diverse and healthy environment for plants, animals, and people.

Meet the Buyer: An L.A. Produce Market Tour for Los Angeles Growers and Food Advocates

December 9th, 2015
6:30 am-3:30 pm

SIGN IN, COFFEE & BOARD BUS — **6:30- 6:45 am**

DEPART FROM UNION STATION — **6:45 am**
800 N Alameda St, Los Angeles

TRAVEL
- Introduction from UC SAREP by Thomas Nelson
- Grower and Advocate Introductions

SANTA MONICA FARMERS' MARKET — **7:30 am**
2640 Main St, Santa Monica
- Laura Avery - Farmers Market Supervisor, Santa Monica Farmers' Market
- Sarah Delevan - Food Sourcing Manager, Heirloom LA

SPACE EXPLORATION TECHNOLOGIES — **9:30 am**
1 Rocket Road, Hawthorne
- Ted Cizma - Executive Chef, Space X

WHOLE FOODS MARKET DISTRIBUTION CENTER — **12:30 am**
5000 Pacific Blvd, Vernon
- Jeff Biddle – Executive Coordinator of Purchasing, Whole Foods Market

HEATH & LEJEUNE — **2:00 pm**
1417 South Eastman Ave, Commerce
- David Weinstein Buyer / Seller – Heath & Lejeune

RETURN TO UNION STATION — **3:30 pm**

University of California Agriculture and Natural Resources | UCDAVIS AGRICULTURAL SUSTAINABILITY INSTITUTE | FARM CREDIT

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THANK YOU TO OUR GENEROUS HOSTS!

Space Exploration Technologies - http://www.spacex.com

SpaceX designs, manufactures and launches advanced rockets and spacecraft. The company was founded in 2002 to revolutionize space technology, with the ultimate goal of enabling people to live on other planets.

Santa Monica Farmers' Market - https://www.smgov.net/Portals/FarmersMarket

For over 30 years, the Santa Monica Farmers Market has provided reasonably priced, high quality produce to the city. The Wednesday Farmers Market is widely recognized as one of the largest and most diverse grower-only Certified Farmers Markets in the nation. Some nine thousands food shoppers, and many of Los Angeles' best known chefs and restaurants, are keyed to the seasonal rhythms of the weekly Wednesday Market.

Heirloom LA - http://heirloomla.com

Heirloom LA is way more than your average catering company. Not only did they invent the Lasagna Cupcake and build a successful business around comfort food, they also believe healthy eating is a right, not a privilege. Everyone should know what's in their food and who grows and raises it, and have convenient access to fresh produce and whole grain food. Co-Owners Matt Poley and Tara Maxey are committed to supporting small, local organic farms and promoting education and welfare around this work.

Whole Foods Market Distribution Center - http://www.wholefoodsmarket.com

Who are we? Well, we seek out the finest natural and organic foods available, maintain the strictest standards in the industry, and have an unshakeable commitment to sustainable agriculture. Add to that the excitement and fun we bring to shopping for groceries, and you start to get a sense of what we're all about. Oh yeah, we're a mission-driven company too.

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SCB14007 Attachment 12

Pequeños agricultores se embarcan en búsqueda de oportunidades

Norma De la Vega (951) 781-2142

15 de diciembre del 2015



Un grupo de agricultores a pequeña escala del condado de San Diego y otros condados del Sur de California, se embarcaron recientemente en un extenso recorrido por cuatro grandes centros de distribución de alimentos ubicados en Los Ángeles en búsqueda de nuevas oportunidades.

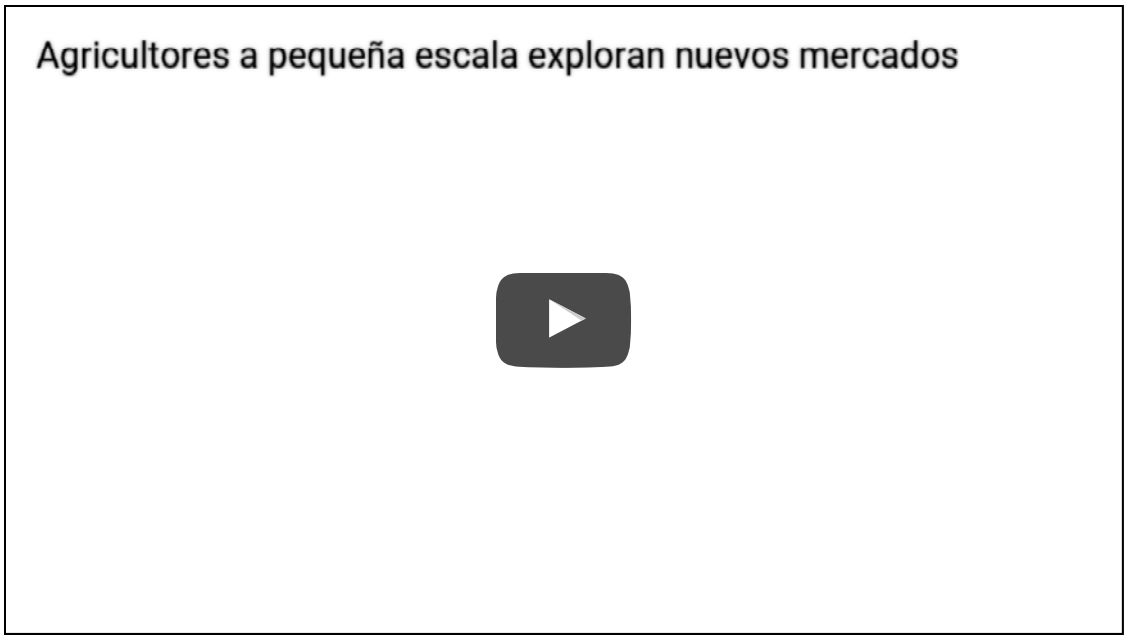
El viaje de exploración fue organizado por Extensión Cooperativa de la Universidad de California para ayudar a los pequeños agricultores a encontrar nuevos mercados para sus productos.

"Los pequeños productores contribuyen no tanto en volumen pero si en diversidad. Si vamos a los mercados de agricultores vemos que hay una gran cantidad de alimentos que se producen en pequeña escala. También contribuyen a generar actividad económica en las comunidades donde residen y nos permiten tener alimentos frescos todo el año", sostiene Ramiro Lobo, asesor agrícola en el condado de San Diego.

ENGLISH SUMMARY:

A group of small-scale farmers from San Diego and other counties recently embarked on an extensive bus tour of four major food distribution centers in Los Angeles in search of new marketing opportunities. The tour was organized by UC SAREP and UCCE San Diego.

Se clasifica como pequeños agricultores a aquellos que generan alrededor de 250 mil dólares o menos en ingresos brutos al año. En el condado de San Diego el ochenta y dos por ciento del total de los agricultores trabajan a pequeña escala. Muchos son inmigrantes, carecen de contactos, algunos no dominan el inglés y enfrentan varios obstáculos para comercializar sus productos; pero gracias a su dedicada labor, la disponibilidad de una gran variedad de frutas y verduras continua creciendo en California.



Haga clic aquí para leer el guión.

"¡Es increíble! La colaboración entre productores a pequeña escala y los productores miembros de la asociación de productores de frutas exóticas de California, hace posible que cualquier fruta que se cultive en el mundo se pueda encontrar en el Sur de California. Muchas veces los mercados son tan pequeños que un agricultor produce suficiente para suplir la demanda. Pero el mercado ha evolucionado y se está expandiendo como es el caso de la guayaba, el tejocote, la caña de azúcar y ahora la pitahaya", afirma Lobo.

Durante el recorrido por los distintos centros de distribución – *Harvest Sensations, Melissa's* y *Heath & LeJenue*- algunos de los agricultores repartieron muestras de sus cultivos. Una agricultora residente de Fallbrook compartió una fruta exótica conocida como lima dedo o caviar cítrico (*finger lime),* la cualtiene piel dura y forma alargada, precisamente como un dedo. Cuando se le parte por la mitad brotan bolitas rosadas transparentes y ácidas, pero refrescantes y sabrosas. Se sabe que era un alimento de origen australiano, pero en la actualidad es parte de la cocina gourmet en varios países.

Por otra parte, agricultores asiáticos residentes de Escondido llevaron jujubes*,* azufalfa o dátiles rojos, fruta que se ha cultivado en China por más de 4,000 años como se le conoce en occidente. La ofrecieron fresca y seca, y junto con las muestras de la fruta repartieron hojas informativas mostrando que es una fruta muy valorada en la medicina tradicional china por su alto valor nutritivo. El jujube fresco que compartieron tenía la piel roja y arrugada, la pulpa no estaba jugosa pero tenía un sabor dulce.

También se habló de la necesidad de educar a los consumidores respecto a los nuevos alimentos porque existen preguntas y dudas. Por ejemplo, si determinada fruta se debe comer con todo y piel o si debe pelarse; si se debe esperar un sabor dulce o ácido. Además se habló de la necesidad de difundir información sobre la historia que hay detrás de cada fruta o verdura y cuáles son los beneficios para la salud.

Las pláticas entre productores y distribuidores se desarrollaron en un ambiente informal y amigable. Se comentó que en el mercado crece la demanda por los

alimentos tropicales como el mango, guayaba, papaya y la pitahaya. Hay también un creciente interés por verduras de hojas verdes y miniatura. Los gustos del consumidor están cambiando y alimentos que no se consumía antes, en la actualidad, se encuentran en casi en todos los supermercados.

En la visita al centro de distribución de productos orgánicos Heath & LeJeune, uno de los distribuidores sugirió a los pequeños agricultores sembrar el alimento que más les apasiona, pero cuidando siempre los detalles; "el empaque cuenta", les dijo y les agradeció sus contribuciones a la agricultura local. Agregó que California goza de una gran riqueza agrícola gracias a la perseverancia de los pioneros, la gran labor de los agricultores y las contribuciones de las universidades para ayudar a los productores a producir de manera sostenible los alimentos.

TEMAS RELACIONADOS:

El café se cultiva ya en California

La pitahaya, que deleita a paladares latinoamericanos, se cultiva en California

Podcast: La conexión con agricultores locales

Podcast: Los latinos en la agricultura de California

Video: Festival de la pitahaya

El recorrido fue organizado por el Programa de Investigación y Educación de Agricultura Sustentable de la División de Agricultura y Recursos Naturales de la Universidad de California (UC SAREP), Extensión Cooperativa de la UC en el condado de San Diego y el Instituto de Sostenibilidad Agrícola de UC Davis.

Una iniciativa para mejorar sistemas alimentarios sustentables y competitivos es parte de la Visión Estratégica 2025 (Strategic Vision 2025) de la División de Agricultura y Recursos Naturales de la UC.

regresar al inicio

Universidad de California, Agricultura y Recursos Naturales

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SCB14007 Attachment 13

University of California
Grown in Marin

Wholesale ahead

by Julia Van Soelen Kim, UCCE Food Systems Advisor

It's early morning at the San Francisco Wholesale Produce Market—the closest terminal produce market to Marin County—and the steady pace and constant flow of people and produce is dizzying. Farmers pull up in pickup trucks to deliver their freshly harvested produce in boxes, refrigerated distribution trucks beep as they back up to loading docks, and there is a bright orange blur from forklifts moving pallets.



From talking with farmers in Marin County and the North Bay, I've found that *wholesale* is a confusing term for many. Wholesale means to sell goods in large quantities which will then be re-sold to others. It sounds simple enough, but what one farmer considers wholesale, another farmer doesn't. And for many farmers, their gut reaction is to say that they simply aren't interested in selling their products wholesale. They prefer to *direct market*, or sell their products directly to their end customers through local farmers markets, farm stands, and Community Supported Agriculture (CSAs). That's because they want to be able to make a connection with the people who are going to eat what they've produced and let them know how the food was grown or raised. They also want to be price setters, not price takers, and they want to know that by cutting out the "middle men," they're getting top dollar for their high quality products. In fact, many say, they can't afford to sell wholesale.

In contrast, for most buyers, including grocery stores, restaurants, schools, and institutions, being able to purchase wholesale is a necessity. It's how they run their businesses efficiently. It's how they ensure that they have enough food on hand to stock their shelves and put on their plates, and it's how they are able to purchase what they need to at the time, frequency, volume, price point, and ease that they expect.

While wholesale is not for every farmer because of its most obvious disadvantage—the prices they receive are almost always lower than through direct marketing—there are important advantages. Farmers can create economies of scale by specializing in fewer items that they are more skilled at growing or that are more suited for their climate, they can gain new production efficiencies, and they can significantly reduce the time and resources they spend transporting their products to and staffing farmers markets. Through wholesale, both farmers and buyers can reduce the number and complexity of contacts needed to make sales, making the transaction cost per unit of produce sold far lower than through direct sales. Additionally, wholesale can be a great option for any farmer who is not a "people person" because it requires making fewer connections with buyers than direct marketing.

This is why, standing amongst the hustle and bustle of the San Francisco Produce Market, I'm convinced that if we want to grow our local food economy, wholesale has to be part of the equation. And so I wonder, how do we bring these two contrasting views of wholesale closer together in order to foster a more local, resilient, and economically viable food system?



From what I've seen, the best kinds of wholesale transactions are a negotiation between farmers and buyers, in which both parties understand the needs and constraints of the other party and honestly assess if they are the right ones to meet those needs. In essence, just like with our local farmers markets, farm stands, and CSAs, it all comes down to the relationships between local farmers and local buyers, and increasingly, the stories that add value to their products. In fact, there is a term for this trend: *values-based supply chains*. According to Gail Feenstra, with the UC Sustainable Agriculture Research and Education Program, values-based supply chains are wholesale channels that provide additional marketing options for small- to mid-sized, values-based producers, increasing consumers' access to their products, and allowing them to participate in "farm to fork" efforts. She explained that values-based supply chains are created "when middlemen are good at telling the stories of the family farmers they buy from to the people who they sell

to." Colleague David Visher agreed, explaining that it is important for farmers to "make sure that your delivery person, you, your label, your prices, your produce pack, and your attitude all tell the same story."



I think part of what makes wholesale confusing is that it encompasses a wide range of scales, needs, services, and price points—only some of which are based on keeping intact and communicating messages about farmers' values. According to Thomas Nelson, a supply chain analyst for the UC Sustainable Agriculture Research and Education Program, "businesses that are located at wholesale markets, purchasing and selling at wholesale prices, and distributing products with fleets of trucks can be called very different things." Below are just a few of the terms that get tossed around along with the produce.

Brokers negotiate contracts for the purchase and sale of the product but do not take title of the product.

Food hubs offer a combination of aggregation, distribution, or marketing services of source-identified locally and regionally produced foods, providing small and mid-sized producers with entry into new markets that would be difficult or impossible to access on their own.

Grower-Packer-Shippers not only grow and harvest produce, they also pack their produce and other farmers' produce and transport it to buyers.

Jobbers purchase products from growers, packers, wholesalers, or distributors and resell products to retailers such as restaurants, or to other wholesalers.

Produce distributors source products from other wholesalers or directly from farmers and transport product from their centralized locations (such as the San Francisco Produce Market) to their retail customers, including supermarkets, grocery stores, restaurants, and institutions.

Wholesalers work directly with farmers, food hubs, distributors, and others to aggregate produce and sell to others.

Wholesale markets, also called “Terminal Markets,” located in or near urban centers and serve as the final or “terminal” point for the wholesale produce marketing channel. Terminal market sales activity is based on the USDA AMS Market News Reports which are issued daily based on information provided from the 15 major U.S. terminal markets, including price data on the commodities traded at the markets.

It is no wonder that the world of wholesale can be confusing to a new farmer, or even a veteran farmer venturing into a new market channel. But as David advises farmers visiting the San Francisco Wholesale Produce Market for the first time, “don’t be intimidated by the direct language and curt manner that you might hear and see. Buyers want you to say up front and quickly what you have, when you will have it, how much it will cost, and why it is better.”

Next >>

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CASFS ORGANIC PRODUCTION *best practices*

What are the Best Practices for GROWING PEPPERS ORGANICALLY?



This pepper planting is part of part of a 3-year project documenting organic farming methods, water use, weed and pest control, and other production and marketing information to help inform growers about best practices for growing peppers and other specialty crops.

Peppers come in many varieties, offer value-added options, and are relatively disease and pest free, making them a good choice for specialty crop growers.

What are some of the best practices used here?

- Seeds are started in soil mix on heat mats in the greenhouse for rapid and uniform germination
- Cover crops and compost provide adequate fertility to establish a large healthy plant with good leaf coverage for higher yields and to protect fruit from sunburn
- Weed management is optimized by planting peppers in single rows and cultivating with a light hilling once plants are established







Why is this a good crop for a grower with a mixed crop operation?

- Peppers are relatively pest and disease resistant
- The many varieties of peppers offer growers a range of flavor choices, from sweet to very hot
- Most peppers are colorful (red or yellow) at full maturity, making them an attractive draw at farmers' markets and a nice addition to any Community Supported Agriculture (CSA) share
- With some varieties there is a market for early fruit harvested as green peppers (unripe) and later fruit as "colored" peppers
- Peppers offer a broad range of value-added product opportunities, e.g., roasted, dried, smoked, pickled, or ground into powder

This project is funded by the CDFA Specialty Crop Block Grant "Training and Resources for Specialty Crop Growers Featuring Organic and Sustainable Methods," Project #SCB14015. A set of Grower Guides based on the project is being developed for publication and online posting in 2017.

What are the Best Practices for GROWING POTATOES ORGANICALLY?



Preparing seed potatoes for planting

This potato planting is part of a 3-year project documenting organic farming methods, water use, weed and pest control, and other production and marketing information to help inform growers about best practices for this crop and other specialty crops.

Potatoes can be a productive, profitable, and beneficial rotational crop in diverse small- to medium-scale mixed crop farms in California.

What are some of the best practices used here?

- Seed potatoes are exposed to warm, moist conditions that encourage sprouting prior to planting so that shoots emerge rapidly
- Planting ~3 ounce seed pieces provides ample carbohydrate reserve for the plant, but not enough to create conditions for rot
- Seed potatoes are planted into moist or pre-irrigated soil and not watered until after the plants emerge—this minimizes weed growth and reduces disease potential
- The crop is "hilled" once or twice to increase yield, using Lilliston cultivators to pile soil around the plants
- Drip irrigation helps avoid late blight (Phytopthora infestans), a fungal disease



Eliza Milio drives an Italian-made potato digger with under-cutter bar and shaker cage that lifts the potatoes and leaves them on the soil surface



Specialty varieties of potatoes for sale at the UCSC Farm & Garden Market Cart

Why is this a good crop for a grower with a mixed crop operation?

- A potato crop requires minimal maintenance: plant, hill, cure, and harvest
- Growers can market the crop both early as "new" potatoes and as a fully mature cured crop
- Potatoes store well for many months in cold storage so you produce a crop that can be marketed over time
- Lesser known specialty varieties can bring a good price

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What are the Best Practices for GROWING DRY-FARMED TOMATOES ORGANICALLY?



Tomatoes are planted deep into moist soil.

This dry-farmed tomato planting is part of a 3-year project documenting organic farming methods, weed and pest control, and other production and marketing information to help inform growers about best practices for this crop and other specialty crops.

Where adequate winter rain, moderate summer temperatures, and the right soil conditions exist, dry-farmed tomatoes can be a good option for organic growers. Dry farming generates an intensely flavored crop that's a favorite of consumers and retailers.

What are some of the best practices used here?

- Following winter rains, the farmers create a "dust mulch" with a rolling cultivator to eliminate weeds and seal in soil moisture, making it available during the growing season
- Tomatoes are planted deep into moist soil using a wider-than-normal spacing and weeds are carefully controlled to minimize competition for water
- Once plants reach adequate height, beds are re-formed by throwing dirt into bed middles with a rolling cultivator—when timed well this last cultivation pass smothers weeds starting to establish within the plant line
- Varieties are selected for their ability to perform well in a dry-farmed system



Beds are spaced wider apart than in irrigated plantings to minimize competition for water.





Why is this a good crop for a grower with a mixed crop operation?

- Creates options for good market return and value-added products
- Maintains production in areas where water is limited
- Minimizes weed seed development and makes it easier to deal with problem weeds
- Facilitates the extraction of nutrients that have leached below the root zone of most irrigated crops by forcing deep rooting. Roots may reach up to 5 feet deep

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What are the Best Practices for GROWING CROPS FOR COMMUNITY SUPPORTED AGRICULTURE/CSA?



These blocks of mixed crops are part of a 3-year project documenting organic farming methods, water use, weed and pest control, and other production and marketing information to help inform growers about best practices for a CSA program. CSA shareholders receive a weekly box of produce in return for their season-long commitment.

What are some of the best practices used here?



- Growers make careful crop plans to ensure timely sowing, planting, and harvest schedules
- Crops are grouped in "blocks" according to their days to maturity and water needs –
  - Successional crops that mature quickly and have short harvest "windows"—including salad mix, spinach, kale, and carrots—are direct sown or transplanted at the same time to ensure efficient bed preparation, planting, irrigation, and weed control
  - Crops with a longer growing season, such as tomatoes, winter squash, corn, and onions, are planted in separate blocks
- Plantings include an "insectary" row of flowers and other crops that attract and support beneficial insects



Why is a CSA program a good option for growers?

- Provides an assured market
- Up-front payments help cover early-season costs
- Diversifies direct sale markets
- Helps ensure overall farm health—crop diversity can reduce pest and disease pressure

This project is funded by the CDFA Specialty Crop Block Grant "Training and Resources for Specialty Crop Growers Featuring Organic and Sustainable Methods," Project #SCB14015. A set of Grower Guides based on the project is being developed for publication and online posting in 2017.

What are the Best Practices for GROWING CUT FLOWERS ORGANICALLY?



This cut flower planting is part of a 3-year project documenting organic farming methods, weed and pest control, and other production and marketing information to help inform growers about best practices for this crop and other specialty crops.

Cut flowers can add an economically valuable dimension to a mixed crop operation as well as creating good habitat for beneficial insects.

What are some of the best practices used here?



- A diversity of annuals and perennials are planted in several blocks throughout the season to provide a long harvest window
- Supplemental fertility is applied via "fertigation" (organic fertilizer applied through the drip irrigation lines or as a foliar spray) to increase pest and disease resistance, and increase plant vitality and vase life by providing major and minor nutrients
- Fertility practices encourage a large vegetative plant early in the growth cycle, which can support long, sturdy stems, and more and bigger flowers
- Flowers are irrigated 24 hours prior to harvest to increase turgidity, then harvested in the morning when the plants are most turgid and core temperatures are cooler, contributing to a longer vase life
- Because flowers are in the ground for an extended period, maintaining weed free fields is a priority
- Seed can be easily saved from many types of flowers (cosmos, bachelors buttons, scabiosa, sunflowers, dianthus, larkspur, etc.), saving the farmer money and allowing the grower to select for specific, preferred flowers



Why is this a good crop for a grower with a mixed crop operation?

- The market value of flowers is high compared to vegetables
- Flowers are a draw for farmers' market shoppers and provide an attractive "add on" to a Community Supported Agriculture share
- Cut flowers can provide the grower with a "value-added" component to their business, e.g., producing and arranging bouquets for events (weddings and parties). Dried flowers and edible flowers also offer value-added options.

This project is funded by the CDFA Specialty Crop Block Grant "Training and Resources for Specialty Crop Growers Featuring Organic and Sustainable Methods," Project #SCB14015. A set of Grower Guides based on the project is being developed for publication and online posting in 2017.

What are the Best Practices for GROWING BUSH BEANS ORGANICALLY?



Darryl Wong direct seeds beans into a bed that has been irrigated and cultivated to control weeds prior to planting.

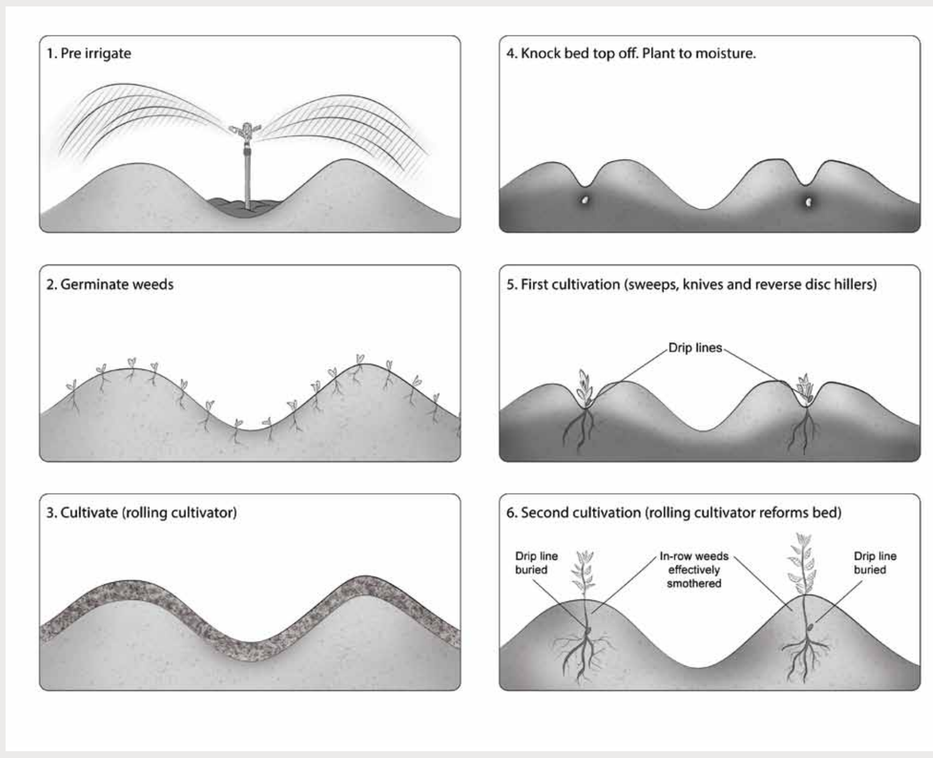
This bush bean planting is part of a 3-year project documenting organic farming methods, water use, weed and pest control, and other production and marketing information to help inform growers about best practices for this crop and other specialty crops.

Bush beans can be a productive, profitable, and beneficial rotational crop in diverse small- to medium-scale mixed crop farms in California.

What are some of the best practices used here?

- The "planting to moisture" technique used here minimizes both water use and weed growth, saving time and energy, and reducing weed seed bank pressure in subsequent crops
- Drip irrigation saves water, limits weed growth, and reduces soil compaction by harvest crews
- A portion of the crop is saved for future plantings

PLANTING TO MOISTURE





Dry beans from Fifth Crow Farm in Pescadero fifthcrowfarm.com

Why is this a good crop for a grower with a mixed crop operation?

- There is a relatively low cost of production up until time of harvest
- A short production window eliminates a significant amount of financial risk compared to most other vegetable crops
- Bush beans can also be grown as shell or dry beans, adding another dimension to a specialty crop grower's product mix

This project is funded by the CDFA Specialty Crop Block Grant "Training and Resources for Specialty Crop Growers Featuring Organic and Sustainable Methods," Project #SCB14015. A set of Grower Guides based on the project is being developed for publication and online posting in 2017.

CASFS GROWER GUIDE

TILLAGE, BED FORMATION, AND PLANTING TO MOISTURE:
A Guide for Beginning Specialty Crop Growers







This short guide reviews tillage, bed formation, and planting to moisture practices used on small- and medium-scale specialty crop farms.

Tillage Sequence

Understanding tillage sequences is critical for good soil and bed preparation prior to spring planting. Ill-timed or poorly executed tillage will lead to frustration and soil cloddiness. This is especially true for more challenging soils higher in clay content. The specific sequences you use will depend on soil type and implement selection.

Here are two examples of common tillage and bed formation sequences used on California's Central Coast. One uses a mechanical spader to incorporate cover crop residue, the second an offset disc.

Spring incorporation of cover crop residue and bed formation

TOOLS: flail mower, mechanical spader, rolling cultivator



Flail mow cover crop at appropriate soil moisture to minimize compaction. With a tall cover crop (3–4' or more), do an initial "high mow" pass with the mower set 1–2' above the ground, then mow at ground level to further chop and shred the crop into small pieces prior to incorporation to facilitate the breakdown process.



Immediately after flail mowing cover crop, use a spader to incorporate residue.



Immediately after spader incorporation of cover crop, form beds with rolling cultivator.



Allow adequate time for breakdown of cover crop residue. If rainfall is not adequate after bed forming then pre-irrigate to maintain enough moisture to facilitate residue breakdown.



Shortly after weed emergence re-work the beds with rolling cultivator.

Beds are now ready for shaping and planting.

TOOLS: flail mower, heavy offset disc, chisel, rolling cultivator, rototiller



Flail mow cover crop at appropriate soil moisture to minimize compaction (as described on page 1).



Disc and cross disc cover crop until residue is adequately cut and mixed into the top 6 inches of soil.



Chisel and cross chisel to break up compaction from disc and open up ground. It may be necessary to disc again after chiseling.



Form beds with rolling cultivator.*

Shortly after weed emergence re-work the beds with rolling cultivator.

Beds are now ready for shaping and planting.

* You may need to rototill to break up clods prior to bed formation. Moisture from either rain or sprinkler irrigation will facilitate rototilling. Once clods are mitigated then beds can be formed with the rolling cultivator.



FIGURE 1. Rolling cultivator. *Photo: Jim Clark*

Bed Shaping



Once beds are raised with either listing shovels or a rolling cultivator (Figure 1), and assuming optimum tilth has been achieved through well-timed tillage, you can use a "bed shaper" to shape a bed suitable for precision seeding (e.g., carrots, beets), or multi-line transplanting (e.g., lettuce, brassicas), and follow-up weed management.



FIGURE 2. Bed shaper and markers. *Photo by Jim Leap*

Bed shapers are three-point implements that run behind the tractor and flatten out the bed top, providing a smooth, uniform, and well-defined bed for planting. Vegetable seeders can be attached directly to the shaper so that beds can be shaped and planted in one pass. Markers can also be attached to the shaper to provide distinct lines for transplanting (Figure 2).

Planting to Moisture

This often-overlooked planting technique is an effective way to minimize weed competition when planting large-seeded crops such as beans, squash, and some cover crops, especially in California's Mediterranean climate. Potatoes and dry-farmed tomatoes can also be planted to moisture. Here is a suggested sequence (Figure 3):

FIGURE 3. Planting to moisture sequence

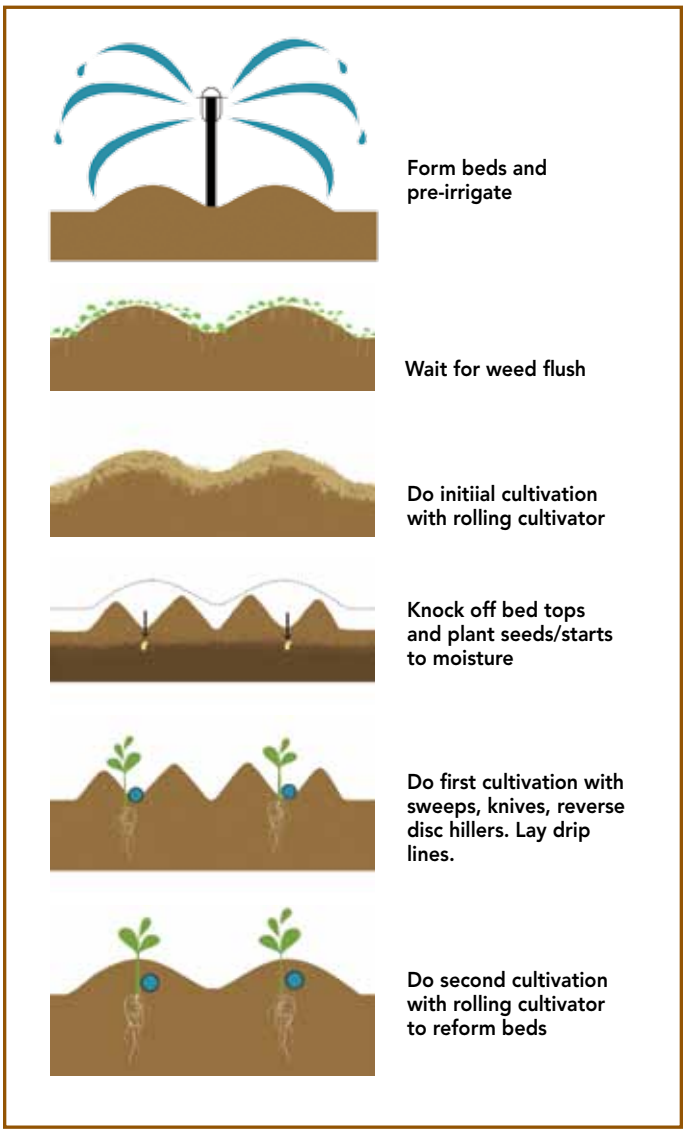


Illustration by Laura Vollset

Step 1: Pre-irrigation

When planting to moisture –

- Form beds prior to planting (see above)
- Pre-irrigate with drip or overhead irrigation to flush weed seeds and get deeper moisture into the root zone. Apply approximately 1–1.5" on most soils, assuming there is good moisture deep in the soil either from irrigations on previous crops or from winter rains.
- If water is limited, drip can be used to pre-irrigate, but drip lines must then be retrieved before planting.
- On rare occasions, a well-timed rain event of an inch or more can provide adequate moisture to flush weeds.

Step 2: Initial cultivation of fallow (unplanted) beds

Once you see weeds emerge on the beds and in the furrows (about a week after pre-irrigation), make a quick pass with a cultivating implement such as a rolling cultivator to knock out the newly emerged weeds (Figure 4) and newly germinated weed seeds that have not yet emerged. This pre-emergent weed growth stage is referred to as "white thread," because the radical (first root) of the newly germinated weed seed literally looks like a white thread. At this stage of growth weeds are extremely susceptible to light cultivation. Avoid deeper cultivation, as this would bring up new weed seeds from lower in the soil that have not yet germinated.



FIGURE 4. Cultivate pre-emergent (white thread stage) and newly emerged weeds (bottom in photo) with rolling cultivator. *Photo: Jim Clark*

Note that the "fallow bed" cultivation following pre-irrigation must be timed well to minimize tractor tire soil compaction from soil that is too wet in the furrow bottoms. Timing is critical as well in terms of the maturation level of the emerged weeds: once true leaves are formed on many weed species they can become much more difficult to terminate/kill when relying on mechanical cultivation. This is especially true for purslane.

On many soils, the best guide for timing of this fallow bed cultivation is when the soil in the furrows starts to dry down to a similar color as the bed tops about an hour after sunrise. This cultivation, if done well, will kill all germinated weeds, leave the beds intact, and mulch the soil surface—effectively inhibiting deeper soil moisture loss through surface evaporation.

The only weeds that will continue to emerge at this point will be problem perennials such as field bindweed *(Convolvulus arvensis)*. Bindweed management requires diligent, repeated cultivations to keep it in check.

Step 3: Planting to moisture

For beans, winter squash seeds:

When planting to moisture, the bed top must be mechanically knocked off so that the planter can place seeds into moist soil. This operation is most efficiently done with a wide "Alabama" shovel mounted on the planter to run ahead and push off the dry dirt on top of the bed (Figure 5). When set correctly, the shovel should leave a flat "V" pattern down the center of the bed. At the bottom of the "V" the soil should contain adequate residual pre-irrigation moisture (or rain moisture) to initiate germination of the newly planted seed.

Planting beans and winter squash seed at the low point in the middle of the bed will conserve moisture deeper in the soil because there is still a lot of loose soil above the seed line, limiting evaporative loss of soil moisture. Planting large-seeded crops to moisture also minimizes the risk of soil borne pathogens (damping off complex) that can affect their development. Damping off is more likely to occur when seeds are "irrigated up" with either overhead irrigation or drip irrigation.



FIGURE 5. Alabama shovels knock off the dry bed top; seed is dropped into moist soil and covered by "soil cappers" run behind the tamp wheel. *Photo: Jim Leap*



FIGURE 6. Dry-farmed tomato planting. *Photo: Carolyn Lagattuta*

For dry-farmed tomatoes:

Use an Alabama shovel as described above to create a V-shaped furrow. Hand-plant well-hydrated tomato starts deep into moist soil (Figure 6).

For potatoes:

Drop the seed pieces into a depression or trough formed by an Alabama or furrowing shovel (Figure 7), and cover with 3–4" of soil (enough to cover the seed pieces and keep them from drying out) by pushing some of the soil pushed off the bed top back into the middle of the bed.

When the potatoes are tall enough (8–12") make a second pass with a rolling cultivator, reverse disc hillers, or shovels to re-form the bed. This process is referred to as "hilling" and will ensure that the potatoes are adequately covered with soil to minimize sun damage.



FIGURE 7. Potato seed planting. *Photo: Martha Brown*

ADDITIONAL RESOURCES

Equipment and tools for small-scale intensive crop production, by Andy Pressman. NCAT Publication #IP417, 2011. attra.ncat.org/attra-pub/summaries/summary.php?pub=373

Introduction to weed management in a small scale organic production system (video). Produced by the Center for Agroecology & Sustainable Food Systems. www.youtube.com/user/casfsvideo

Teaching organic farming and gardening: Resources for instructors. Unit 1.2, Tillage and cultivation. Edited by Martha Brown, Jan Perez, and Albie Miles. Santa Cruz: Center for Agroecology & Sustainable Food Systems, 2015. casfs.ucsc.edu/about/publications/Teaching-Organic-Farming
Note: See Appendix 7 in Unit 1.2 for details on the tillage pattern for an offset wheel disc.

Tillage, Bed Formation, and Planting to Moisture: A Guide for Beginning Specialty Crop Growers by Jim Leap. Edited by Martha Brown and Ann Baier.

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This publication was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

Photos, p. 1: Top left and right, Elizabeth Birnbaum. Bottom left, Martha Brown. Icon illustrations: Laura Vollset.

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ORGANIC DRY-FARMED TOMATO PRODUCTION ON CALIFORNIA'S CENTRAL COAST:
A Guide for Beginning Specialty Crop Growers







Introduction

Where appropriate climate and soil conditions exist, growing dry-farmed tomatoes can be a good option for specialty crops growers. Dry farming generates an intensely flavored crop much prized by consumers and retailers.

A limited number of geographic regions are suited to dry farming, which requires adequate winter rainfall and—in the case of annual crops—a summer-time marine influence that generates cool mornings and warm afternoons. These climatic conditions, combined with careful soil preparation, appropriate variety selection, adequate plant spacing, and vigilant weed control are all required to successfully produce dry-farmed crops.

This guide describes the steps involved in growing dry-farmed tomatoes organically on the Central Coast of California, with a focus on proper soil preparation, planting, and weed control.

Features of dry-farmed tomato production

- Heightens the intensity of crop flavors
- Produces a desirable specialty crop that can command a good price
- Creates options for value-added products
- Maintains production in areas where water is limited
- Minimizes weed seed development
- Makes it easier to deal with problem weeds
- Facilitates the extraction of nutrients that have leached below the root zone of most irrigated crops by forcing deep rooting

PRODUCTION PRACTICES — SUMMARY

Appropriate conditions

- Minimum 20" winter rain.
- Early morning fog, mild afternoon temperatures (max to mid 80°s F).
- Evapotranspiration (Et) rate approximately .15"/day.

Soil type

- Relatively high clay content (works best).
- Sandy loam soils or loam soils that overlay deeper clay soils also work well (see sidebar, page 4).

Crop placement

- Plant tomatoes in isolation from potatoes and other solanums to minimize potential for spread of late blight *(Phytopthora infestans)* from potato foliage.

Fertility requirements

- Fall/winter cover crop: single species legume or primarily legume mix.
- Fall-applied compost.

Recommended timing of planting / Successions

- Plant when soil warms to approximately 60°F at 8" depth and incorporated cover crop has decomposed (residues brown, leaves no longer recognizable).
- Successional plantings can extend the harvest season. Depending on climate, growing season and markets, successions can be planted 2–3 weeks or 4-6 weeks apart.
- Warmer soil conditions promote the rapid growth rates and deep root development essential for successful dry-farmed tomato production.
- Early and late plantings face lower soil temperatures, cool and moist weather, risk of rain or frost, have slower growth rate and vigor, and increased susceptibility to pests and diseases.
- Early or late plantings that succeed have the potential to mature during market windows when there is less crop availability and therefore may command higher prices *(there are rarely any guarantees about pricing!)*.

Plant and row spacing

- 18"–24" between plants; 6' between rows.
- Lower winter rainfall may necessitate wider spacing.

Planting technique

- Transplant starts in furrows formed in the bed middles.
- When planting to moisture, plant well-hardened plants that are at least 12" tall.
- Ensure that root ball is surrounded by moist (darker) soil; if necessary, hand dig into deeper moisture to get the roots as deep as possible into moist soil.
- Firm the soil around the roots to re-establish capillarity.

Days to maturity

- Fruit matures approximately 90 days after transplanting; earlier in hot weather.

Harvest tips

- Harvest at full ripeness (uniform deep red color) for maximum flavor.
- Ensure that tomatoes are still firm, not soft.
- Harvest thick-skinned varieties into 5-gallon buckets; handle fruit gently.
- Harvest with calyx intact to improve appearance for immediate direct sales.

Post-harvest handling

- Sort and pack in the shade.
- Store in cool, shady location to hold up to a week without refrigeration.

Crop rotation

- Rotate crops (plant different plant families) to break disease cycles.



PRODUCTION SEQUENCE — OVERVIEW



(crop day -25*) In spring, mow cover crop to facilitate breakdown.



(crop day -25) Incorporate cover crop residue.



(crop day -11) Form beds with rolling cultivator or listing shovels.



(crop day -10) Pre-irrigate beds with overhead irrigation (1–1.5"). Wait for dry down and weed emergence.



(crop day -1) Do a shallow cultivation with a rolling cultivator to terminate weeds and create a dust or soil mulch. If planting is delayed, maintain dust mulch with rolling cultivator as needed until planting time.

***Numbers in parentheses refer to crop day, with crop day 0 = planting day, based on a typical season at the CASFS/ UC Santa Cruz Farm.**

See Appendix (page 8) for more on crop days and related activities.



(crop day 0) Break open bed middles with Alabama shovels and promptly plant tomato transplants deep into moist soil using hand trowels; on larger acreage, plant with mechanical planter.



(crop day 11) Cultivate with sweeps, side knives, and shallow furrow chisels when first weeds appear in furrow bottoms or as necessary to maintain dust mulch.



(crop day 12) Once plants reach adequate height (~12"), hill tomatoes with rolling cultivator.



(crop day 21, 43, 63) Stake and string plants no later than when the plants reach 1' in height; continue stringing as plants grow.



(crop day 68) Initiate harvest when tomatoes reach full color; harvest may extend for 8–10 weeks, depending on variety and weather.



(crop day 150) Disc plants and prepare soil for fall cover cropping to enhance infiltration of winter rains.

Drill cover crop seed prior to fall/winter rains.

Production Practices — Additional Details

Soil amendments

Dry-farmed tomatoes will extend roots up to 8′ deep or more to access moisture. Because there is no irrigation to carry solubilized nutrients to the root zone, dry-farmed tomatoes can be considered a "scavenger" crop in terms of nutrient uptake and demand.

Plant a winter cover crop ahead of a dry-farmed tomato crop to keep the soil covered over the winter, minimize soil erosion and nutrient leaching, fix nitrogen and build soil organic matter, stimulate microbial activity, improve water infiltration deep into the root zone, and enhance overall soil conditions. Use either a single species legume or primarily legume mix to grow a low-lignin cover crop whose residues break down quickly to facilitate earlier spring planting and maximize use of winter rains.

Because dry-farmed tomatoes are so deeply rooted, the crop will benefit from a fall application of compost prior to planting a cover crop. Compost applied at the time of cover crop incorporation would not benefit the dry-farmed tomato crop, although slow-release of nutrients would benefit subsequent irrigated crops.

Soil preparation and weed control

Soil preparation to conserve or "trap" winter rainfall is critical for successful dry farming. To maintain the winter moisture bank, follow this two-step process:

- **Step 1: Incorporate the cover crop**

Mow and incorporate the winter cover crop early to minimize water loss from the soil through transpiration from the cover crop. Specific timing of incorporation is linked to your particular soil type and stage of cover crop maturation. Ideally, it will take place during a spring break in the weather that allows entry into the field with tillage equipment without undue soil compaction, and allows for subsequent decomposition of the cover crop.

To determine the optimum time to incorporate the cover crop, use a shovel or probe to assess the soil at various depths. Incorporate the cover crop and till when the soil is at about ~70% field capacity. This is on the wetter side of what is normally considered ideal; you will need to take care to prevent compaction.

- **Step 2: Create a "dust mulch"**

Once the cover crop is incorporated and adequately decomposed (this may take 10–20 days depending on the type of cover crop, its maturity, and soil conditions at the time it is worked in), list up beds in the field with a rolling cultivator. In the absence of adequate spring rainfall or if soil moisture is low, pre-irrigate beds with 1–1.5" of water using overhead irrigation to facilitate further breakdown of the cover crop; when spring rains are adequate (>1" after listing the beds) this step is unnecessary.

Wait for weed flush, then cultivate the weeds when they are at the pre-emergent "white thread" stage or still small (see Figure 1) and create a dust mulch. Use relatively shallow (4–6") mechanical soil tillage tools such as a rolling cultivator, rototillers, or disc harrows, often followed by secondary tillage implements such as spring tooth harrows. The loose soil created by this cultivation pass is referred to as a dust mulch or soil mulch. Because of the loose aggregation of the soil, the capillary action that would normally wick soil moisture to the surface is broken. Thus, the dust mulch provides an effective barrier to evaporative loss of moisture held within the root zone of the soon-to-be-planted dry-farmed crop.

Timing is critical for creating the initial dust mulch: you must trap as much rain moisture in the soil as possible, yet avoid working the soil when it is too wet. Tractor operations on wet soils, especially "heavier" soils high in clay content, can cause clod formation and compaction.

Similarly, it is important to minimize tillage depth when preparing soil for planting annual dry-farmed crops, since deeper tillage could disrupt the lower soil capillaries that are critical for soil water movement below the tilled zone.

Maintain the dust mulch and control weeds with light and fairly frequent tillage operations (every two or three weeks) from the time of initial tilling until the crops are too large to cultivate effectively.



FIGURE 1: Control newly emerged weeds (bottom left and right) with timely cultivation. *Photos: Jim Clark*

ASSESSING YOUR SOIL FOR DRY FARMING

The best soils for dry farming have relatively high clay content; sandy loam soils or loam soils that overlay deeper clay soils also work well. Soils higher in sand content do not hold soil moisture as well as clay and clay loam soils and therefore are typically not used for dry farming.

If you are considering dry farming, bore numerous holes up to 4′ deep throughout the production area using a 2" slide hammer soil probe or a soil auger to obtain soil "plugs." Soils that are suitable for dry farming will exhibit continuity within the different horizons and a loam or sandy loam upper horizon with clay directly below it.

Preparing and planting a small area of the field is the best way to determine whether the site and conditions are suited to dry farming. Although conditions vary from year to year, and management practices may be refined, it is less risky to experiment with dry farming (or any substantially new practice) on a small scale. If the small plot does well, you can expand it in future years.

Varietal recommendations

Varieties that do well as dry-farmed crops typically have an aggressive root system capable of reaching deep into the soil horizon to tap the stored moisture.

Growers in the Central Coast region have trialed literally hundreds of varieties of heirloom, open pollinated, and hybrid tomatoes. To date, none has compared to the hybrid 'Early Girl' in its ability to set deep roots and consistently produce a good yield of high quality, flavorful, and marketable fruits with no irrigation. 'New Girl', a recently introduced variety, is closely related to 'Early Girl' and appears to have many of the same favorable characteristics, but produces lower yields.

Some newer varieties have been bred with the pollen parents of 'Early Girl' yet (unlike 'Early Girl') claim to be resistant to spotted wilt virus, but these are not yet commercially available.

Seedlings

Depending on your farm's greenhouse facilities, tomato seedlings can either be grown on site or purchased from an organic seedling supplier. Plant well-hardened, "tall" plants (at least 12" tall) so that the seedlings can be planted deep to ensure root contact with moist soil.

Pre-irrigation

As noted above, dry spring conditions may make it necessary to pre-irrigate the beds before planting, with either overhead irrigation or drip lines, to establish an optimal stand. This pre-irrigation should always be followed by a cultivation to take advantage of planting to moisture, which gives the tomatoes a jump start on weeds (please see the publication *Tillage, Bed Formation, and Planting to Moisture* in this **Grower Guide** series for additional details).

On a garden scale, you may need to hand water the newly planted starts to ensure rooting and uniform establishment.

Plant spacing and planting technique

A typical spacing for dry-farmed tomatoes (depending on soil type and rainfall amounts) is 6' between rows and 2' between plants. Some growers use a closer spacing to further "stress" the plants for increased flavor; however, closer spacing will likely limit harvest windows, making additional successions necessary to increase overall yield (see page 2 for successional planting information).





FIGURE 2. Alabama shovels open planting furrows. *Photos: Carolyn Lagattuta*

Note that the recommendations below assume that you are planting into beds that have been prepared with a rolling cultivator and that the moisture is fairly close to the surface.

On the day of planting, set up a tractor-mounted tool bar with a wide Alabama shovel and open the middle of the bed to be planted (Figure 2). This pass with the shovel should remove the dry soil on the bed top and form a "V" down the length of the bed middle, allowing for easy access to deeper soil moisture in the bed middle and providing a "guide" for planting and follow-up cultivation.



FIGURE 3

Water the starts so they are well hydrated prior to planting, and do not allow them to dry out before planting into moist soil.

Plant seedlings at the desired spacing, as deep as possible, either by hand or with a mechanical transplanter. Plant vertically and ensure that the roots are in contact with moist soil (Figures 3 and 4).

Check plants following transplanting to make sure the roots have good contact with soil moisture. If you notice uniform wilting in the early morning on the day following transplanting you may need to "water in" the transplants to ensure survival. Slight wilting in the late afternoon—especially during warm weather—is common during the first week following transplanting. Tomatoes are aggressive rooters and will survive and root with very limited soil moisture as long as daytime temperatures are not extreme (>85°F).

To minimize weed pressure and maintain a soil mulch, cultivate the soil frequently (every 2–3 weeks) following planting. The first cultivation will typically focus on furrow bottom weed management using a three bar cultivator running sweeps, side knives, reverse disc hillers, and shallow furrow chisels. Once the crop's stems have lengthened enough, use a rolling cultivator to throw dirt into the planted line to smother any



FIGURE 4. Plant tomato start deep into moist soil. *Photo: Carolyn Lagattuta*



FIGURE 5. Use a rolling cultivator to "hill" or "dirt" tomato plants. *Photos: Martha Brown*

newly emerged weeds there (Figure 5). Unless high clearance cultivating tractors are available this cultivation will be the last.

Support system options

Although dry-farmed tomatoes may be grown without support, most Central Coast growers stake and tie their crop in order to increase crop yields, minimize fruit contact with the soil, and make harvest easier.

The following system is used at the UCSC Farm (see Figure 6):

- Once plants reach 1' in height, place untreated 5' wooden stakes a foot deep every 4' (every 2 plants) within the plant row, using a metal t-post every 4th spot for stability.
- Place a t-post at either end of the row at an angle as an anchor.
- Wrap string lines around the stakes starting at 8" above the ground, with a second line placed a foot above the first, and a third a foot above the second.
- Use a "basket weave" system to train the plants between the strings (for a similar system, see www.youtube.com/watch?v=XSf3aSj46jo).

Harvest and post-harvest considerations

Growing 'Early Girl' or similar thick-skinned varieties makes harvest easier since the tomatoes resist bruising or damage from handling. Tomatoes can be harvested into 5-gallon buckets; fruit at the bottom of the bucket will hold up under the weight of the tomatoes above them as long as the bucket is handled gently and the tomatoes aren't overly ripe.

If you grow and harvest heirloom tomato varieties grown in a dry-farmed system, use extreme care during handling since these fruit are generally much more delicate than thicker-skinned varieties. The rest of the discussion below assumes production of small, thick-skinned, red tomato varieties. If you are growing heirloom varieties, please disregard those parts of this discussion that are not applicable to your crop.

For the best eating quality and flavor for direct market sales, harvest mature fruit just at the point where it develops a uniform color on the plant. Orange fruit will ripen to red post-harvest, but the fruit will taste much better when left to mature on the plant.

When harvesting, leave the calyx attached by carefully breaking off the tomato at the abscission zone just above the calyx. This takes some practice but will provide a more pleasing product at the point of sale (see Figure 7). When stacking in the bucket at time of harvest, place the tomatoes so that the stem will not puncture tomatoes as they are added.



FIGURE 7. Dry-farmed tomatoes at UCSC's farm stand. *Photo: CASFS*

Transport tomatoes from the field to a shaded packing area for sorting and packing into suitable boxes for transport to market. Never refrigerate tomatoes! They lose flavor quickly at lower temperatures. Tomatoes will hold for up to a week after harvest without refrigeration in a cool, shady place.

For best quality and appearance tomatoes should be sold within a week of harvest. If you need to store them longer prior to sale, remove the calyx at harvest time as it will dry out and reduce the visual quality of the fruit.

'Early Girl' tomatoes will hold on the plant for up to a week after ripening even in warm weather, so harvest intervals can be as long as a week; however, every two or three days is optimal once fruit ripens.



FIGURE 6. A basket weave system using metal t-posts and wooden stakes. *Illustration: Laura Vollset*

Pests and Diseases

Before you select varieties and plant your dry-farmed tomato crop, look up common pests and diseases that affect the crop in your area. Learn about pest and disease life cycles, preventive practices, and possible treatments using resources such as the UC IPM website (ucipm.edu), your county Cooperative Extension offices, ATTRA's Biorationals: Ecological Pest Management Database (www.ncat.org/attra-pub/biorationals), neighboring farmers, and other knowledgeable professionals.

The main tomato arthropod pests in the Central Coast region are:

- Green peach aphid, *Myzus persicae*. Potato aphid, *Macrosiphum euphorbiae*: both green peach and potato aphids spread viruses that severely affect tomato plants.
- Tomato russet mite, *Aculops lycopersici*: mite nymphs suck the life out of plant cells, causing leaves and stems to bronze, dry up, and die.
- Stink bugs. Consperse stink bug, *Euschistus conspersus*. Redshouldered stink bug, *Thyanta pallidovirens (= T. accerra)*. Sayi stink bug complex, *Chlorochroa sayi* and *Chlorochroa uhleri*. Southern green stink bug, *Nezara viridula*: several stink bugs feed on and damage tomatoes.

The main tomato diseases in the Central Coast region are:

- Late blight, *Phytopthora infestans*: a serious disease that develops rapidly and can destroy an entire tomato field in a few weeks' time.
- Tomato spotted wilt virus (TSWV) in the tospovirus group, spread by Western flower thrip: plants infected with TSWV do not usually produce marketable fruit.

Please see *Organic Pest and Disease Management in Selected Crops on California's Central Coast* in this **Grower Guide** series for additional information on the pests and diseases listed here, and suggestions for their control in dry farmed tomatoes.

ON CALIFORNIA'S CENTRAL COAST, 'Early Girl' and/or 'New Girl' are currently the best tomato varieties for dry farming. The fruits are easy to handle, they don't crack, and the flavor is remarkable. However, when grown without irrigation, these varieties are prone to a physiological condition known as blossom end rot.

Blossom end rot is related to the plant's inability to move calcium to the blossom end of the fruit; this is exacerbated when water is limited or irregular. The symptom is a brown or black sunken spot on the blossom end of the fruit that—depending on the severity of the symptom—is prone to rot.

Although the condition often becomes less prevalent as the season progresses, it may affect 10–20% of the crop. Fruit showing symptoms of blossom end rot are not marketable.



FIGURE 8. Advanced damage caused by blossom end rot.

ADDITIONAL RESOURCES

Common misconceptions and key points about dry farming: Case study of dry farmer with more than 40 years experience, by Amy Garrett. Small Farms Program, Oregon State University, 2014. smallfarms.oregonstate.edu/sfn/su14dryfarming

Dry farming. California Ag Water Stewardship Initiative. agwaterstewards.org/practices/dry_farming/

Dry farming at Molino Creek Farming Collective. The Water Stewardship Project, Ecological Farming Association. agwater.wordpress.com/dry-farming/

Knock weeds out at critical times, by Mark Schonbeck. eOrganic, 2010. articles.extension.org/pages/18882/knock-weeds-out-at-critical-times

Organic tomato production, by Steve Diver et al. NCAT IP439, 1995, revised 2012. attra.ncat.org/attra-pub/summaries/summary.php?pub=33

Overview of dry farming on the Central California Coast, by Jim Leap. Supplement 4, Unit 1.5: Irrigation, principles and practices *in* Teaching organic farming and gardening: Resources for instructors. Santa Cruz, CA: Center for Agroecology and Sustainable Food Systems, 2016. casfs.ucsc.edu/about/publications/Teaching-Organic-Farming/part-1.html

Organic Dry-Farmed Tomato Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers by Jim Leap, Darryl Wong, and Kirstin Yogg-Comerchero, with contributions from Ann Baier and Doug O'Brien. Edited by and Martha Brown and Ann Baier.

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This publication was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

Photo, p.1, left: Carolyn Lagattuta; p. 2: Elizabeth Birnbaum. Icon illustrations, p. 3, Laura Vollset.

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APPENDIX: PRODUCTION SCHEDULE, ECONOMIC DATA

Crop day	# beds (1 bed = .02ac)	Action	work rate (hr/ac)	fixed rate (hrs)	Total labor cost @ $16.10/hr	Total machine cost @ $21.70/hr	Harvest Week	% total harvest	Harvest Amt.	Harvest Value
-25	10	Flail Mow:heavy	2.5	0.2		$15.19				
-25	10	Spade	4.8	0.2		$25.17				
-11	10	Mark Lines	2	0.2		$13.02				
-11	10	List	1.25	0.2		$9.77				
-11	10	Overhead Irr:set up	3.75		$12.08					
-10	10	Overhead Irr:run		0.5	$8.05					
-1	10	Light cultivation	1.25	0.2		$9.77				
-1	10	Shape/JD 71 Seed/Furrow	2	0.2		$13.02				
0	5	Transplant:1 line	58	0.5	$101.43					
11	10	Cultivate	2	0.2		$13.02				
12	10	Hill	1.25	0.2		$9.77				
21	5	Trellis:stakes	48.4	0.5	$85.97					
21	5	Trellis:tie up	48.4	0.5	$85.97					
42	5	Trellis:tie up	48.4	0.5	$85.97					
63	5	Trellis:tie up	48.4	0.5	$85.97					
68	10	Harvest x 2 @ 75#/hr	259	1	$42.50		1	5%	194	$388.40
75	10	Harvest x 2 @ 75#/hr	259	1	$57.80		2	5%	194	$388.40
82	10	Harvest x 2 @ 75#/hr	259	1	$141.20		3	15%	583	$1,165.20
89	10	Harvest x 2 @ 75#/hr	259	1	$182.90		4	20%	777	$1,553.60
96	10	Harvest x 2 @ 75#/hr	259	1	$182.90		5	20%	777	$1,553.60
103	10	Harvest x 2 @ 75#/hr	259	1	$141.20		6	15%	583	$1,165.20
110	10	Harvest x 2 @ 75#/hr	259	1	$99.50		7	10%	388	$776.80
117	10	Harvest x 2 @ 75#/hr	259	1	$57.80		8	5%	194	$388.40
124	10	Harvest x 2 @ 75#/hr	259	1	$57.80		9	5%	194	$388.40
150	10	Disc:x1	0.5	0.2		$6.51				
-	10	Drill/Cover Crop	1.6	0.2		$11.28				
				Sub-total:	$1,429.04	$126.51		*Sub-total:*	3,884	$7,768.00
				Labor + Machine Cost ($)			***Yield***			
				Per Block (.2 Acres):		***$1,555.55***	***Per Block (.2 Acres):***		**3,496**	***$7,768.00***

Harvest Assumptions	
Harvest (#/acre)	19420
Harvest (#/row')	2.675
Harvest Rate (#/hr)	75
Price ($/#)	2

Item	*Cost per unit*	*Cost per acre*	*Notes*
Tomato Starts	$.025/plant	$90.75	1 line/bed; every other bed; 7260 row'/ac
Tomato Stakes	$3/stake	$4,356.00	5' grade stakes, 1 stake/5row';
T-posts	$5/stake	$1,815.00	6' (every 20'); 363/acre
Twine	$.002/ft	$87.12	
Boxes	$.98/box	$1,274.00	.98/bx; 1300bx/ac
Total Expenses (per acre):		***$7,622.87***	

Per Acre Totals	
Income:	$38,840.00
Labor + Machine Cost:	-$7,777.74
Expenses:	-$7,622.87
Production Profit:	**$23,362.92**

Data reflect direct field production costs and do not include other potential overhead (e.g., water, electricity, land rent).

ORGANIC CUT FLOWER PRODUCTION ON CALIFORNIA'S CENTRAL COAST:
A Guide for Beginning Specialty Crop Growers





Introduction

Cut flowers have become a popular crop for small- and medium-scale mixed organic production farms. They can diversify and increase your income stream and offer an attractive option that draws consumers to your farmers' market stall or farmstand. Cut flowers are a value-added specialty crop that in general can be managed like many other row crops while generating increased income per acre compared to most vegetables.

Growing, processing, and marketing cut flowers is a labor-intensive undertaking that can tie up land for a longer portion of the season than many vegetable crops. If you are thinking about adding cut flowers to your operation, consider starting with a relatively small area to gain experience and establish markets before committing a large area to cut flowers.

This grower guide provides examples of how to select and grow cut flowers, with a focus on crop planning and selection, harvest efficiencies, equipment needs, and market bouquets.

Features of cut flower production

- Offers consumers a chance to support local flower production
- Taps into diverse markets: florists, weddings, other events
- Offers u-pick opportunities
- Attract customers to direct market venues, including farmers' market and roadside stands
- Provides biological benefits to a mixed cropping system, including attracting beneficial insects and offering crop rotation options
- Where possible, incorporating herbaceous perennials minimizes need for annual tillage

PRODUCTION PRACTICES — SUMMARY

Soil type and pH

- Varies by crop, but generally do well on a range of soil types from sandy loam to heavier clay soils with high organic matter content and pH 5.8 – 6.5.

Fertility requirements

- Fall/winter cover crop (bell beans, triticale, vetch).
- Compost as needed (5–10 tons/acre).
- Fertigation (foliar sprays; see page 7 for details).

Soil temperature for planting

- Cool seasons crops (e.g., stock, agrostemma, sweet peas, cornflower): high 40°s to low 50°s F.
- Warm season crops (e.g., dahlias, marigolds, zinnias): 60° in top 6" of soil for a week prior to planting.

Planting technique

- Transplant most crops for season extension, weed management, protection from predators and environmental elements, and water and seed use efficiency.
- Some crops (e.g., sunflowers) can be direct sown successfully; requires consistent weed control and irrigation (see sidebar, page 6 for direct sow vs. transplant recommendations).

Bed spacing

- From 36–60" center to center; based largely on bed preparation equipment and farm system
- Wider beds = more land in production and less in paths or alleys
- Wider beds can accommodate 3–5 rows per bed. This makes staking more efficient and a thicker stand means the flowers support themselves.
- Narrower beds give easier bed access, e.g., for harvesting from both sides at once.

Plant spacing within row

- Most cut flowers do well 8–12" apart.





- Exceptions: sunflowers grown closer together result in smaller plants, which can be an advantage for bouquets. Single stem (non-branching) species such as stock can also be planted closer together; competition increases stem length in some species.
- Maintain balance between giving enough room to meet water and fertility needs and planting close enough that plants can help support each other.

Planting depth

- For direct seeding, varies according to species/variety.
- For transplants, must be able to identify growth tip; generally, plant at the same depth as the soil level in the container.
- Zinnias, marigolds, safflower, sunflower: transplant deep to encourage adventitious rooting.

Irrigation

- Water overhead for first week or two after transplanting, then move to drip after weed flush and cultivation.
- Drip tape preferred to minimize disease incidence and conserve water.
- Overhead watering can cause lodging, damage flower blooms.

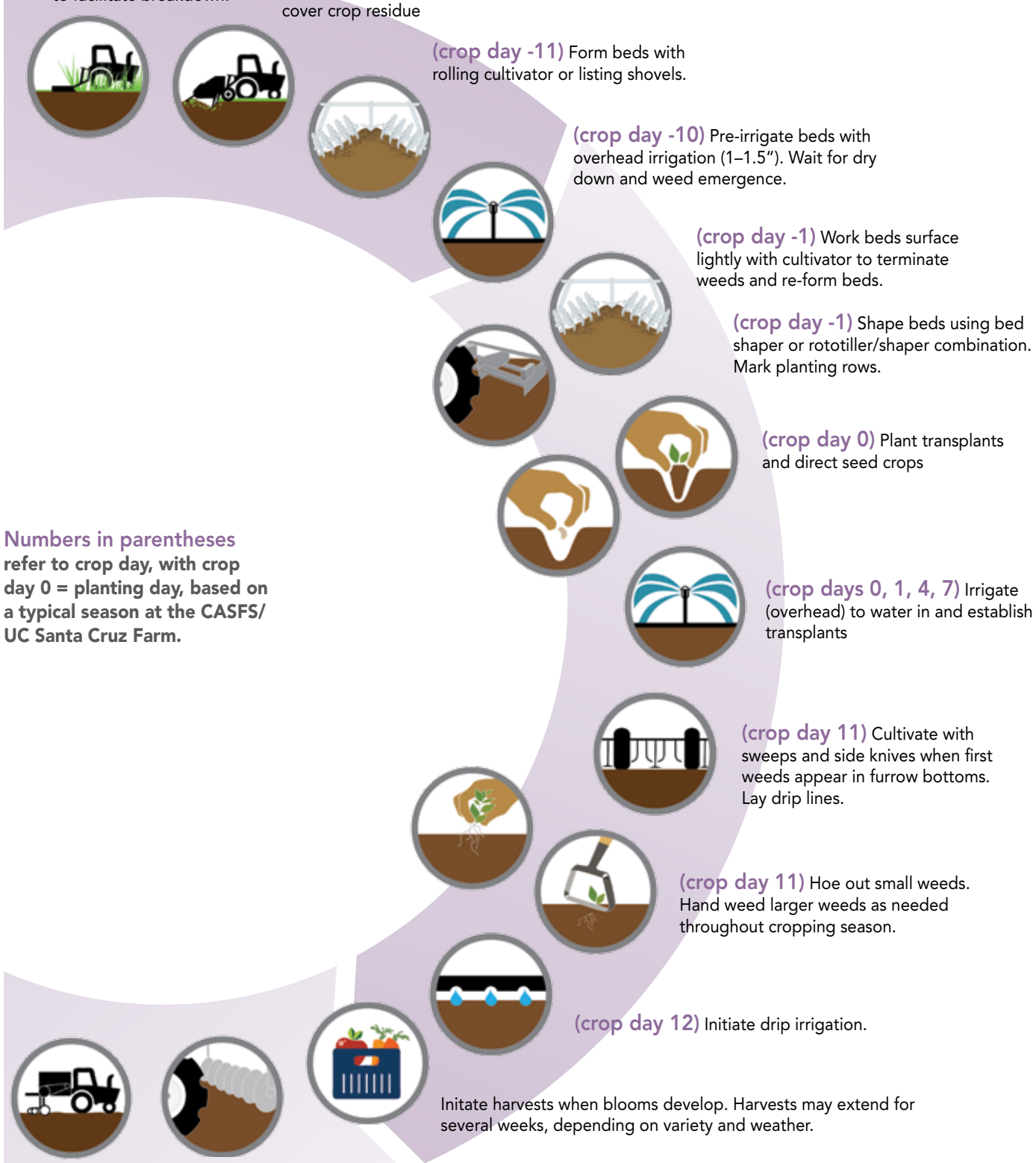
Weed management

- Control with mechanical tillage.
- May require additional hand weeding due to length of time in the ground.
- Weed cloth and plastic mulch can be used (and re-used).

Crop rotation

- Use in rotation with more disease-prone vegetables (e.g., solanum family species, strawberries) to break disease and pest cycles.
- Keep in a block for efficient management, as many flowers are in the ground longer than vegetables.

PRODUCTION SEQUENCE — OVERVIEW



(crop day -25*) In spring, mow cover crop to facilitate breakdown.

(crop day -25) Incorporate cover crop residue

(crop day -11) Form beds with rolling cultivator or listing shovels.

(crop day -10) Pre-irrigate beds with overhead irrigation (1–1.5"). Wait for dry down and weed emergence.

(crop day -1) Work beds surface lightly with cultivator to terminate weeds and re-form beds.

(crop day -1) Shape beds using bed shaper or rototiller/shaper combination. Mark planting rows.

(crop day 0) Plant transplants and direct seed crops

Numbers in parentheses refer to crop day, with crop day 0 = planting day, based on a typical season at the CASFS/ UC Santa Cruz Farm.

(crop days 0, 1, 4, 7) Irrigate (overhead) to water in and establish transplants

(crop day 11) Cultivate with sweeps and side knives when first weeds appear in furrow bottoms. Lay drip lines.

(crop day 11) Hoe out small weeds. Hand weed larger weeds as needed throughout cropping season.

(crop day 12) Initiate drip irrigation.

Initate harvests when blooms develop. Harvests may extend for several weeks, depending on variety and weather.

Drill cover crop seed.

Following completion of harvests, remove drip lines from field, mow crop residue, and undercut beds. Disc spent plants and prepare soil for next planting or fall cover cropping.

Production Practices — Special Considerations

In general, cut flowers are managed much like vegetable row crops in terms of soil fertility, bed preparation, planting, irrigation, and weed management (see, for example the pepper production information in this Grower Guide series). However, there are a number of considerations specific to cut flowers addressed here.

Successions and timing: determine a crop plan and planting schedule

To extend cut flower production through the season, plan for 3–4 successive planting blocks with distinct harvest windows, with 12–15 species for each block. Figure 1 shows an example of seasonal planting blocks at the UCSC Farm. See page 6 for considerations in deciding what species/varieties to grow.

Determine the following to create a planting schedule for successive blocks:

- sowing to transplant days (if sowing your own seeds) – how many days will plants be in the greenhouse before transplanting?
- days to maturity (DTM) – how many days does it take from transplant or direct sowing to harvest?
- length of harvest window – how many days can you expect to harvest each species/variety?

Use this information to calculate when to transplant or direct sow crops. Crop planning software programs can help you quickly and easily make these calculations to determine sowing and planting schedules. Examples of software

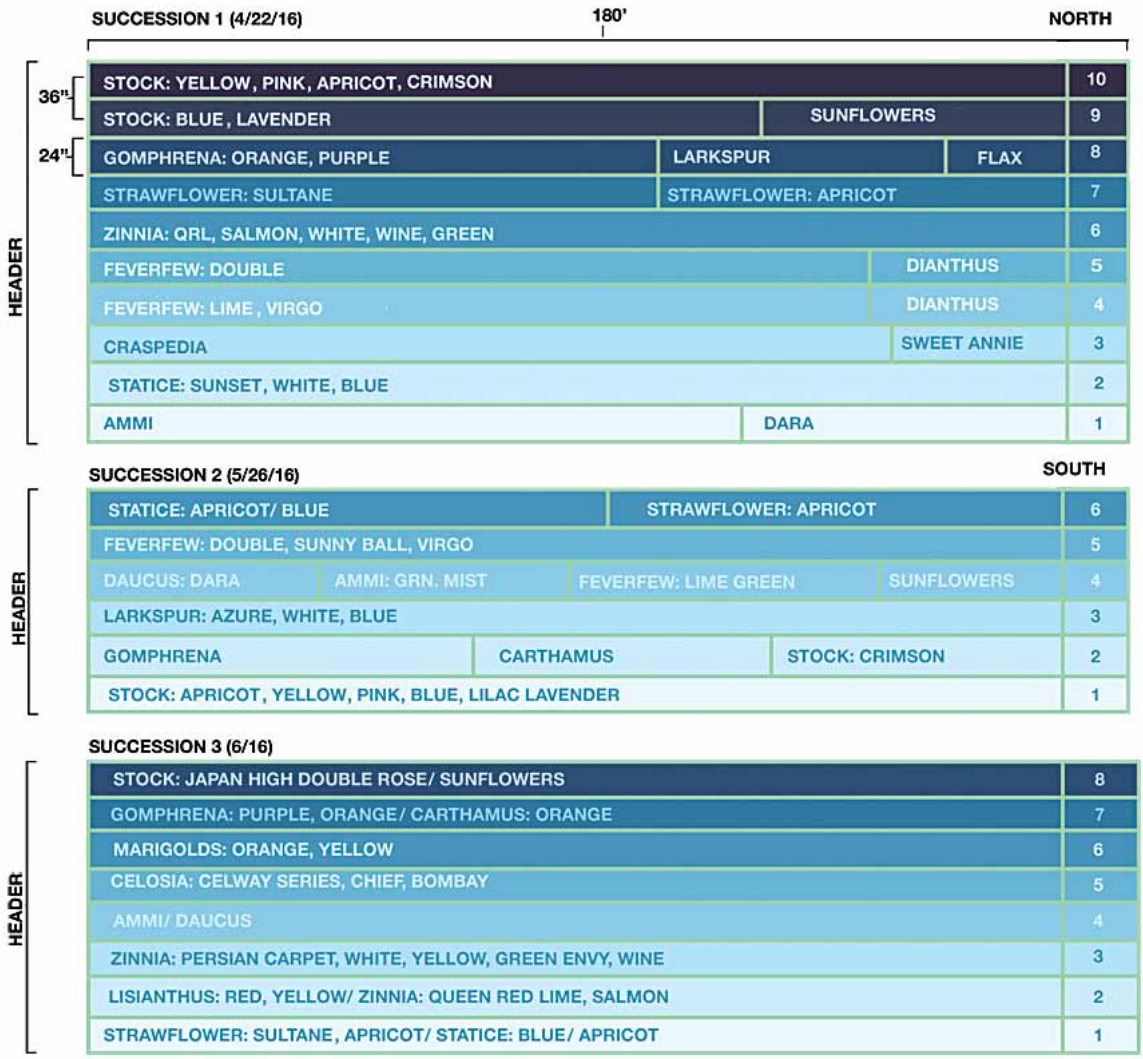


FIGURE 1. Example of seasonal planting blocks.

platforms include Tend (Figure 2) and AgSquared. If you're sowing your own seeds, keep careful greenhouse records to help inform future crop planning efforts.

Other information that will help you develop a crop plan and planting schedule include peak harvest period and yield on your site. See Table 1 for data on some of the species and varieties grown at the UC Santa Cruz Farm. Keep careful notes to develop your own dates and timelines to use in plans and schedules for future years.

Account for harvest windows when designing a block

When planning and planting flower blocks, group crops with long bloom and harvest windows together within the block to maximize harvest efficiency and field maintenance (Figure 3).

For example, statice and feverfew both have long harvest windows and can be mowed to encourage a second bloom from regrowth; they can be managed more easily if planted in adjacent beds. Separate these beds from shorter-lived crops with relatively short harvest windows, e.g. sunflowers and stock, which give only one cut, or larkspur, which has a narrow harvest window. A block of shorter-lived crops can be disked or tilled in to free up that ground for cover cropping, double cropping, etc.

Soil temperature for planting

Cool season crops, e.g., stock, agrostemma, sweet peas, cornflower, bells of Ireland, etc., need soil temperatures to reach high 40°s–low 50°s F to grow and crop. On the Central Coast, establish these plantings in late summer or early fall for late winter bloom, or December–January for spring blooms.

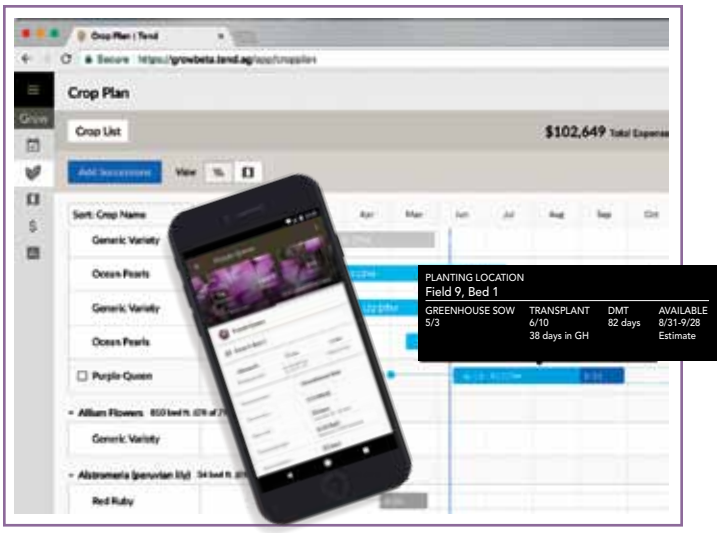


FIGURE 2. Example of Tend crop planning software.



FIGURE 3. Block plantings of cut flowers. *Photo: Elizabeth Birnbaum*

TABLE 1. Examples of cropping data from the UCSC Farm.

CROP	VARIETY	AVERAGE DAYS TO MATURITY*	AVERAGE HARVEST WINDOW IN TOTAL DAYS	PEAK HARVEST PERIOD IN CROP DAYS	AVERAGE YIELD STEMS/PLANTS
Ammi visnaga	Green Mist	75	40	75–85	1.5–2
Craspedia	Sun Ball	50	70–80	80–115	6
Daucus	Dara	85	40–60	95–120	7
Feverfew	Virgo	75	60–80	95–130	9
Gomphrena	Purple	75	60	n/a	14
Larkspur	Azure Blue	65–70	30	85–95	4
Statice	Apricot Mix	65	50–65	70–100	20
Strawflower	Apricot/Peach Mix	60	110	100–140	6
Zinnia	Queen Red Lime	60–70	70	60–90	8
Zinnia	Benary's Giant Mix	65	65–75	85–135	8–12

***(DTM) in crop days (from direct sowing or transplanting)**

EXAMPLES OF DIRECTLY SOWN AND TRANSPLANTED CUT FLOWERS

DIRECT SOW

Ammi majus (thin to 12" between plants)
Cerinthe (thin to 18")
Daucus (thin to 12")
Dill (thin to 8")
Larkspur (pre-chill seed for 7–14 days)
Sunflowers (thin to 10" for single heads, 6–8" for smaller varieties)

TRANSPLANT

Bachelor Buttons
Campanula
Celosia
Cosmos
Delphinium
Feverfew
Gomphrena
Rudebeckia
Scabiosa
Snapdragons
Stock
Strawflower
Sweet Peas
Zinnia

DIRECT SOW OR TRANSPLANT

Ammi majus, Daucus, Larkspur, Sunflowers

HOW DO YOU DECIDE WHAT TO GROW?

Factors to consider in deciding what species/varieties to grow:

- **What's trending?** Follow florists and farmer/florists on social media, talk to other flower growers, join groups such as the Association of Specialty Cut Flower Growers (ASCFG, ascfg.org).
- **What are your potential markets?** Grocery stores and farmers' market offer options for many species/varieties, while florists have more specific needs. If you plan on marketing flowers for weddings, the crop selection gets even narrower and potentially costly, as many brides and grooms have specific color schemes and species in mind; consider supplementing your own crops with bought-in flowers.
- **Are you growing for market bouquets?** If so, choose varieties that provide material for focal flowers, filler, foliage, and accent flowers (Figure 4). Consider planting different colors within species to expand your selections.



FIGURE 4. A mix of focal, filler, foliage, and accent flowers.
Photo: Elizabeth Birnbaum

Examples of focal flowers

Dahlias
Dianthus
Larkspur
Lilies
Lisianthus
Mums
Roses
Rudbeckia
Stock
Sunflowers
Zinnias

Examples of filler flowers

Ammi
Dara
Dill
Feverfew
Statice
Sweet Annie

Examples of foliage

Buplerum
Cerinthe
Dusty Miller
Eucalyptus
Ferns
Grasses
Herbs (rosemary, mint, basil)
Hypericum
Safflower
Scented Geranium

Examples of accent flowers

Celosia
Crespedia
Echinops
Gomphrena
Lavender
Nigella
Scabiosa
Snapdragons
Strawflower

- **How much space do you have?** Cut-and-come again species, such as zinnia, dahlias, and strawflower will maximize available space. Single cut species, such as sunflowers, stock, and larkspur take up more space; to have consistent blooms you will need more successions.
- **What is your preferred palette?** Create your own "brand" by highlighting your unique color scheme as a way to stand out from the crowd.
- **What grows well in your climate?** Visit local farmers' markets, talk to other growers and local Cooperative Extension agents, contact the Association of Specialty Cut Flower Growers (ASCFG, ascfg.org) for regional resources.
- **See a list of recommended Hardy/Half Hardy/Tender annuals** for California's Central Coast on page 12.

Once sustained daily temperatures reach the high 70s°F, these cool-season crops fail or die, as they flower too quickly or don't establish vegetatively (roots dry and die off).

Warm season crops (of tropical or subtropical origins) such as zinnia, dahlias, and marigolds, need the top six inches of soil to reach 60°F for a week before it is safe to plant—usually by the first week of May on California's Central Coast, although it can be earlier or later depending on the year and influence of microclimates.

Supplemental fertility

Some flowers benefit from supplemental fertility in the form of a foliar spray or soil drench.

Applied early in the growth cycle following transplant, supplemental nitrogen (N) helps establish a vigorous plant that will generate more robust blooms. Phosphorus (P) promotes early root growth and flowering, and potassium (K) contributes to strong stems and quicker maturation; they are best provided by longer-term soil fertility management.

Liquid kelp promotes leaf and stem cell wall strength, leading to stronger, longer, sturdier stems and increased vigor. It is easy to use in combination with a liquid nitrogen source such as fish emulsion, or a soy-based product. Apply foliar sprays weekly via a backpack sprayer to most cut flowers. Stop fertilizing once vegetative growth is established so as not to delay bloom or develop stems and flowers that snap or bruise easily. Note that sunflowers should not receive supplemental fertility; they perform well in marginal soils and tend to grow too tall and "leggy" if overfertilized.

Staking and netting

Although cut flowers are bred and selected for naturally long, strong, straight stems, some species are worth growing but require extra support. Snapdragons, for instance, are famous for leaning, then self-correcting, resulting in bent stems.



FIGURE 5. Netting helps ensure straight stems on snapdragons (Hortonova trellis, Peaceful Farm Supply). *Photo: Elizabeth Birnbaum*

Staking and netting (Figure 5) will ensure straight stems, which are essential for cut flower production. At a minimum, use stakes and twine on the bed edges to prevent stalks from falling into the aisles (Figure 6).

Pinching

Many species of flowers benefit from having the growing tip (apical meristem) pinched off to encourage branching and multiple blooms. See Table 2 for a list of plants that should be pinched, as well as those not to pinch.



FIGURE 6. Stakes and twine support cut flowers. *Photo: Martha Brown*

TABLE 2

PINCH

Bachelor Buttons, Bells of Ireland, Celosia (plume type), Cosmos, Craspedia, Dahlias, Didiscus, Dusty Miller, Gomphrena, Marigolds, Nigella, Rudebeckia, Safflower, Scabiosa 'Black Night', *Scabiosa purpurea*, *Scabiosa stellate*, Strawflower, Sweet Peas (thin center branch), Zinnias (a few times)

DON'T PINCH

Ammi, Buplerum, Campanula, Cerinthe, Daucus, Delphinium, Dill, Eryngium, Flower Kale, Hyacinth Bean, Larkspur, Lisianthus (but pinch out center flower), *Rudebeckia triloba*, Stock, Sunflowers



BIOLOGICAL BENEFITS FOR VEGETABLE PRODUCTION SYSTEMS

In addition to making economic sense, cut flowers also make biological sense. Most Central California vegetable crops don't feature flowers prominently, if at all. By including cut flowers in a mixed vegetable cropping system you can increase the biodiversity of your system.

Showy flowers attract crop pollinators, usually winged insects. Flowers also provide shelter, moisture, and nutrition to various predators and parasitoids (beneficial insects) that in turn help control pests.

A number of plant families provide easy-to-access food for beneficial insects and include excellent cut flowers. Consider incorporating some of these when developing your planting plan (as your climate permits):

Adoxaceae (elderberry family): Elderberry

Apiaceae (carrot/dill family): Ammi, Angelica, Daucus, Didiscus

Asteraceae (aster family): Ageratum, Asters, Chrysanthemum, Coreopsis, Cornflower, Cosmos, Echinacea, Goldenrod, Marigold, Sunflower, Venidium, Yarrow

Brassicaceae (cabbage family): Iberis, Stock

Caryophyllaceae (carnation family): Carnation, Gypsophila, Saponaria, Sweet William

Dipsaceae (scabiosa family): Scabiosa

Polygonaceae (buckwheat family): Shrub Buckwheats

Plumbaginaceae (statice family): Statice/Limonium

Timing of harvest

Harvest cut flowers either early in the morning or in the late afternoon/early evening to avoid midday heat (Figure 7). Both times take advantage of minimum transpiration, when plants are not losing moisture at a high rate.

In the morning plants have a cooler core temperature and are most turgid, having had all night to recover from the moisture losses of the previous day. Flowers with a cool (<50°F) core temperature will keep longer post harvest.

Cutting at dusk or early evening takes advantage of high sugar levels in the plant, a byproduct of a day's worth of photosynthesis. These sugars keep the flower's metabolism going and contribute to vase life. The main disadvantage of afternoon or evening cutting is a high core temperature and low turgidity. You can overcome this by refrigerating the flowers (34°–50°F) and/or "pulsing" them.

Pulsing involves placing the stems in deep, tepid (90°–100°F) water for one hour, and then plunging them into cold water (40°F). In phase one (warm water) the stems rapidly absorb water and achieve maximum turgidity. Phase two (cold water plunge) reduces core temperature and thus slows transpiration (water loss).

If harvest takes place midday, keep plenty of water in the buckets, and get flowers quickly into a cooler or cool space to maintain them successfully.

Incorporating herbaceous perennial flowers

Herbaceous perennials (non-woody plants living more than 3 years) can complement annual cut flower production. Often the blooms (both form and color) are distinctive; even in small numbers they add a sophisticated look to bouquets, elevating both "eye appeal" and price. While all flower are a draw at direct marketing venues, perennials really distinguish themselves.



FIGURE 7. Early morning harvests take advantage of the flowers' cooler core temperature. *Photo: Martha Brown*

EQUIPMENT AND TOOLS FOR HARVEST AND PROCESSING

- Clean buckets; keep separate from other operations.
- Transportation to move buckets from field to processing/storage area.
- Processing area: shaded, tables, stem cutter.
- Toolbelt/holster to carry pruners, snips, gloves, etc.
- Lightweight, sharp clippers. Look for those specially made for flowers or fruit, which are smaller and lighter than those made for pruning branches.
- Rubber bands for banding bouquets (#32 and #33s fit on wrist easily).
- Paper sleeves or brown paper for bouquets.
- Cold storage (at minimum, shade structure).

TIPS FOR HARVEST EFFICIENCIES

- Easier to harvest in a well maintained stand (staked, minimal or no "spent" blooms).
- Know optimal degree of openness and "cut to color," i.e., maintain the block by cutting all that are ready.
- Use sharp snips and clean buckets.
- Wear gloves for sharp, spiny stems, and for stripping leaves
- Bunch and band in the field for single species bunches to sell; this can be helpful to avoid damage and tangled stems in the bucket, as well as to track data (Figure 8). Carry enough rubber bands if bunching in the field.
- Line up heads of flowers while picking, then trim stems to even height.
- Cut stems on a small diagonal to allow more surface area for water to be absorbed.
- Cut stems long (18–24") and to a consistent length to minimize damage in bucket (Figure 9).
- In the bucket, line up flower heads on an even plane.
- Harvest into your hand, strip ½–3/4 of foliage. Using pre-determined bunch size, band a group of stems together and place in furrow, or tuck under arm.
- Pick up bunches as you walk out of the field, carrying many bunches in fewer trips.
- Count bunches as you carry them out of the field and place them all into a bucket at the same time to decrease jostling and recounting later.
- Many flowers are hearty enough to stay out of water (ideally in partial or full shade) for up to 20–30 minutes before being placed in water, which can make harvest more efficient.
- Buckets should only be filled with enough water to cover stems during the harvest, as buckets are heavy and will be lifted many times. If needed, add water before placing in cooler or overnight storage.
- Use a truck, gator, or cart of some type to move buckets; this saves time and physical energy.



FIGURE 8. Bunching and banding single-species bunches.
Photo: Martha Brown



FIGURE 9. Long stems minimize damage in bucket.
Photo: Martha Brown

POST-HARVEST HANDLING, STORAGE TIPS

- Clean buckets with soap and water (occasionally a small amount of bleach) before water and flowers are placed inside.
- Re-trim stems right before submerging in water to reopen tissue for maximum water absorption.
- All cut flowers should be kept out of direct sunlight, ideally in shade or under cover.
- Most flowers will respond well to refrigeration (35–45°F). Avoid freezing temperatures.
- Many flowers benefit from conditioning overnight in a cooler, and can hold for several days up to a week in a cooler at the proper temperature. Note: flowers need to be kept in a cooler without fruit crops that produce ethylene gas (e.g., apricots, avocados, tomatoes), which will make petals drop prematurely.
- Zinnias do not do well in a cooler—petals tend to turn brown. Certain crops, e.g., poppies, euphorbia, cerinthe, need other conditioning, such as singeing stems.

Once established, herbaceous perennials eliminate the need for annual tillage and outcompete weeds more effectively than annuals. Maintain them with a top dressing of compost and regular weeding plus irrigation.

Herbaceous perennials also present challenges. Quality organic seed may be difficult to source, and is more expensive than that of annuals. Perennials take two to three years to begin blooming and generally produce fewer blooms over a shorter time span than annuals. They also tie up the ground for a number of years.

Despite these limitations, herbaceous perennials can enhance your cut flower operation. Some relatively easy-to-grow perennials to consider:

Alstromeria
Aquilegia
Asclepias
Aster (perennial species)
Carnation
Caryopteris
Centaurea
Chrysanthemums
Coreopsis
Dahlia
Delphinium
Echinops
Erigeron
Eryngium
Euphorbia (perennial species)
Gypsophila (perennial species)
Helenium
Heliopsis
Heuchera
Michaelmas daisies
Phlox (perennial species)
Salvia farinacea
Solidago
Veronica

Marketing

There are numerous options for marketing cut flowers, including —

- Florists
- U-pick operations
- Farmers' markets
- Grocery stores
- Restaurants
- Community Supported Agriculture (CSA) flower shares (Figure 10)
- Special events (e.g., weddings, corporate meetings)
- Value-added options: dried flower wreaths and everlasting bouquets, medicinal, salves, edible flowers

Before committing ground to cut flowers, analyze potential markets in your area.

So much of marketing is relationship building, branding, and consistency of quality product. Develop relationships with local florists, caterers, event centers, spas, restaurants, and hotels. Once you've started growing, take buckets of flowers to potential clients and give samples to the managers.

Farmers' markets can be a great way to make connections and get your face and your product out there. Bringing flowers to market will naturally attract customers who want to support local growers for their special events. This type of word of mouth and networking can be the best marketing strategy.



FIGURE 10. CSA members' bouquets ready for pick up.
Photo: Elizabeth Birnbaum

TIPS FOR MAKING BOUQUETS FOR MARKET



FIGURE 11. Stack flowers on clean surface.
Photo: Elizabeth Birnbaum.

- You need to make many bouquets in a short amount of time (20–30/hour) in order to be profitable.
- Standardize bouquet size and number of stems.
- Consider how buckets of bouquets will look together at market and design accordingly.
- Come up with a "design recipe," and know how many of each ingredient to include before you start (see at right for examples).
- Include high levels of contrast and bright colors in your design.
- Organize ingredients into neat piles on a clean flat surface, for quick, easy handling (rather than pulling each stem out of a bucket; Figure 11).
- Have everything close at hand, and minimize amount of body movement to increase speed and efficiency.
- Cut stem lengths so that they are equal and proportional to size of bouquet—large bouquets should have long stems (Figure 12).
- Arrange blooms at the same level at the top of the bouquet (rather than a rounded globe shape), as customers will look at them from above.
- Place rubber bands, stem cutter, and paper sleeves at end of table closest to buckets where finished bouquets will be placed.
- Prefill clean buckets with water.



FIGURE 12. Cut stems to equal length for banding.
Photo: Elizabeth Birnbaum.

- Consider having one person arranging hand off of completed bouquets to another person who bands, trims, sleeves, and places in bucket.

Example of market bouquets from the UCSC Farm:

LARGE BOUQUETS

20–30 stems, 16" stem length (below the bloom)

4–6 species total (e.g., dahlia, feverfew, snapdragons, strawflower, flax, statice)

5–10 higher-value "focal" flowers per bunch (as opposed to filler)

SMALL BOUQUETS

15–16 stems, 12" stem length (below bloom)

3–4 species total (e.g., zinnia, statice, strawflower)

3–5 "focal" or higher value flowers per bunch (as opposed to filler)

SEASONAL EXAMPLES

Spring: Agrostemma, Dianthis, Mignonette, Roses, Sweet Peas

Summer: Ammi, Artichoke leaves, Celosia, Dahlias, Dusty Miller or Feverfew, Statice, Strawflower, Sunflower, Zinnia

Fall: Amaranth, Flowering Basil, Gomphrena, Rudbeckia, Sweet Annie



Fall bouquets. *Photo: Elizabeth Birnbaum.*

USEFUL HARDY (H) AND HALF HARDY (HH) ANNUAL CUT FLOWERS

Hardy

Calendula
Centaurea (Cornflower)
Clarkia
Cynoglossum (Chinese Forget Me Not)
*Dianthis barbatus** (Sweet William)
Godetia
Larkspur
Nigella
Scabiosa (Pincushion Flower)
Snapdragon
Statice
Sweetpeas
Sweet mignonette

Half Hardy

Canterbury Bells (biennial species)
Didiscus
Gypsophila elegans (Annual Baby's Breath)
Iberis (Candytuft)
Linaria
Saponaria (a bigger Gypsophila)
Stocks

*biennial species

TENDER ANNUAL CUT FLOWERS

Ageratum
Amaranthus
Asters
Calliopsis
Carthamus (Safflower)
Celosia
Cosmos
Dahlias
Gomphrena
Marigold
Phlox
Rudbeckia (perennial treated as annual)
Salpiglosis
Salvia coccinea
Salvia farinacea (tender perennial often treated as annual)
Salvia horminum/viridis (annual Clary sage)
Sunflowers
Tithonia
Venidium
Zinnias

EASY TO GROW, FLORIFIC PERENNIAL CUT FLOWERS

Alstromeria
Asters (Michaelmas Daisies, *Aster novi-belgii*)
Aster alpinus
Aquilegia spp. (Columbines)
Campanula persicifolia
Caryopteris clandonensis
Catanache caerulea (Cupid's Dart)
Centaurea montana, C.dealbata, C. macrocephala
Chrysanthemum spp.
Coreposis
Delphiniums
Dianthus spp. (Carnations)
Echinacea
Echinops ritro (Globe Thistle)
Erigeron (Fleabane)
Eryngium planum (Sea Holly)
Helenium
Heliopsis
Heuchera rubescens (Coral Bells)
Lilium spp.
Limonium caspia and *L. tatarica* (Statice species)
Nicotiana sylvestris
Perennial cornflowers
Physostegia virginiana (basically a perennial snapdragon)
Stachys lanata (Lamb's Ear)

ADDITIONAL RESOURCES

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Slow flowers: Four seasons of locally grown bouquets from the garden, meadow, and farm, by Debra Prinzing. St. Lynn's Press, 2013

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Organic Cut Flower Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers by Eliza Milio, Sky DeMuro, and Orin Martin. Edited by Martha Brown.

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This publication was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA. Mention of commercial products does not constitute an endorsement.

Photos, pp. 1 and 2: Elizabeth Birnbaum. Illustrations, pp. 3 and 4, Laura Vollset.

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ORGANIC PEST AND DISEASE MANAGEMENT OF SELECTED CROPS ON CALIFORNIA'S CENTRAL COAST:

A Guide for Beginning Specialty Crop Growers







This brief guide to organic pest and disease management reviews general management strategies, then describes options for reducing the occurrence and impacts of the most common pests and diseases affecting dry-farmed tomatoes, potatoes, winter squash, peppers, and bush beans on California's Central Coast. Much of the information provided here is based on the UC IPM website (ucipm.edu).

General Management Strategies

Effective ecological arthropod and disease management begins with design and management of a farming system that avoids or suppresses pests and diseases. Such a system requires few external inputs. Knowing which pests and diseases are prevalent in your area allows you to implement strategies to manage them before they occur. By anticipating likely pest and disease species for crops you intend to grow, you can identify them correctly when they do appear.

Before you select varieties and plant your crop, look up common pests that affect the crop in your area. Learn about pest and disease life cycles, preventive practices, and possible treatments using resources such as the UC IPM website (ucipm.edu), your county Cooperative Extension offices, ATTRA's Biorationals: Ecological Pest Management Database (ncat.org/attra-pub/biorationals), local growers, and other knowledgeable professionals. The information in this guide is not intended to take the place of advice provided by professional pest and disease management experts or organic certification personnel.

Note that if using material inputs, include all materials you plan to use in your organic system plan (OSP); apply only after the material is approved for your intended use by your certifier. If you decide during the season to use a material that was not included in your OSP, check with your certifier first. Use material inputs only when preventive practices, including natural enemies, are insufficient to prevent economic damage. Select pesticide materials for minimal toxicity to beneficial insects (see ATTRA's Biorationals: Ecological Pest Management Database).

Arthropods

- Use resistant varieties when available.
- Exclude pests. Use certified seed and pest-free planting materials; certified seed means the planting stock is certified to be free of certain pests and diseases. Seed certification is distinct from, but complimentary to organic certification. Organic producers should seek both, as well as varieties that are well adapted to local growing conditions.

- Create habitat for biological control organisms (e.g., insect predators and parasites, birds, bats, soil and foliar microorganisms). This usually involves increasing in- and around-field plant diversity to enhance biological control organisms:
  - Insectary plants as rows within the crop (normally 1 bed/12 beds of crop), or as individual plants (one plant every 50 sq. ft.): e.g., white alyssum, regular cilantro, and green and white dill. Insectary plant species vary with crop and time of year to match insectary flowering with crop life cycle.
  - Hedgerows: native woody perennial shrubs and small trees planted along roads, pruned as necessary to discourage vertebrate pests.
  - Summer and winter cover crops.
- Control host vegetation, manage weeds. Mow field margins to reduce alternate hosts for pest arthropods.
- Reduce tillage to destroy fewer soil-dwelling biological control organisms.
- Practice temporal crop rotation (timing). Avoid growing crops during times of the season when pests may be unmanageable.
- Practice spatial crop rotation/isolation. Put serial plantings upwind (especially for weak fliers such as aphids). Isolate serial plantings from each other as much as possible (for strong fliers, such as cucumber beetles).
- Use row covers.
- Use insect vacuums (bug vacuums). Four bed and larger are most effective. Fields should always be vacuumed at least twice during each treatment. Vacuums are a little dangerous if used early in the season because natural enemies of pests may also be removed before they can control the infestation. Begin vacuuming a few weeks before harvest when it is clear that natural enemies won't provide control and there won't be time for another pest to build up.
- Scout fields regularly and use farm-developed action thresholds for insecticide applications. Effective field scouting is 1–3 times per week. Frequency should increase with temperature. As you gain experience, you will learn what level of uncontrolled infestation leads to crop loss and therefore triggers insecticides application(s).
- Use insecticides only when necessary and choose materials with little to no impact on biological control organisms when possible. Cooperative Extension, other farmers, and ucipm.edu are the best sources for information on specific materials. Be sure that registrations and inclusion on lists of products allowed for use in organic production are current. Always follow the label.
- Rogue (remove) affected plants.

Diseases

- Exclude pathogens. Use certified seed and disease-free planting materials (see page 1). Compost using disease-destructive methods. Sanitize equipment.
- Use resistant varieties when available.
- Design fields and rows with aspect and airflow in mind. South slopes get more sun and dry more quickly. Orienting rows N-S prevents rows in multi-row beds from getting less sun and more humidity than others. N-S rows also improve airflow, reducing pockets of high humidity.
- Build your soil, e.g., by adding compost, growing cover crops, and reducing tillage. Manage nutrients, balance cations, and match nitrogen with crop need. These practices increase soil organic matter and augment biological activity with microorganisms that suppress damping-off diseases, while reducing excessive growth that makes some crops more susceptible to some diseases.
- Practice temporal crop rotation (timing). Avoid growing crop during times of the season when diseases may be unmanageable.
- Practice spatial crop rotation/isolation. Put serial plantings of the same crop upwind. Isolate serial plantings from each other as much as possible to minimize foliar diseases that spread with wind and/or rain.
- Practice genetic crop rotation. Rotate crops such that those that share the same important soilborne diseases (or foliar diseases that overwinter in soil) are grown on the same ground as infrequently as possible (never sequentially; sometimes separated by several years' time). Best rotations include pasture, livestock, trees, broad-leaved species after or before grass family species, and different plant families.
- Irrigate to minimize foliar/fruit wetting (for non-powdery mildew foliar diseases) and to minimize periods of soil saturation (for soilborne diseases).
- Supplement drip irrigation with sprinkler irrigations (for some powdery mildews).
- Reduce crop residue (for damping-off diseases and other diseases that survive on crop residue). Time, tillage, and irrigation facilitate breakdown of crop residue.
- Maximize airflow (for foliar diseases). Generous plant spacing, staking, and pruning can reduce the canopy's relative humidity.
- Reduce soil/fruit contact by using drip irrigation, staking, mulch (for fruitrot; soilborne diseases that affect fruit).
- Provide covered growing areas, such as high tunnels or plastic covered hoops (for foliar diseases that spread with abundant free moisture and/or water splashing).
- Scout fields regularly, and use farm-developed action thresholds for disease-suppressive materials applications. Effective field scouting is 1–3 times per week. Frequency should increase with temperature.
- Apply disease-suppressive materials before disease is seen. E.g., apply dusting sulfur to prevent powdery mildew in late season cucurbit crops. Disease pressure varies widely with crop and time of year. Most crops receive no supplemental pesticides for diseases, others require regular protection. Your goal is to anticipate disease and apply materials before disease starts: pesticides are less effective after diseases start.
- Rogue (remove) affected plants.

Dry-farmed Tomatoes: Pests and Diseases, Prevention, and Management Options

Main dry-farmed tomato arthropod pests

Aphids and viruses: Green peach aphid, *Myzus persicae* **and Potato aphid,** *Macrosiphum euphorbiae*

Aphids can spread many tomato viruses that severely affect tomato plants. High aphid populations can cause necrosis, distort foliar growth, and stunt plants. The honeydew secreted by aphid feeding promotes secondary infections of sooty mold on foliage and fruit. Aphid feeding reduces yields most when aphid populations are high, 6–8 weeks before tomato harvest. Yield losses are less significant closer to harvest. However, sunburn of fruit may result if heavy aphid feeding reduces leaf area. Although green peach aphid feeding is less significant, they can transmit viruses such as Alfalfa mosaic virus (calico).

- **Exclusion:** Plant virus-free seed.
- **Beneficial habitat:** Maintain alternate food sources for beneficial insects, such as extrafloral nectaries on fava and bellbeans, and hedgerows with year-round flowers. Generalist predators are natural enemies that can significantly reduce aphid populations.
- **Weed management:** Control weeds in non-crop areas to minimize nearby sources of early season aphid infestation of tomato crops. Important overwintering hosts include tumble mustard (*Sisymbrium altissimum*), penny cress (*Thlaspi arvense*), and other mustards (*Brassica* spp.).
- **Crop rotation/isolation:** Avoid planting next to, or downwind of, other crops commonly infested by green peach aphid, such as lettuce.
- **Scouting and pesticides:** Allowed pesticide materials can be useful when preventive management strategies are insufficient to control an unusual outbreak. Use high volumes of water (100–200 gal/acre if possible) and get good coverage. Apply two sprays 5–7 days apart.
- **Roguing:** Remove plants with virus symptoms as soon as you see them.

Tomato russet mite, *Aculops lycopersici*

Tomato russet mites are tiny, wedge-shaped acarids. Seeing them requires a hand lens. Adults lay clear round eggs on the underside of leaves, usually in dusty areas, low on the plant. Nymphs suck the liquid out of plant cells, causing leaves and stems to bronze, dry up, and die.

- **Weed management:** Control weeds, especially alternate hosts such as nightshades and bind weed that can sustain a population of mites to reinfest a subsequent year.
- **Crop rotation/isolation:** Separate tomato plantings. Situate successional crops upwind of earlier plantings.
- **Scouting and pesticides:** Check for mites above any greasy-looking or bronzed lower leaves and stems every 2–3 days at the stage of crop development when green fruit reaches 1" in diameter. Mark the boundaries of infested areas. Treat immediately if damage symptoms spread. Apply micronized sulfur 7–14 days apart.

Stink bugs: Consperse stink bug, *Euschistus conspersus*. **Redshouldered stink bug,** *Thyanta pallidovirens* **(=** *T. accerra*). **Say stink bug complex,** *Chlorochroa sayi* **and** *Chlorochroa uhleri*. **Southern green stink bug,** *Nezara viridula*

Several stink bugs feed on and damage tomatoes. All have the characteristic shield shape of true bugs, with similar life histories and damage. Adults are brown or green, some with distinct markings. Adults overwinter on the ground under leaves of legume crops, blackberries, or certain weeds such as Russian thistle, malva, and mustards. Adults lay drum-shaped eggs in clusters on leaves in March or April. Nymphs resemble adults, but without wings. On green tomato fruit, feeding damage looks like pinpricks, and their piercing mouthparts can insert yeast or other pathogens that can cause fruit to grow soft and rot.

- **Habitat to foster natural biological control organisms:** Generalist predators and parasites both attack stink bug egg masses. Native parasites can parasitize a majority of eggs. If parasitized egg masses are found, monitor newly hatched nymphs. Treatment may be unnecessary.
- **Weed management:** Control overwintering hosts such as legumes, blackberries, Russian thistle, mustards, and malva around fields that are to be planted to tomatoes in spring.
- **Scouting and pesticides:** Examine stink bug eggs to determine levels of parasitization. Parasitized eggs are dark, and emergence holes are irregular, unlike the round holes stink bugs leave when they emerge. Monitor for stink bugs by shaking the vines and checking the ground. Stink bugs leave brown liquid frass that dries into minute spots on leaves and fruit.
- **Treatment with kaolin clay or insecticidal soap can deter feeding or kill the bugs, respectively:** Apply with high water volume and slow speed to get canopy penetration and coverage of bugs on the ground.

Main dry-farmed tomato diseases

Late Blight, *Phytophthora infestans*

Late blight is a serious disease that develops rapidly and can destroy an entire tomato field in a few weeks' time. The disease is common in coastal areas because it develops in humid conditions (foggy, dewy, rainy), and moderate temperatures (50–80°F). The disease survives only in living tissue. To prevent its spread to new plantings, avoid

introduction into the fields or proximity of infected living hosts, including solanaceaous weeds, and volunteer potatoes and tomatoes.

Learn to recognize the disease! See photos of the disease on tomato leaves, stems, and fruit (Figure 1; see also *Late blight on tomatoes* in **Additional Resources**, page 12). Lesions start as small, dark brown, oily-looking lesions on leaves and stems. These quickly develop white fungal growth that produces thousands of spores, which can be spread by the wind in a matter of hours.

The "Scouting" section of the article *Organic management of late blight of potato and tomato* (see reference in **Additional Resources**) describes the importance of acting quickly to salvage what can be harvested of a current crop affected by late blight, and/or destroying foliage to minimize late blight survival and spread to crops in future years and neighboring fields.

Although certain copper-based products are allowed with restrictions in organic production, their use must be limited (to avoid copper build-up in the soil), and used preventively (see reference in **Additional Resources**). Use of a copper-based fungicide, at best, delays the demise of a susceptible host crop where the inoculum is present and conditions are favorable to development of the disease.

- **Field sanitation/Pathogen exclusion:** Use clean planting stock. Eliminate volunteer tomatoes and solanaceous weeds.
- **Resistant varieties:** Plant tomato cultivars with late blight resistance. Organic Seed Alliance trials identified some late blight resistance in tomato cultivars 'Stupice' and 'Juliet'.
- **Crop rotation/isolation:** Isolate successive tomato plantings, and plant as far as possible from other susceptible crops such as potatoes.
- **Air and humidity management:** Stake and prune tomatoes to facilitate air circulation and allow leaves to dry. Consider growing under cover in hoophouses.



FIGURE 1. Late blight *(Phytopthera infestans)* **on tomato leaves.**

Powdery Mildew caused by *Leveillula taurica (Oidiopsis taurica)*

Leaves of tomato plants infected by powdery mildew develop irregular, bright yellow blotches, where spots of dead tissue eventually develop; when severely affected, leaves die but usually remain on the plant. Stems and fruit do not develop lesions. You may see patches of white spores on the upper or lower surface of affected leaves. Loss of leaf cover may lead to sunburn damage, fruit cracking, and weakened plants.

- **Pathogen exclusion:** A small infestation in an early crop can provide inoculum for a more serious infestation in later blocks: remove above-ground growth as soon as harvest is over.
- **Crop rotation/isolation:** Tomato powdery mildew also infects peppers and some weeds such as annual sow thistle and groundcherry. Planting tomatoes away from, and upwind of, peppers may be somewhat helpful.
- **Pesticides:** Under favorable conditions and climates, powdery mildew spreads too rapidly to be controlled after first symptoms appear. Preventive sprays of micronized sulfur 7–14 days apart may be necessary, beginning just after the first flowers open, and continuing until two weeks before the end of harvest.

Tomato spotted wilt virus (TSWV) in the tospovirus group

Plants infected with TSWV do not usually produce marketable fruit. This virus is not seedborne or spread by physical contact. It is only transmitted from one plant to another by western flower thrips (see *Tomato spotted wilt virus* in **Additional Resources**).

Susceptible hosts include crops, ornamentals, and weeds, though the thrip can only complete its entire life cycle on certain plants. In California, key crop hosts include tomato, pepper, radicchio, and lettuce. Weed hosts include *Malva parviflora*, sowthistle (*Sonchus oleraceus*), and prickly lettuce (*Lactuca serriola*).

In areas where it is known to occur, effective management of tomato spotted wilt includes use of resistant plant varieties, and an integrated (challenging) approach to managing western flower thrips and onion thrips, vectors of the virus.

- **Pathogen exclusion:** Use virus- and thrips-free transplants (sources that monitor for thrips and inspect for disease).
- **TSWV-resistant cultivars:** Select varieties with the Sw-5 gene, when practical.
- **Vector management:** Manage thrips on transplants.
- **Crop rotation/isolation/weed management:** Isolate new plantings from older fields (especially those confirmed to have TSWV infection) with key crop hosts and weeds. Control weeds and volunteers near fields where tomato crops will be planted.
- **Roguing:** Destroy plants infected at the seedling stage to prevent spread of the disease.

Potatoes: Pests and Diseases, Prevention and Management Options

Main potato insect pests

Cucumber beetle: Western spotted cucumber beetle, *Diabrotica undecimpunctata undecimpunctata* and Western striped cucumber beetle, *Acalymma trivittatum*

The spotted cucumber beetle is more common on the Central Coast than the striped cucumber beetle. However, both may be present, and potatoes can tolerate a number of either beetle. Significant damage generally occurs only in warmer inland areas, surrounded by rangeland, and usually later in the year. Cucumber beetles do not have effective natural enemies in California (although bats can eat large numbers of them). Insecticides allowed for use in organic production are mostly ineffective.

- **Crop rotation/isolation:** Cucumber beetles are strong fliers. Isolate potatoes and other highly susceptible crops, such as cucurbits and corn. Separate sequential plantings of the same crop; plant new blocks upwind and away from older blocks. In areas where pressure is high, consider planting after a recent cash crop instead of a cover crop, as cucumber beetle larvae infest cover crop roots, and adults emerge to feed on crops.
- **Row covers:** Exclude new entry of cucumber beetles by securing row cover over the crop when it is young. Effective prevention of entry must be weighed against risk of enclosing beetles already infesting the field, as well as the cost of the fabric and the labor to keep it in place (more difficult in windy areas). Another downside is that row cover may protect early aphid and mite infestations from the natural enemies that could otherwise reduce their populations. However, mites and aphids are easier to control than cucumber beetles, using cultural practices such as sprinkler irrigation, biological control with insect releases, or pesticides approved for use in organic crop production.
- **Bug vacuum:** Vacuum several times per week during the warmest time of the day when the beetles are most active.
- **Scouting:** Scout by inspecting the undersides of plants. Depending on the stage of the crop, one beetle per plant may be an action threshold. Younger plants are most vulnerable.

Tuber moth, *Phthorimaea operculella*

Tuber moth larvae, or tuberworms, cause economic damage when they tunnel into potato tubers, both in the field and in storage. This pest is most problematic in warmer climates where temperatures do not drop below 50°F, such that all stages—eggs, larvae, pupae, and adults, can overwinter in potatoes either in the soil or after harvest. Tubers that are exposed to the air or close to the soil surface are most vulnerable to infestation. Prevention is key, since currently available insecticides allowed for use in organic production are ineffective against this pest.



FIGURE 2. Spotted cucumber beetle (at left) and assassin bug eating beetle. *Photo: Doug O'Brien*

The adult moth is brown with black markings, with a wingspan of about half an inch, and rests with its wings folded next to its body. Moths lay pale oval eggs on potato leaves or directly on tubers that are exposed or accessible through cracks in the soil. Caterpillar larvae have brown heads and pale bodies up to half an inch long. When eggs hatch, larvae may feed on stems or leaves, then drop to the soil and burrow into the tubers. Webbing and frass (excrement) may be visible where a larvae has entered the potato and begun to tunnel. Larvae feed mostly just below the potato surface, but occasionally go deeper. They leave a dark tunnel ("dirty" because it is filled with frass, unlike "clean" tunnels of wireworms).

- **Field sanitation/exclusion:** Prevent introduction of pests by using certified seed. Certified seed means the planting stock is certified to be free of certain pests and diseases. Seed certification is distinct from, but complimentary to organic certification. Organic producers should seek both, as well as varieties that are well adapted to local growing conditions, and resistant to common pests and diseases. Eliminate pest reservoirs by managing weeds and eliminating volunteer potatoes, both of which can increase populations and be a source of early season infestation.
- **Temporal crop rotation:** Plant early, especially in warmer inland areas; late plantings are more susceptible to tuberworm.
- **Monitoring:** Sample potatoes directly. If you find one tuberworm feeding hole in 10 tubers, harvest potatoes as soon as possible. Pheromone traps also detect tuber moth activity.
- **Minimize exposure of tubers:** Plant potatoes deep in the soil. Maintain hilling so that tubers are always covered with at least 2" of soil. If soil is prone to cracking, use sprinkler irrigation to help close cracks in the soil, and prevent potato tuber moths from access to potatoes on which to lay their eggs.

- **Prompt, thorough harvest:** Harvest potatoes a few days after vine kill or dieback. Do not leave harvested potatoes in the field overnight; moths can lay eggs on them. Clean bins and storage areas before storing potatoes. Destroy culls by burying them deeply or feeding them to livestock. Avoid piles of cull potatoes that provide a year-round tuber moth breeding site.

Aphids and viruses: Green peach aphid, *Myzus persicae* and Potato aphid, *Macrosiphum euphorbiae*

Aphid feeding on potatoes is a problem mainly because they are vectors that transmit plant viruses. Potato Leaf Roll Virus (PLRV), cucumber mosaic and alfalfa mosaic (calico) viruses are spread by both green peach and potato aphids, the former being the more effective vector. Early season PLRV infection stunts plants. Infected russet and yellow-skinned potatoes develop phloem net necrosis, a brown discoloration that diminishes market quality. Other viruses spread by aphids include cucumber mosaic and alfalfa mosaic (calico).

- **Sanitation:** Purchase clean, certified seed. Plants grown from infected seed potatoes will not produce marketable potatoes.
- **Habitat enhancement and biological control:** Manage habitat to foster natural biological control by beneficial insects (generalist predators), or release beneficial insects.
- **Weed management:** Control weeds, especially malva and brassicas, in non-crop areas that host overwintering aphids and facilitate early season aphid infestation.
- **Crop rotation/isolation:** Plant upwind of other potato plantings or other crops that are commonly infested by green peach aphid, such as lettuce.
- **Allowed pesticides:** Use high water volume (100–200 gal/acre) to maximize coverage. Two sprays 5–7 days apart are most effective (preferable to additional sprays or a longer interval between sprays).
- **Roguing:** Remove plants with virus symptoms as soon as you see them.

Tuber Flea Beetles, *Epitrix tuberis*

Sporadic outbreaks of flea beetles occur in potatoes on the Central Coast, mostly in warmer inland areas, after dry winters, and late in the season. The adults are small (1/16") and jump like fleas. Several species of shiny flea beetles cause economic damage to leafy crops such as brassicas when the adults eat many tiny holes "shot-holes" in the foliage.

It is the Tuber Flea Beetle whose larvae feed on tubers that causes economic damage to potatoes. Preventive strategies, such as crop rotation and weed host management, are key to organic flea beetle management. Allowed pesticides are not very effective against flea beetle, which tends to hide in the soil.

Flea beetles overwinter as adults in weeds and field borders, emerging when temperatures reach about 50°F. Adult flea beetle feeding on potato foliage is of concern only because it indicates a future risk of economic damage by larval feeding on the tubers. After feeding for several days, adults lay eggs in the soil at the base of plants. Slender white larvae hatch and feed on roots, underground stems, and tubers. Damage appears as a pimply surface and small brown tunnels in the tubers.

- **Crop rotation:** Plant potatoes in a field previously planted to a non-susceptible plant family such as legumes or grasses, not solanums or brassicas. Avoid planting potatoes soon after potatoes or other susceptible crops, such as brassicas.
- **Weed management:** Manage weeds (especially those in the brassica family) in and around potato fields.
- **Row cover:** Exclude flea beetles by covering crops immediately after planting, provided that the field is not already infested. Seal the edges of row cover well to keep these very small and persistent insects out.
- **Bug vacuum:** Vacuum beetles into fine mesh nets because flea beetles are small and resistant to dying.

Wireworms. Common local species of wireworms include: Pacific coast wireworm, *Limonius canus*. Sugarbeet wireworm, *Limonius californicus*. Dryland wireworm, *Ctenicera pruinina*

Wireworms are click beetle larvae that live in the soil. They cause economic damage by eating potato seed pieces or roots of young plants, or burrowing into developing tubers. Adult click beetles mate in early summer and lay eggs just below the soil surface in grassy or weedy areas. Wireworms begin as small white larvae, feed on many different crops, and mature over 3–5 years into hard (wiry) cylindrical orange-brown worms. Feeding damage is worst in years 2–3.

Wireworms are more prevalent in sandy soils previously in pasture or apple orchard. To assess their presence, monitor by direct observation during normal tillage operations, or by baiting with carrot or potato pieces placed 4–6" deep when soil temperatures warm up above 50°F. Small, localized infestations may be reduced by manually killing wireworms eating this bait. Using this as a damage predictor for the current season is relatively impractical, since it needs to be done when soils are warm. Early planting of potatoes is preferable.

- **Crop rotation/location:** Avoid planting potatoes after sod or in fields where populations are high.
- **Biological control:** The fungus *Metarhizium anisopliae* holds promise as a biocontrol, but commercial products may not yet be available.

Many other management options have downsides. E.g., tillage, disking, cultivation, and summer fallow reduce wireworm populations, but some of these practices also diminish soil structure and organic matter. Flooding for one week during warm weather will kill all stages in the soil, yet this may not be practical given the value of water on the Central Coast.

Main potato diseases

Late Blight, *Phytophthora infestans*

Late blight caused the Irish Potato famine in the mid-1800s. The disease is common in coastal areas because it develops in humid conditions (foggy, dewy, rainy), and moderate temperatures (50°–80°F). Late blight develops rapidly, and can defoliate a crop within a few weeks. The disease survives only in living tissue. To prevent its spread to new plantings, avoid introduction/proximity of infected living hosts, including volunteer potatoes and tomatoes, and solanaceous weeds.

Although certain copper-based products are allowed with restrictions in organic production, their use must be limited (to avoid copper build-up in the soil), well timed, and preventive (see *Organic management of late blight of potato and tomato with copper products* in Additional Resources). At best, use of copper-based fungicides delays the demise of a crop where the inoculum is present and conditions are favorable to development of the disease on a susceptible host plant.

Lesions on infected leaves start as small, irregular, water-soaked spots, but expand quickly to dark, dead tissue. Infected tubers show a firm, brown decay on the outside. See photos of the disease on potatoes at *Late blight on potatoes* in Additional Resources.

- **Field sanitation/pathogen exclusion:** Plant certified disease-free seed. Eliminate volunteer potatoes and solanaceous weeds. Destroy potato culls by burying or feeding to livestock.
- **Resistant varieties:** Plant potato cultivars with late blight resistance, such as 'Defender,' (russet type), 'Jacqueline Lee' (round yellow), 'Ozette' (white fingerling) or other emerging varieties resistant to late blight that may become available (see www.ospud.org).
- **Crop rotation/isolation:** Isolate successive potato plantings, and plant as far as possible from other susceptible crops such as tomatoes.
- **Timing:** Plant only in April–May near the coast; later and earlier plantings are more likely to be damaged by blight.

Verticillium Wilt, *Verticillium dahliae*

Verticillium wilt infestation appears as yellowing (chlorosis) and death (necrosis) of lower leaves. These wilt symptoms progress up the plant, causing plants to senesce and die early, resulting in very low yields. The fungus can persists in soil for years, and infects many broad-leaved crops, including strawberries. Infection occurs most in cool weather, but high temperatures favors disease development, such that this disease is more of a problem on potatoes grown inland. The disease interferes with the plant water transport (vascular) system, so the impact becomes visible quickly in hot weather.

- **Pest and disease avoidance:** Do not plant potatoes in fields known to be infested with problematic potato pests, including Verticillium, but also wireworm or tuberworm (discussed on page 6).
- **Resistant varieties:** Choose Verticillium-tolerant cultivars. Yellow Finn is susceptible.
- **Crop rotation:** Use a 2–3 year rotation grasses and legumes before planting potatoes and other susceptible crops.
- **Timing:** Avoid late plantings, when temperatures favor the disease.

Scab, *Streptomyces* spp.

Scab causes potato tubers to be unmarketable. Common scab may look similar to tuber lesions caused by *Spongospora subterranea* or russetting caused by *Rhizoctonia solani*. Scab inoculum, or fungal spores, may persist in soil on decaying organic matter, or be brought into the field on infected seed tubers. New young tubers may be infected as soon as they begin growing; mature tubers are not susceptible. Implement long crop rotation to break this disease cycle.

- **Sanitation/Pathogen exclusion:** Plant certified seed potatoes free from common scab.
- **Soil amendment:** More alkaline soils favor scab development. Acidify with soil amendments such as sulfur and gypsum to decrease soil pH and reduce favorability to disease development.
- **Resistance:** Plant resistant varieties
- **Crop rotation:** Choose cover crops such as rye and oats. Avoid rotations with carrots, beets, spinach, turnips, or radishes.
- **Irrigation management:** Maintain high soil moisture (80–90% of available water storage) during tuber initiation and the following 6–8 weeks.

Winter Squash: Pests and Diseases, Prevention and Management Options

Main winter squash insect pests

Cucumber beetle: Western spotted cucumber beetle, *Diabrotica undecimpunctata undecimpunctata* and Western striped cucumber beetle, *Acalymma trivittatum*

The spotted cucumber beetle is most common and does more damage to squash foliage, but the smaller striped cucumber beetle may feed on the fruits, making them unmarketable. Expect more damage during warm weather, in warmer climates, in areas surrounded by rangeland, and later in the year. Cucumber beetles do not have effective natural enemies in California (though bats can eat large numbers). Currently, organically-approved insecticides are mostly ineffective against this beetle.

- **Crop rotation/timing:** Avoid planting squash where infestations of cucumber beetle have been heavy or common. Plant early. Rotate crops. Cucumber beetles are strong fliers—plant upwind and separated from older sequential blocks, and other highly susceptible crops, such as potatoes, cucurbits, beans, and corn.

- **Row covers:** Consider excluding new entry of cucumber beetles by covering young crops with row cover. Weigh potential benefits against the costs of material and labor to secure the fabric in place, and the risks of enclosing beetles already in the field and excluding natural enemies of pests. Row covers must be removed when the plants flower to allow pollination, and thus do not help with a late season infestation. Note that cucumber beetles can completely kill young seedlings; if heavy cucumber beetle populations are likely, apply row covers before seedlings emerge and remove them when plants are at the 4-true leaf stage.
- **Bug vacuum:** While bug vacuuming may be used to manage beetles in other crops, it may not be practical or cost-effective in squash.
- **Scouting:** Monitor for beetles at growing points and undersides of young plants.

Melon Aphid, *Aphis gossypii* and other aphids

The melon or cotton aphid may be yellow, green, or black, winged or wingless (see *Melon aphid or cotton aphid* in Additional Resources). A pest with many host plants, they are problematic with high temperatures later in the season (September and October), feeding on the underside of older leaves. The plants may lose vigor, become stunted, or die. Fruits coated with sticky honeydew can develop secondary infections of sooty mold and become unmarketable. Aphids can also transmit plant viruses.

- **Weed and residue management:** Manage common weeds that harbor aphids. Incorporate crop residues as soon as harvest is finished.
- **Crop rotation/isolation:** Rotate crops. Locate new sequential plantings upwind of older squash plantings, or other crops that are frequently infested by melon aphids such as chard, beets, and other cucurbits.
- **Scouting:** Scout for pests, taking note of beneficial insects and mummified aphids. Very often, natural enemies will control aphids.
- **Pesticides:** Pesticides allowed for use in organic production can be useful when cultural practices and natural enemies are insufficient. Apply two sprays 5–7 days apart, using high volumes of water (100–200 gal/acre if possible) to get good coverage.
- **Roguing:** Rogue out plants with virus symptoms as soon as you see them.

Main winter squash diseases

Powdery mildew: *Sphaerotheca fuliginea* (=*Podosphaera xanthii*) and *Erysiphe cichoracearum* (=*Golovinomyces cichoracearum*)

Powdery mildew is caused by several different organisms, and affects leaves and stems of older, fruit-bearing plants. It is most common in the fall, when humidity is high (50–90%), days are warm (60–80°F), and nights are cool. Spores overwinter on weeds, and carry long distances on the wind. Powdery mildew is especially damaging to highly susceptible squash such as spaghetti, acorn, and kabocha varieties. Some other varieties (e.g., butternut) are more resistant.

Powdery mildew begins as pale yellow spots, then its mycelium spreads quickly over plant surfaces, producing spores that have a powdery appearance (Figure 3). Infected leaves lose vigor, and eventually die and turn papery brown. When leaves no longer shade the fruit, it will not mature properly, and dark-skinned squashes can be badly sunburned.

- **Resistance:** Plant resistant cultivars.
- **Manage weeds and residue:** Eliminate sources of above-ground inoculum that can readily infect a crop. Incorporate crop residue as soon as harvest is complete.
- **Crop rotation:** Plant squash where the crop will have full sun exposure and good air circulation. Rotate crops.
- **Sprinkler irrigation:** Sprinkler water inhibits germination and kills spores of powdery mildew, but can only provide early season control; it must stop when fruits form or they will rot on the damp ground. Early season control with sprinkler water sometimes delays the epidemic long enough for fruit to mature. Late season prevention with sulfur may be needed if the weather is favorable for powdery mildew; growers usually do one sulfur spray after the sprinklers are turned off, compared with 2–3 sprays for fields that start on drip irrigation. Where weeds are problematic, growers often prefer drip irrigation combined with multiple sulfur sprays for powdery mildew, rather than fewer sprays and more hand labor to control weeds in fields with sprinklers.
- **Pesticides:** When conditions are favorable for powdery mildew, the disease spreads too fast to be controlled after symptoms appear. Pesticides may be effective as preventive or suppressive, not curative. Apply a biorational material, such as micronized sulfur, bicarbonate, or biological materials beginning just after the first flowers open until three weeks before the end of harvest. Backpack spraying may be necessary for vining varieties.

Verticillium Wilt, *Verticillium dahliae*

Verticillium wilt affects all cucurbits, but varieties vary in their susceptibility. Symptoms begin as chlorosis (yellowing) on the



FIGURE 3. Powdery mildew on winter squash.

edges of leaves and progress into wilting and necrosis (dying) out to the ends of runners. The disease grows in the vascular system (xylem), where it interferes with water transport; symptoms show up as brown streaks. The progression of the disease depends on the host's susceptibility. It may kill the plant in a matter of weeks, or, in more resistant hard squashes, merely reduce yield and quality.

Verticillium dahliae can survive dormant in the soil for years, and affects a wide host range. Infection happens in cool weather, but symptoms show up when temperatures are high and the plant is stressed, often after fruit set. It is more of a problem in inland areas.

- **Resistance:** Plant resistant crop varieties.
- **Crop rotation/location:** Use long rotations (2–3 years or more) out of susceptible crops such as cucurbits, solanums, and strawberries to non-susceptible crops, such as grasses and legumes. Microsclerocia persist in the soil. Do not plant where soils are heavily infested and therefore unsuitable to susceptible crops.
- **Timing:** Plant early in the season; avoid late plantings when high temperatures favor the disease.
- **Fertility/irrigation:** Manage fertility and irrigation to avoid excess of nitrogen or moisture. Where weather warm enough for it to be effective, consider soil solarization.

Peppers: Pests and Diseases, Prevention and Management Options

Main pepper insect pests

Thrips. Western flower thrips, *Frankliniella occidentalis***. Onion thrips,** *Thrips tabaci***. Chili thrips,** *Scirtothrips dorsalis* **and other species.**

Thrips can be vectors of Tomato Spotted Wilt Virus (TSWV; see disease section, page 10). Scout early by looking for the tiny insects on growing tips with a hand lens. Apart from virus transmission, thrips cause the most damage to peppers before first fruits form, and as temperatures warm up. They feed on young growing tips, causing young leaves to distort, discolor, and stunt. Tolerance is low: one thrips per growing tip. A heavy infestation can stunt plants and lower yields. Natural enemies can be helpful, but may not control populations early enough to prevent economic damage.

- **Site management**: Mow field borders to reduce thrips habitat and prevent their migration to young peppers.
- **Pesticides:** Apply pesticides if scouting shows more than one insect per plant tip.

Aphids: Green peach aphid, *Myzus persicae*

Peppers can tolerate a small population of aphids, particularly if natural enemies are abundant nearby. However, heavy infestations will coat fruit with sticky aphid exudates that are difficult to remove.

- **Plant in-field insectaries:** Cilantro and dill are good insectary plants for slow maturing peppers. Natural enemies, nourished by the insectaries, will often control aphids in peppers.
- **Crop rotation/isolation:** Avoid planting peppers next to, or downwind of, other crops such as lettuce that are frequently infested by green peach aphid.
- **Row covers:** Row covers may be used to exclude aphids, but they also exclude natural enemies that may otherwise control aphids.
- **Scouting and pesticides:** Scout early and frequently. Apply two sprays, 5–7 days apart, of a minimally toxic pesticide to prevent harm to beneficial insects. Use high volumes of water (100–200 gal/acre if possible) and get good coverage.

Cucumber beetle: Western spotted cucumber beetle, *Diabrotica undecimpunctata undecimpunctata* **and Western striped cucumber beetle,** *Acalymma trivittatum*

The spotted cucumber beetle is more common and does more damage to foliage, but the smaller striped cucumber beetle may feed on fruit calyxes, making fruit unmarketable. Scout early. Expect more damage during warm weather, in warmer climates, in areas surrounded by rangeland, and later in the year. Cucumber beetles do not have effective natural enemies in California. Currently, organically-approved insecticides are mostly ineffective.

- **Location/timing:** Avoid planting peppers where infestations of cucumber beetle have been heavy or common. Plant early. Rotate crops. Cucumber beetles are strong fliers—plant upwind and separated from older sequential blocks, and other highly susceptible crops, such as potatoes, cucurbits, beans, and corn.
- **Monitoring:** Scout by inspecting the undersides of plants. Depending on the stage of the crop, one beetle per plant may be an action threshold. Younger plants are most vulnerable.
- **Row covers:** Exclude new entry of cucumber beetles by securing row cover over the crop when it is young. Benefits of excluding the pest must be weighed against risk of enclosing beetles already infesting the field, as well as the cost of the fabric and the labor to keep it in place (more difficult in windy areas). Another downside is that row cover may protect early aphid and mite infestations from the natural enemies that could otherwise reduce their populations. However, mites and aphids are easier to control than cucumber beetles, using cultural practices such as sprinkler irrigation, biological control with insect releases, or pesticides approve for use in organic crop production.
- **Bug vacuum:** Vacuum removal of cucumber beetle can be effective if done frequently during the warmest time of the day when the beetles are most active. The lack of natural enemies makes vacuuming one of the best strategies.

Main pepper diseases

Powdery mildew caused by *Leveillula taurica* (*Oidiopsis taurica*)

Powdery mildew can be a serious disease of peppers, especially in warm climates, in late season plantings, in high tunnels, and with drip irrigation. The diseases affects older leaves most, showing up as patchy white spots that can spread rapidly under favorable conditions. Infected leaves curl up and leave fruit vulnerable to sunburn.

Prevention and management options:

- **Field sanitation/pathogen exclusion:** Even small infestations early in the crop cycle can be sources of inoculum and cause a serious infestation. Incorporate all crop residue as soon as harvest is over.
- **Crop rotation:** Rotate peppers with crops not susceptible to powdery mildew. Avoid planting in close proximity to susceptible crops.
- **Irrigation:** Sprinkler irrigating can delay the development of powdery mildew long enough to harvest the crop, or to avoid one or more prevention sprays. Although they grow best in high humidity, unlike most fungal diseases, powdery mildews are suppressed by overhead irrigation. Time irrigation carefully—start later in the season, after the canopy shades the ground, to minimize weed growth. Discontinue use of sprinkler irrigation when fruit is mature enough to touch the ground and rot.
- **Pesticides:** If other management methods are insufficient to control powdery mildew, apply micronized sulfur when mildew is anticipated just after flowers open, and continue until two weeks before the end of harvest. If sprinkler irrigation is used, at least one of the early sprays can be eliminated.

Tomato spotted wilt virus (TSWV) in the tospovirus group

This disease is sporadic, but serious, since plants infected with TSWV usually do not produce marketable fruit. Symptoms in peppers vary with the stage of growth infected, the cultivar, other viruses, and environmental conditions, but typically include spotting, bronzing, dying leaves, and ringspots on fruit. In areas where it is known to occur, effective management of tomato spotted wilt includes use of resistant plant varieties, and an integrated (challenging) approach to managing western flower thrips and onion thrips, which are key vectors of the virus (see Tomato spotted wilt virus in Additional Resources).

- **TSWV-resistant cultivars:** Select varieties with the Sw-5 gene, when practical.
- **Pathogen exclusion:** Use virus- and thrips-free transplants (from sources that monitor for thrips and inspect for disease).
- **Vector management:** Manage thrips on transplants.
- **Site selection/Spatial crop rotation:** Isolate new plantings from older fields (especially those confirmed to have TSWV infection) with key crop hosts and weeds. Control weeds and volunteers near fields where peppers will be planted.
- **Monitoring:** TSWV can be identified in 5–10 minutes using dipsticks smeared with prepared plant sap samples (ELISA, immunostrip tests that recognize TSWV proteins; PCR tests detect the virus's genetic material). TSWV immunostrip supplies are from companies such as AgDia (www.agdia.com) and EnviroLogix (www.envirologix.com).
- **Roguing:** To prevent spread of the disease, destroy plants infected at the seedling stage.

Beans: Pests and Diseases, Prevention and Management Options

Main bean insect pests

Aphids: Cowpea aphid, *Aphis craccivora*. Black bean aphid, *Aphis fabae*. Pea aphid, *Acyrthosiphon pisum*. Green peach aphid, *Myzus persicae*

Aphids suck plant juices, weakening and distorting crops, and feed on many different host plants. Their piercing mouthparts transmit viruses. Presence of aphids makes some crops unmarketable.

The black bean aphid is the most common and problematic of the aphid pests of beans. These, and other aphids, can proliferate rapidly.

- **Encourage beneficials:** Prevent outbreaks by planting and maintaining in-field insectaries to sustain beneficial insects. Generalist predators such as ladybeetles, green lacewing larvae, and syrphid fly larvae eat many aphids. Plant white alyssum for fast-maturing bush beans, and a mix of alyssum and cilantro for pole beans.
- **Timing/isolation:** Plant early in the season, as late plantings may suffer more damage. Avoid planting near, or downwind from other susceptible crops such as fava bean, chard, and cucurbits.
- **Scouting:** Scout early and frequently by looking on the undersides of leaves. Look also for hollow brown aphid "mummies". Parasitoide wasps, *Lysiphlebus testaceipes*, lay their eggs in aphids. Their developing larvae eat out their insides, leaving an empty brown shell (see photo http://ipm.ucanr.edu/PMG/A/I-HO-AGOS-LT.015.html). Their activity may be sufficient to prevent a serious outbreak.
- **Irrigation/pesticides:** If you do not see mummified aphids, take action quickly to control infestations. Water spray or sprinkler irrigation can help dislodge aphids and also favors beneficial fungus as biological control to kill aphids. Pesticides can be useful to treat early infestations on small plants. Choose least toxic materials (see Biorationals: Ecological Pest Management Database) to prevent harming natural enemies that can help control aphids. Apply two sprays 5–7 days apart, using high volumes of water (100–200 gal/acre if possible) to get good coverage.

Cucumber beetle: Western spotted cucumber beetle, *Diabrotica undecimpunctata undecimpunctata* and Western striped cucumber beetle, *Acalymma trivittatum*

The spotted cucumber beetle is more common on the Central Coast and most serious. Tolerance for this pest in beans is low; even one bite can render a bean pod unmarketable. Damage is worst in warmer inland areas, near rangeland, and later in the year. Cucumber beetles do not have effective natural enemies in California (although bats can eat large numbers of them), and insecticides allowed for use in organic production are mostly ineffective against this beetle.

- **Timing/isolation/crop rotation:** Plant early. Avoid planting beans where infestations of cucumber beetle have been heavy or common. Rotate crops. Cucumber beetles are strong fliers—plant upwind and separated from older sequential blocks, and other highly susceptible crops, such as potatoes, cucurbits, beans, and corn.
- **Row covers:** Exclude new entry of cucumber beetles by securing row cover over the crop when it is young. Benefits of excluding the pest must be weighed against risk of enclosing beetles already infesting the field, as well as the cost of the fabric and the labor to keep it in place (more difficult in windy areas). Another downside is that row covers may protect early aphid and mite infestations from the natural enemies that could otherwise reduce their populations. However, mites and aphids are easier to control than cucumber beetles, using cultural practices such as sprinkler irrigation, biological control with insect releases, or pesticides approved for use in organic crop production.
- **Bug vacuum:** Vacuum removal of cucumber beetle can be effective if done 4–5 times per week during the warmest time of the day when the beetles are most active, starting 3 weeks before harvest.

Main bean diseases

Damping off caused by *Pythium spp.*, *Fusarium spp.*, *Rhizoctonia solani,* and *Thielaviopsis basicola*

Damping off is the most serious disease of beans in the Monterey Bay area, resulting in pre-emergent rot of the whole seed, emerging plant, or the first true leaves. Although symptoms are somewhat different depending on the organism, exact diagnosis is not usually important because all damping-off fungi are managed the same way. Cool soil is the most common reason for damping off, followed by oxygen deprivation caused by too much water.

- **Timing/location:** Plant after soil has warmed sufficiently. Design fields and rows with aspect in mind, using south-facing slopes for spring planting.
- **Irrigation:** Manage irrigation—for best results, follow the instructions for planting beans to moisture (see Organic Fresh Market and Dry Bean Production in this **Grower Guide** series).

Powdery mildew caused by *Erysiphe polygoni*

Powdery mildew can be a problem in dry beans, pole beans, late season plantings, warm areas, and with drip irrigation. It affects all above-ground parts of bean plants. Initial symptoms are small, white spots on the upper surface of leaves. Spots grow and run together in a whitish growth that gradually spreads over a large area of the leaves. Severe infestation reduces yields and shortens the productive life of plants.

- **Exclude pathogens:** A small infestation in an early crop can provide inoculum for a more serious infestation in later blocks: incorporate above-ground growth as soon as harvest is over.
- **Irrigation:** Sprinkle irrigate once, just before flowering, to delay powdery mildew long enough to harvest the crop. Unlike most fungal diseases of plants, powdery mildews are damaged by overhead irrigation. Time/apply this sprinkler irrigation carefully. If too early in the crop cycle, it promotes weed growth; if too much, it may favor growth of *Botrytis* mold.
- **Pesticides:** If other management methods are insufficient, apply micronized sulfur once as soon as symptoms are anticipated or first seen. Symptoms usually appear just before flowering. Application of sulfur after beans are half formed may not improve harvest, and may result in undesirable residue on the pods.

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ADDITIONAL RESOURCES

Biorationals: Ecological pest management database, by Rex Dufour. https://attra.ncat.org/attra-pub/biorationals/

Use database to search for individual pests and diseases, e.g., powdery mildew, Verticillium wilt.

Bug vacuums for organic crop protection, by George Kuepper and Raeven Thomas. NCAT IP194, 2002. https://attra.ncat.org/attra-pub/summaries/summary.php?pub=128

Farmscaping to enhance biological control, by Rex Dufour. NAT CT065, 2000. https://attra.ncat.org/attra-pub/summaries/summary.php?pub=145

Hedgerows for California agriculture: A resource guide, by Sam Earnshaw. Community Alliance with Family Farmers (CAFF), 2004. http://caff.org/wp-content/uploads/2010/07/Hedgerow_manual.pdf

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Photos of late blight at various stages on potatoes.

Late blight on tomatoes. College of Agriculture and Life Sciences, Cornell University. http://livegpath.cals.cornell.edu/gallery/tomato/tomato-late-blight/

Photos of late blight at various stages on tomatoes.

Melon aphid or cotton aphid. Featured Creatures, Entomology and Nematology. University of Florida. http://entnemdept.ufl.edu/creatures/veg/aphid/melon_aphid.htm

Organic IPM field guide, by Ann Baier et al. 2006. NCAT. https://attra.ncat.org/attra-pub/summaries/summary.php?pub=148

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Pest management strategic plan for organic potato production in the west. Summary of workshops held on February 16, 2006, Buhl, Idaho and January 9, 2008, Portland, Oregon. Jennifer Miller, Ronda Hirnyck, Lisa Downey-Blecker. Issue Date, December 19, 2008. http://www.ipmcenters.org/pmsp/pdf/CA-CO-ID-OR-WAOrganicPotatoPMSP.pdf; see pages 7–9

Pesticide Safety Information Series (PSIS), California Department of Food and Agriculture. http://www.cdpr.ca.gov/docs/whs/psisenglish.htm (En Español: http://www.cdpr.ca.gov/docs/whs/psisspanish.htm)

Potato scab, by Rosemary Loria. Vegetable MD Online, Cornell University, 1991. http://vegetablemdonline.ppath.cornell.edu/factsheets/Potato_Scab.htm

Thrips *in* Pests in gardens and landscapes, UC IPM, Statewide Integrated Pest Management Program. http://ipm.ucanr.edu/PMG/PESTNOTES/pn7429.html

Tipsheet: Organic pest management, by Rex Dufour. NCAT IP404, 2015. https://attra.ncat.org/attra-pub/summaries/summary.php?pub=518

For general pest management strategies that are compliant with USDA organic regulations.

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Organic Pest and Disease Management of Selected Crops on California's Central Coast: A Guide for Beginning Specialty Crop Growers by Doug O'Brien and Ann Baier.

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This publication was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

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ORGANIC POTATO PRODUCTION ON CALIFORNIA'S CENTRAL COAST:
A Guide for Beginning Specialty Crop Growers







Introduction

Potatoes can be a good addition to a small-scale, mixed specialty crop system. With access to the proper tools for mechanized weed management, hilling, and harvest, they are relatively easy to grow. Multiple varieties offer an array of shapes, sizes, and colors to make potatoes an excellent choice for direct sales, including Community Supported Agriculture (CSA), farmers' markets, specialty markets, and restaurants.

The Central Coast's climate is ideal for potato production. Yields can reach an impressive 10 tons per acre. This guide describes the steps involved in growing potatoes organically, reviews equipment needs, and provides information on "new" and "creamer" potato growth habits and recommended varieties.

Features of potato production

- Can be harvested as "new," "creamer," or fully cured storage potatoes, all of which can be grown on the same production schedule
- Easy to store when fully cured
- Mechanization makes weed management and harvest extremely efficient
- A good rotation crop where symphylan pressure is high, being extremely tolerant to symphylan feeding pressure; they have been shown to reduce symphylan populations in subsequent crops

PRODUCTION PRACTICES — SUMMARY

Soil type and pH

- Potatoes grow best in loose, well-drained, non-crusting, sandy loam or loam soils with high organic matter content and pH between 5.5 and 6.5.

Site selection

- Isolate successive potato plantings, and plant as far as possible from other susceptible crops such as tomatoes to minimize the risk and impact of late blight *(Phytopthera infestans)*.

Fertility requirements

- Fall/winter cover crop (bell beans, triticale, vetch).
- Compost, as needed (5 tons/acre).

Soil temperature

- Seed pieces can germinate when soil temperatures are cool (less than 55°F).

Bed spacing

- Bed spacing of 48" allows for a balance of workability and yield potential.
- 30" bed spacing is possible if using 4-gang Lilliston cultivators, disc hillers, or shovels.
- 60" beds provide for ease of field operations, but may reduce yield potential.
- Potatoes grow best planted in a single line per row to allow for "hilling" (see page 5) to ensure that potatoes are covered with soil. Potatoes exposed to sunlight turn green and become unmarketable.

Plant spacing within row

- 8–12" between plants in the row. Closer spacing will result in smaller tubers (see page 9, New and Creamer Potatoes).

Planting size and depth

- Use 1.5–3 ounce seed pieces with at least 2 "eyes."
- Place seed pieces 2–4" deep.

Irrigation

- Pre-irrigate beds with overhead sprinklers and cultivate for weed management.
- Use drip irrigation after planting; overhead irrigation increases risks of fungal infection, *Phytopthora infestans* (late blight).

Days to maturity

- Most varieties suitable for the Central Coast region reach full maturity in 100 to 120 days.
- Harvest "new" potatoes at the growth stage following bloom when the canopy is full, typically 8–9 weeks after planting, depending on variety and weather.
- Harvest "creamers" 10–12 weeks after planting, depending on variety and weather.

Crop rotation

- Rotate ground out of solanums and strawberries for a minimum of 4 years to break disease cycles.



PRODUCTION SEQUENCE — OVERVIEW

(crop day -25*)
In spring, mow cover crop to facilitate breakdown.



(crop day -25) Incorporate cover crop residue.



(crop day -11) Form beds with rolling cultivator or listing shovels.



(crop day -21) Begin chitting potato seed.



(crop day -10) Pre-irrigate beds with overhead irrigation (1–1.5"). Wait for dry down and weed emergence.

(crop day -3) Cut potato seed in preparation for planting.



(crop day -1) Work bed surface lightly with cultivator to terminate weeds and re-form beds.

(crop day 0) Create a trench down the center of the bed using a small furrowing shovel or an "Alabama" shovel. Plant potatoes, cover seed lightly with 3–4" of soil using a rolling cultivator (run slowly).



(crop day 11) As soon as first weeds appear, cultivate furrow bottoms and bed sides with sweeps and knives. In the same pass, run chisels in furrow bottoms to break tractor tire compaction.**



(crop day 11) Set up drip irrigation

(crop days 30, 40) Hill plants with soil as potato stems elongate (usually twice prior to bloom).



(crop day 30) Begin drip irrigation. Note: Drip irrigate to maintain even moisture until the tubers for main crop harvest are ~75% of desired size, then cut irrigation and let vines die. Potatoes will continue to size up.



(crop days 55–95) Check tuber size after flowering. Harvest new potatoes at 8–9 weeks after planting; creamers at 10–12 weeks.



(crop day 60) Spot weed large flowering weeds.



(crop day 116) Run overhead irrigation (0.25–0.5") prior to harvest of main crop to make harvest easier and avoid scuffing.



(crop days 120, 140) Harvest main potato crop.
(crop days 160) Pull drip lines.





(crop day 180) Disc plants, prepare soil for fall cover crop.

Drill cover crop seed prior to fall/winter rains.

***Numbers in parentheses refer to crop day, with crop day 0 = planting day, based on a typical season at the CASFS/ UC Santa Cruz Farm.**

See Appendix (page 12) for more on crop days and related activities.

**Some growers use a flame weeder at this stage, ideally just before potato leaf emergence, but even just after emergence, if necessary.

Production Practices — Additional Details

Soil type

Potatoes grow best on light textural soil classes: sands and silts with organic matter (O.M.) >3%. Potato tubers have a high respiration rate, and require ample oxygen in the soil. Lighter soils let in air that allow potatoes to breathe. Lighter soil textures also offer less physical resistance to tuber formation; thus the plant can put more caloric energy into forming large, cosmetically even tubers. Lighter, sandier soils also make harvest easier.

Heavier soils higher in clay content tend to provide better fertility and water holding capacity, but can cause tuber deformation, and make washing challenging. Although you cannot change the texture of soil, you can enhance its structure by increasing its organic matter content by adding compost and incorporating cover crops (green manures).

Fertility

Potatoes yield well when planted following incorporation of a mixed legume/cereal cover crop, e.g., bell bean (30–35%), peas (20–30%), vetch (30%), and triticale (10–15%). When incorporated well, the cover crop residue leaves the soil loose and friable, and microbial decomposition releases nutrients to provide adequate fertility (available nutrients).

If applying compost, use a rate of not more than 5 tons per acre (100 lb. N per acre) to avoid over-application of nitrogen (N). Excess nitrogen can:

- Make plants more susceptible to late blight *(Phytopthora infestans)*
- Delay tuber set and maturation
- Increase water content in tubers, which leads to a shorter storage life and more post-harvest physiological disorders

Bed spacing

Plant potatoes in a single line system to facilitate hilling. Depending on equipment available and standard bed spacing used on your farm, beds can be spaced from 30" up to 60" center to center. Hilling potatoes is more challenging with narrower beds; 4-gang Lilliston cultivators, disc hillers, or shovels are potential options with this spacing. Wider bed spacing means loss of yield potential. Consider the trade-offs between ease of hilling operations, efficiencies of land use, and labor required to adjust equipment. Take into account the other crops you grow, and choose the bed spacing that works best for your farming system as a whole.

Timing of planting

Spring is the best time to plant potatoes on California's Central Coast. Potato seed pieces can easily germinate in cool soils (less than 55°F). Plant following incorporation and initial breakdown of cover crop residue, typically in late April or early May. The goal is for the crop to develop prior to the onset of foggy conditions that favor late blight infestations in late summer (August). Staggered plantings are not recommended in areas where fog may be a factor. Some growers successfully plant in late July, growing a fresh market crop for fall holidays.

In inland valleys, potatoes are usually planted in February so that tuber maturation takes place prior to high summer temperatures that can delay tuber formation.

Preparing seed potatoes for planting

"Certified seed" sold for planting has been inspected and meets the tolerance for pest and disease disorder symptoms established by an agricultural certification program (e.g., White Rock Specialties seed is certified by the Colorado Board of Agriculture). This use of the word "certified seed" is complementary to, and distinct from the meaning of seed that is "certified organic." The National Organic Program (NOP) requires that organic growers purchase organic seed, unless the variety needed (or an equivalent variety) is not commercially available in an appropriate form, quantity, or quality.

To prepare seed for planting (also called "greening" or "chitting"), bring potatoes to room temperature (or warm up your cooler to 50–55°F) two to three weeks before planting to initiate sprouting. Expose to bright shade, but do not let them dry out while sprouting.

Seed potatoes that are large enough can be cut into smaller pieces to extend planting stock volume. Cut tubers into



FIGURE 1. Preparing seed pieces for planting. *Photo: Elizabeth Birnbaum*



FIGURE 2. Alabama shovels with "drop tubes" for placing seed pieces. *Photo: Martha Brown*



FIGURE 3. Plant potato seed into furrows created by furrowing or Alabama shovels. *Photo: Martha Brown*

1.5–3-ounce pieces (a little larger than a hen's egg) with at least two "eyes" on each cut piece (Figure 1). Cut through the center of the potato and allow the cut to heal over for 3 days prior to planting. Seed cut immediately before planting may experience decay in the ground, especially if soil is too dry or too warm at planting.

Planting technique

Because tubers form adjacent to and above the seed piece, place seed as deep as possible. Deep planting leaves room to "hill" the plant as the stems elongate (see below). However, plant no deeper than the depth of your harvester to reduce risk of slicing potatoes during harvest.

Create a depression down the middle of the planting bed—to the depth of the furrow if possible— using a small furrowing shovel or an "Alabama" shovel (Figure 2). Drop the seed pieces into this depression or trough (Figure 3) and cover with 3–4" of soil (enough to cover the seed pieces and keep them from drying out) by re-forming the bed using a rolling cultivator, reverse disc hillers, or shovels.

Hilling potatoes

Re-form the beds after planting deep, then again after the plants emerge, building the beds higher to keep potatoes covered with soil as the stems elongate (Figure 4). This re-forming of the bed, or "hilling," is essential for potato production because it blocks sunlight from the tubers as they form. Any light contact causes "greening"; the presence of chlorophyll and potential for accumulation of toxins (glycoalkaloids), render any green tuber unmarketable. Hilling also facilitates weed management and boosts yields.

Potatoes grow remarkably fast once they emerge (usually about 14 days after planting). Do the first mechanical hilling once plants reach a height of 8–10" (within 30–33 days after planting). Use a rolling cultivator during this time of initial growth to smother any weeds germinating in the bed, and to keep furrows clean of annual weeds. Work the furrows with shallow chisels to break tractor wheel compaction and deepen the furrows. Do the second hilling 5–7 days after the first (Figure 5). On small plots, hilling can be done by hand with a shovel.



FIGURE 4. Potatoes developing in a "hill." *Illustration: Laura Vollset*



FIGURE 5. Hilled potatoes at the UC Santa Cruz Farm.
Photo: Elizabeth Birnbaum

Irrigation

Drip irrigation is the best option for potatoes, allowing you to control irrigation rate and timing, and apply water directly to the growing plants. At planting, set the drip lines in the center of the bed on top of the seed pieces; cover it as you close the furrow and bury it further as you hill the potatoes (note that you can also lay drip tape after the plants have emerged). See the irrigation sequence at right.

Potatoes can be irrigated overhead, but this method favors development of late blight due to prolonged periods of leaf wetting. If overhead sprinklers are used, irrigate mid-day following dry-down of foliage from morning dew, and shut down the sprinklers early enough for leaves to dry prior to sunset.

IRRIGATION SEQUENCE

- Pre-irrigate with a minimum of 1–1.5" using overhead irrigation (if available) to bring up weeds and provide adequate deep soil moisture to support the early growth stage of the potato seed pieces. Cultivate before planting. (See *Tillage, Bed Formation, and Planting to Moisture* in this Grower Guide series for additional details.)
- Plant seed pieces into residual moisture.
- Lay drip line at time of planting or once plants have emerged.
- Initiate drip irrigation after plants have emerged and are well established (between 2 and 4 weeks after planting), and the first hilling has taken place. Depending on weather and soil conditions, pre-irrigation moisture deep in the soil may be adequate to support up to 3 or 4 weeks of growth.
- Schedule irrigations based on regional evapotranspiration (Et) data (available at cimis.water.ca.gov):
  - When plants are at 25% canopy (percentage of the bed's soil covered by crop foliage), irrigate at a rate roughly equal to 25% of the estimated daily Et.
  - Follow this percent canopy rule to determine irrigation rate; when plants are at 100% canopy, irrigation will match Et.
  - During the period of tuber enlargement (usually days 60–90), field capacity should not drop below 60–65%. Uneven irrigation in this phase leads to uneven tuber formation and jeopardizes marketability.
  - Water can be cut to "dry off" and cure crop once plants start to show signs of senescence (yellowing of leaves) and tubers have reached ~75% of marketable size. Wait another 10–14 days before harvest for skins to cure.
  - Apply .25–.5" of water prior to harvesting the main crop to make harvest easier, and to avoid scuffing spuds, which can compromise salability and storage life.

GROWTH PHASES

Phase 1: Vegetative establishment, 0–30 days

Most vegetative growth occurs during this phase. Adequate pre-plant nitrogen (in the nitrite form) ensures a large, effective plant that can support tuber development through sugar and starch translocation.

Phase 2: Stolen and tuber initiation, 30–60 days

Flowering begins at approximately 40–50 days (Figure 6). Dig "new" potatoes during this phase (see sidebar, page 9).

Phase 3: Tuber enlargement, 60–90 days

It is critical to provide adequate irrigation during this phase. Dry down should be less pronounced than in phases 1 and 2; never let the plants get to less than 60–65% field capacity. Dig "creamer" potatoes during this phase (see sidebar, page 10).

Phase 4: Tuber enlargement, skin set and curing, 90–120 days

Tubers enlarge, increase in starch content and individual varietal characteristics. Skins set and thicken, allowing for long-term storage.



FIGURE 6. Potatoes begin to flower at approximately 40–50 days post planting. *Photo: Elizabeth Birnbaum*



Harvest and harvesting equipment

"New" potatoes (see next page) must be harvested by hand. Push a garden fork under the cluster of potatoes and gently lift the plant by the leaves as you push down on the fork handle to raise the tubers to the surface (Figures 7 and 8). New potatoes are extremely delicate; handle very gently to avoid damaging the skin.

When harvesting mature tubers by hand, the process is the same. Take extra care not to "fork" through the potatoes, but get under the tubers.

Use a dedicated potato harvester or an under-cutter pulled behind a tractor for mechanized harvest. For potato production areas much larger than one-quarter acre, it is best to harvest mature tubers with a dedicated potato harvester, such as a single-row PTO- operated digger with an undercutter bar and shaker cage. The harvester lifts the spuds and leaves them on the soil surface to pick up (Figures 9 and 10). Break the furrow tire compaction with chisels before harvest to ensure that the under-cutter or harvester can get below the lowest tuber and work effectively.



FIGURE 7. Harvest new potatoes using a garden fork. *Photo: Elizabeth Birnbaum*



FIGURE 8. Handle new potatoes gently to avoid damaging the fragile skins. *Photo: Elizabeth Birnbaum*

"NEW" POTATOES AND "CREAMERS"

Both new potatoes and creamers offer good niche marketing possibilities, including CSA projects, farmers' markets, roadside stands, and restaurants.

NEW POTATOES are simply young, small, freshly-dug potatoes. They must be marketed quickly (within a few days of harvest) and will last only 7–10 days (refrigerated).

The possibility of digging 100–200 pounds per day for 2–3 weeks offers early season income and a premium price. Also, if well done, new potatoes can create a loyal following of customers and improve your "brand."

In theory, any variety can be used for new potatoes, but those described as early season (maturing in <90–100 days) work best, as they tend to set ample tubers early, and size up evenly.

Suggested varieties include–

'Red Gold'

'Early Red Norland' (distinct from 'Dark Red Norland', which is a high-yielding, mid-season variety)

'Mountain Rose'

Planting seed of the above varieties are easy to source. They are all spectacularly early and high yielding, producing 2.5–3 pounds/plant at 60+ days from planting.

The following also offer a reasonable ratio of pounds per plant to days in the ground (most are red varieties)–

'Anoka' (very early, difficult to source)
'Caribe'
'Cherry Red'
'Desiree'
'Early Purple'
'Kerr's Pink'
'Purple Viking'
'Red LaSoda'
'Rose Gold'
'Yukon Gold'

Tips for Growing New Potatoes

- Use small, whole seed potatoes (1–2 ounces)
- Plant seed 8–9" apart, using standard row spacing
- Plant 2–4" deep in 6–8" deep trenches
- Hill plants at 20–30 days from emergence
- Dig when size of 6–10 tubers reaches 2–8 ounces, usually 60–75 days post planting
- Dig when soil is dry; box and let sit 1–2 days, then wash and pack
- Note that some nicked skins are inevitable with new potatoes. It identifies them as truly new and freshly dug.

CREAMER POTATOES offer another niche market that can generate some early season income due to high demand and relatively low supply.

Creamer potatoes are similar to new potatoes in that they are small (2–4" in diameter, 2–4 ounces). They may be dug early or at full maturation. The main distinction is that they have thicker skins and are thus easier to dig and pack than new potatoes, and rival storage potatoes in their shelf life.

Although not as moist, light, and sweet as new potatoes, they do have an intense, earthy taste and texture that makes them more distinctive than full-size storage potatoes, and offer more nutritional value than new potatoes.

Creamer potatoes show themselves off both on display and on the plate. They can be displayed for loose pack in small net bags by mixing varieties, shapes, sizes, and colors.

As with new potatoes, choose early varieties with plants that mature at <90–100 days. In addition to those listed for new potatoes, preferred varieties include:

'Austrian Crescent' (fingerling)

'Early Ohio'

'Viking Purple'

Fingerling varieties (2–3" long) can also be adapted for this format.

Tips for Growing Creamer Potatoes

- Use close in-row spacing when planting (5–6")
- Grow for 10–12 weeks
- Kill vines (mechanically)
- Dry off (no irrigation) 7–10 days before harvest to set skin
- Hand dig, box, and refrigerate
- Wash only when needed for packing and distribution



FIGURE 9. Example of a PTO-driven harvester with "shaker cage." *Photo: Martha Brown*



FIGURE 10. Shaker cage deposits harvested potatoes on the soil surface. *Photo: Martha Brown*

Post-harvest handling

Tubers going direct to market are usually washed immediately after harvest, especially if the soil is prone to sticking. Tubers harvested for storage should not be washed, as water can spread disease (especially fungal spores that cause late blight), and increase potential for higher incidence of infection while in storage.

Crop rotation

Because potatoes are host to many of the same diseases commonly found on other Solanaceae family crops (tomatoes, peppers, etc.), as well as strawberries, rotate ground out of solanums and strawberries for a minimum of 4 years.

Late blight *(Phytophthora infestans)* is the primary disease of potatoes in the Central Coast region. Because the fungal spores that cause late blight move easily with water and wind, it is best to keep a significant buffer between blocks of potatoes and tomatoes since the blight will most often start on the foliage of potatoes (early season) and spread to tomatoes.

Pests and Diseases

Before you select varieties and plant your potato crop, look up common pests and diseases that affect the crop in your area. Learn about pest and disease life cycles, preventive practices, and possible treatments using resources such as the UC IPM website (ucipm.edu), your county Cooperative Extension offices, ATTRA's Biorationals: Ecological Pest Management Database (www.ncat.org/attra-pub/biorationals), neighboring farmers, and other knowledgeable professionals.

The main potato arthropod pests in the Central Coast region are:

- Tuber moth. *Phthorimaea operculella:* larvae cause economic damage when they tunnel into potato tubers, both in the field and in storage.
- Aphids and viruses—Green peach aphid, *Myzus persicae* and Potato aphid, *Macrosiphum euphorbiae:* aphids act as vectors that transmit Potato Leaf Roll Virus (PLRV), cucumber mosaic and alfalfa mosaic (calico) viruses.
- Cucumber beetle: Western spotted cucumber beetle, *Diabrotica undecimpunctata undecimpunctata,* and Western striped cucumber beetle, *Acalymma trivittatum:* damage foliage.
- Tuber Flea Beetles, *Epitrix tuberis*: beetle larvae feed on tubers.
- Wireworms. Common local species of wireworms include: Pacific coast wireworm, *Limonius canus.* Sugarbeet wireworm, *Limonius californicus.* Dryland wireworm, *Ctenicera pruinina:* wireworms are click beetle larvae that live in the soil. They cause economic damage by eating potato seed pieces or roots of young plants, or burrowing into developing tubers.

The main potato diseases in the Central Coast region are:

- Late Blight, *Phytophthora infestans:* late blight develops rapidly, and can defoliate a crop within a few weeks.
- Verticillium Wilt, *Verticillium dahliae*: this wilt appears as yellowing (chlorosis) and death (necrosis) of lower leaves; it interferes with the plant water transport (vascular) system, so the impact becomes visible quickly in hot weather.
- Scab, *Streptomyces* spp.: causes potato tubers to be unmarketable.

See *Organic Pest and Disease Management in Selected Crops on California's Central Coast* in this **Grower Guide** series for additional information on the pests and diseases listed here, and suggestions for their control in potatoes.

ADDITIONAL RESOURCES

Introduction to weed management in a small scale organic production system (video). Produced by the Center for Agroecology & Sustainable Food Systems. www.youtube.com/user/casfsvideo

Knock weeds out at critical times, by Mark Schonbeck. eOrganic, 2010. articles.extension.org/pages/18882/knock-weeds-out-at-critical-times

Ospud participatory organic potato project, Oregon State University. horticulture.oregonstate.edu/content/publications-and-presentations-ospud-project

Pest management strategic plan for organic potato production in the west. Summary of workshops held on February 16, 2006, Buhl, Idaho and January 9, 2008, Portland, Oregon. Jennifer Miller, Ronda Hirnyck, Lisa Downey-Blecker. Issue Date, December 19, 2008. www.ipmcenters.org/pmsp/pdf/CA-CO-ID-OR-WAOrganicPotatoPMSP.pdf

Potatoes: Organic production and marketing, by Rex Dufour, Tammy Hinman, and Jeff Schahczenski. NCAT IP337, 2009. attra.ncat.org/attra-pub/summaries/summary.php?pub=96

Selecting, cutting and handling potato seed, Bulletin #2412, 2015, by Steven B. Johnson, Ph.D., Extension crops specialist, University of Maine Cooperative Extension extension.umaine.edu/publications/2412e/

Organic Potato Production on the California's Central Coast: A Guide for Beginning Specialty Crop Growers by Jim Leap, Darryl Wong, Orin Martin, and Kirstin Yogg-Comerchero, with contributions from Ann Baier and Doug O'Brien. Edited by and Martha Brown and Ann Baier.

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Photos, p. 1: Left, Martha Brown; top right, Elizaeth Birnbaum, bottom right, CASFS; p. 2: Elizabeth Birnbaum. Icon illustrations, p. 3, Laura Vollset.

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APPENDIX: PRODUCTION SCHEDULE, ECONOMIC DATA

Crop day	Sub Crop/Variety	# beds (1 bed = .02ac)	Action	work rate (hr/ac)	fixed rate (hrs)	Total labor cost @ $16.10/hr	Total machine cost @ $21.70/hr	Harvest Amt. (#)	Unit Price ($/#)	Harvest Value ($)
-25		20	Flail Mow:heavy	2.5	0.2		$26.04			
-25		20	Spade	4.8	0.2		$46.00			
-21		20	Begin Chitting		0.5	$8.05				
-11		20	Mark Lines	2	0.2		$21.70			
-11		20	List	1.25	0.2		$15.19			
-11		20	Overhead Irr:set up	3.75		$24.15				
-10		20	Overhead Irr:run		0.5	$8.05				
-3		20	Cut Potatoes	24.2		$155.85				
-3		20	Overhead Irr:break down	3.75		$24.15				
-1		20	Light cultivation	1.25	0.2		$15.19			
0		20	Plant:driver	4.84	0.4		$50.69			
0		20	Plant:planters	9.68		$62.34				
11		20	Cultivate	2	0.2		$21.70			
11		20	Drip:set up	10	0.25	$68.43				
30		20	Hill	1.25	0.2					
30		20	Drip:run x 2/wk; @ 9 wks		2.7	$43.47				
40		20	Hill	1.25	0.2					
60		20	Hand Weed:spot weed	2		$12.88				
80	Yukon Gold, Red Gold	10	Flail Mow:light	1.25	0.2		$9.77			
94	Desiree, Austrian Crescent	10	Flail Mow:light			-				
115		20	Overhead Irr:set up	3.75						
116		20	Overhead Irr:run		0.5					
100	Red Gold	5	Harvest	83	1	$149.73	$39.06	1,800	$2.0	$3,600
120	Yukon Gold	5	Harvest	83	1	$149.73	$39.06	2,900	$1.5	$4,350
120	Desiree	5	Harvest	83	1	$149.73	$39.06	2,200	$1.5	$3,300
140	Austrian Crescent	5	Harvest	83	1	$149.73	$39.06	2,900	$2.0	$5,800
160		20	Drip:break down	2		$12.88				
180		10	Disc:x1	0.5	0.2		$6.51			
-		10	Drill/Cover Crop	1.6	0.2		$11.28			
					Sub-total:	***$1,019.16***	***$369.03***			

Harvest Assumptions	
Harvest (#/acre)	
Red Gold	18,000
Yukon Gold	29,000
Desire	22,000
Austrian Crescent	29,000
Harvest (row'/hr)	180
Harvest Rate (hr/ac)	80
Price ($/#)	1.5-2

Labor + Machine Cost ($)	
Per Block (.4 Acres):	***$1,388.19***
Per Acre:	***$3,470.48***

Yield		
Per Block (.4 Acres):	***9,800***	***$17,050***
Per Acre:	***24,500***	***$42,625***

Input Costs			
Item	***Cost per unit***	***Cost per acre***	***Notes***
Seed - Non-Fingerling	$.45/#	$816.75	.125#/row'; 1 row/bed; 14520 row'/ac; 1815#/ac;
Seed - Fingerling	$1.30/#	$2,359.50	.125#/row'; 1 row/bed; 14520 row'/ac; 1815#/ac;
Drip Tape	$120/7500'	$232.32	1 row/bed; 14520 row'/ac; $.016/row'
Bags	$.19043/bag	$186.62	25#/bag; 24500#/ac
Total Expenses (per acre):		***$3,595.19***	

Per Acre Totals	
Income:	$42,625.00
Labor + Machine Cost ($):	-$3,470.48
Expenses:	-$3,595.19
Production Profit:	**$35,559.33**

Complete irrigation schedule available online at casfs.ucsc.edu/about/publications/growerguides. Data reflect direct field production costs and do not include other potential overhead (e.g., water, electricity, land rent).

ORGANIC PEPPER PRODUCTION ON CALIFORNIA'S CENTRAL COAST:
A Guide for Beginning Specialty Crop Growers







Introduction

Peppers are an excellent addition to most small-scale, organic mixed cropping systems that focus on local sales. Peppers are highly productive, and will reliably produce fruit from July through October without season extension technologies (such as hoop houses). They are relatively easy to grow and harvest, and provide multiple marketing and culinary options. Peppers can be harvested green or left on the plant to develop color. They offer many possibilities for adding value through processing or drying. Flavor options range from sweet to very hot. A variety of colors, shapes, and sizes allows for striking presentations at farmers' markets and in Community Supported Agriculture (CSA) boxes.

This grower guide addresses the basic production steps in growing peppers organically in California's Central Coast region and provides a varieties' overview for those interested in adding peppers to their specialty crops.

Features of pepper production

- Peppers grow well in most Central Coast locations
- Relatively pest- and disease-free
- Easy and fast to harvest
- Do not bruise or crack easily
- Provide continuous harvest over a long period
- Highly sought after by chefs, retailers, wholesalers, and home cooks
- Highly adaptable from fresh market to processing
- Season can be extended using high tunnels

PRODUCTION PRACTICES — SUMMARY

Climate

- Warm season crop.
- Perform best when daytime temperatures don't exceed 90° F; higher temperatures limit pollination and increase potential for sunburn of fruit.

Soil type

- Grow well on soil types from sandy loams to heavier clay soils.
- Perform best on heavier soils with CEC (cation exchange capacity) ratings greater than 12.
- May require supplemental fertility throughout the growing season on lighter-textured soils.
- Require good drainage to minimize soil borne fungal diseases.

Fertility requirements

- Peppers require relatively high fertility.
- Incorporate legume/cereal cover crop and 5–7 tons/acre of compost before planting.
- Peppers may require supplemental fertility to maintain growth and good fruit production (see page 6).

In the greenhouse

- Buy fresh seed every year.
- Start plants in greenhouse early to mid February, 8–10 weeks before transplanting.
- Use heat mats under seed flats to promote seed germination.

Soil temperature

- Transplant when the threat of frost is past, and soil temperatures are greater than 60° F at planting depth (6") for 5–7 days.
- The best window for transplanting on the Central Coast is mid April through May.

Plants per acre

- 12,000–14,000, varies depending on spacing and growth habit.

Planting technique

- Transplant starts by hand, or with a mechanical transplanter for blocks larger than 0.25 acres.

Bed spacing

- Plant peppers in a single line on beds spaced 36" center to center; single line planting facilitates cultivation.
- Plant in double lines on beds spaced 40–60" center to center (standard spacing in most production systems). Double lines may help shade fruit and protect against "sunburn."

Plant spacing

- 1–2' between plants, depending on row spacing and growth habit of the variety.
- Total plant populations of 12,000–14,000 plants per acre, vary depending on spacing and growth habit.

Planting depth

- Place transplants as deep as possible into pre-irrigated beds that have adequately dried down while keeping all foliage above ground.

Irrigation

- Drip tape facilitates uniform water application, saves on water costs, and minimizes both weed and disease pressure.
- Avoid excessive soil moisture to prevent *Phytopthera* spp. (root rot).

Days to maturity

- Depends on varieties and weather conditions—most peppers are ready to harvest approximately 90 days after transplanting.

Harvest tips

- For small-scale production (blocks < 1 acre), harvest into 5-gallon buckets; walk buckets to the edge of the field for sorting/packing.
- Cull in the field: pick and discard fruit that is sunburned, insect damaged, or has had soil contact that will cause rotting.

Post-harvest handling

- Easy post-harvest handling: light to carry, do not bruise easily, and do not require washing.
- Store well in cooler for 7–10 days.

Crop rotation

- Rotate peppers from other solanums and strawberries every four years, if possible, to minimize buildup of soil-borne fungal disease pathogens.



PRODUCTION SEQUENCE — SUMMARY

(crop day -25*) In spring, mow cover crop to facilitate breakdown.



(crop day -25) Incorporate cover crop residue.



(crop day -11) Form beds with rolling cultivator or listing shovels.



(crop day -10) Pre-irrigate beds with overhead irrigation (1–1.5"). Wait for dry down and weed emergence.



(crop day -1) Work bed surface lightly with cultivator to terminate weeds.



(crop day -1) Shape beds using rolling cultivator or rototiller/shaper combination. Mark planting rows.



(crop day 0) Plant transplants.



(crop days 0, 1, 4, 7) Irrigate (overhead) to water in and establish transplants.



(crop day 11) Cultivate for weed management (sweeps, knives).



(crop day 11) Hoe out small weeds on bed tops. Lay drip lines.



(crop day 12) Initiate drip irrigation; run drip irrigation weekly.



(crop days 35, 65) Hand weed large weeds as needed or cultivate with furrow chisels and sweeps.

Apply supplemental fertility as needed through drip lines.



(crop day 120) Initiate harvest; harvest weekly July through October.



(crop day 175) Remove drip lines from the field. Mow following last harvest. Prepare ground for cover crop planting.



Drill cover crop seed prior to fall/winter rains.



***Numbers in parentheses refer to crop day, with crop day 0 = planting day, based on a typical season at the CASFS/ UC Santa Cruz Farm.**

See Appendix (page 8) for more on crop days and related activities.

Production Practices — Additional Details

Initial fertility

Because pepper plants have a long season—they may be in the ground for up to 8 months with a production window up to 4 months, or longer if season extension is used—they have a relatively high fertility requirement compared to many other crops.

Adequate early season fertility is critical to help plants develop a strong scaffold to hold fruit, and adequate foliar coverage (enough leaves) to protect fruit from sunburn. On heavier soils (CEC ratings greater than 12), fertility requirements of peppers through the season may be met by incorporation of a legume/cereal cover crop, and 5–7 tons per acre of high quality compost prior to planting.

Timing

Plant as early in the spring as is reasonable based on the estimated date of last frost and soil temperatures. Peppers continue to produce fruit as long as temperatures allow for pollination (< 90° F), and fertility and moisture are adequate. Harvest weekly from first fruit (July) through late fall. Because a single planting has a long harvest season, there is no need to stagger plantings.

HIGH TUNNELS FOR SEASON EXTENSION

Commercial pepper producers in the Hollister area (San Benito County) have increased yields and extended harvest of peppers using high tunnels. The temperatures in the tunnels significantly extend the season and allow peppers to develop their full color (red, yellow, "chocolate," etc.). These fully mature peppers typically sell for a premium in the specialty and wholesale markets.

Planting

In a hand-transplanted, single-line system, form a trench approximately 4" deep down the middle of each bed using a small shovel or bed shaper, and transplant into the trench). This shallow trench will improve soil water retention at time of planting, will allow for easy placement of the drip line, and will greatly facilitate weed suppression.

Plant transplants that are tall, with a well-established root system, and well hardened off (Figure 1). Soak the nursery trays prior to planting to ensure good moisture at time of transplant. Plant as deep as possible (keeping foliage above ground) to ensure good root contact with moist soil and encourage adventitious rooting (roots that sprout from the buried stem); Figure 2.



FIGURE 1. Use tall transplants with well-developed root systems. *Photo: Elizabeth Birnbaum*



FIGURE 2. Deep planting ensures good root contact with moist soil and encourages adventitious rooting. *Photo: Elizabeth Birnbaum*

Irrigation

Irrigate (overhead or drip) as soon as possible after transplanting to ensure good initial growth and minimize transplant stress. Keep plants moist until deeper roots are established (~10 days; Figure 3). Assuming there is deep soil moisture from winter rains or pre-irrigation, initial irrigations can be light (2–3" in first 2 weeks). If using overhead for initial irrigations, switch to drip lines after 2 weeks.

Once the plants have extended roots below the root ball, decrease irrigation frequency until the canopy is established. As the weather warms up, irrigate weekly on heavier soils, and 2–3 times a week on lighter soils.

Calculate irrigation amounts based on estimated evapotranspiration (Et) losses using local CIMIS station data (cimis.water.ca.gov) or other source. During the initial growth stages, multiply estimated Et losses by percent canopy. For



FIGURE 3. Initial overhead irrigation on pepper transplants helps establish plants. *Photo: Elizabeth Birnbaum*

example, when the canopy is at 25%, replace 25% of the daily estimated Et loss. Increase proportionally until the plant is in full canopy and irrigation amounts equal the estimated Et loss as reported by CIMIS. Avoid overwatering to minimize both weed pressure and nutrient leaching.

Weed control

Good weed management in peppers begins with careful field selection. Avoid weed pressure from grasses and perennial weeds, since these are both difficult and expensive to manage once the peppers are established. This is critical to organic pepper production, because the peppers will be in the ground for up to 8 months.

Use pre-irrigation whenever practical; it can save significant weeding costs and ensure deep moisture to facilitate good initial crop growth and establishment. Form beds, then overhead water with 1–1.5" of water. Following weed flush, rework beds with a rolling cultivator or other suitable cultivation tool to destroy newly germinated weeds prior to planting. See the publication *Tillage, Bed Formation, and Planting to Moisture* in this **Grower Guide** series for additional details.

Once plants are established, move the soil toward the plant using a rolling cultivator. This "dirting" pass will fill in the planting trench, smother newly emerged weeds within the plant line, brace the plants, and cover the drip line. However in milder climates where peppers do not grow tall before fruiting, dirting or hilling must be done minimally, if at all, in order to prevent fruit set on the hilled soil that can lead to rot.

During the early stages of crop growth weeds can be easily managed between planted lines using standard row crop cultivation equipment including sweeps, side knives, and small chisels in the furrows to break wheel compaction.

When planting double lines per bed, you may need to hand weed between plants, since it is much more difficult to manipulate soil to bury weeds within the plant line.

Assuming there are no problem perennial weeds in the field, and irrigations are well-timed and not over-applied, the field should remain relatively weed free for the duration of the crop cycle. Hand pull any escaped weeds during harvest and irrigation operations.



Peppers at the Everett Family Farm's farmstand, Soquel, California.

VARIETAL OVERVIEW

Select "trendy" varieties for direct sales. Consumers are especially attracted to large and "mini" fruit. Spicy peppers high on the Scoville scale (spicy heat index; see en.wikipedia.org/wiki/Scoville_scale) are not big sellers at farmers' markets. Plant hot peppers in small quantities, if at all, unless you have a known sales outlet.

Popular, attractive pepper types:

LARGER BELLS

Lamuyo (elongated bells) source: Reimer Seeds

Reina
Gemini
Mama Mia Giallo
Lido Lamuyo

Bullhorn varieties

FULL SIZE

Corno Di Toro
Carmen (red)
Escomillo (yellow)

MINIS

Cornito Rosso (red)
Cornito Giallo (yellow)

Blocky Bells

Flamingo (orange/red)
Gourmet (yellow/early)
Double up (red)
Admiral (yellow)
Quadrato D'Asti Giallo/Rosso
Aristotle (red)

New Mexico pod types (red or green) a.k.a. Anaheim, Hatch, etc.

Anaheim (late)
Joe E. Parker (heirloom)
Highlander (big, high yield)

Minis: pimientos, lunch box, snack types: Johnny's seeds lunch box varieties

Eros
Cupid

Ethnic frying types

Jimmy Nardello
Cubanelle/Biscayne
Padron
Shishito
Banana types (sweet and hot)

Note that both padron and shishito peppers are good "niche" peppers that have become important income generators on small farms.

Other small-fruited varieties

Pimiento types (Round of Hungary)

Aura, Lipstick, Glow (4–5" top shape, early, sweet)

These varieties are as sweet or sweeter than bell peppers, easier to grow, and much earlier.

Anchos/Poblanos

Tiburon (biggest, best variety)

Jalapenos

El Jefe and Jalafuego (biggest, best taste)

Supplemental fertility

Apply supplemental fertility to peppers grown on lighter-textured soils with low CEC (<12) to maintain good leaf growth (essential for minimizing sunburn) and adequate production through the last few months of the production cycle. Check soil nitrate levels following initial crown set to assess the need for additional fertility; N>20–25 ppm is required to support ongoing fruit set.

Although expensive (approximately $7/lb of N), organic liquid formulations (4-2-0 or 4-0-0) applied directly through the drip lines via injection into the irrigation header may be the most viable option for post-plant amendment application.

Alternately, you can "band" dry, granulated or pelleted formulations of N-based animal waste products into the soil close to the plants for root uptake. However, it is more effective to incorporate fertilizer ahead of planting.

Staking

Some growers support pepper plantings by placing stakes along the outside of the rows and running a single string line from stake to stake. This helps keep the plants upright and minimizes broken branches from both wind and heavy fruit set. The stakes are typically only as high as the pepper plant (+/- 2').



FIGURE 4. Gently move foliage aside to find ripe peppers for harvest. *Photo: Jim Clark.*

Harvest

Harvest is systematic—it requires tracking where harvest has occurred to maximize efficiency and minimize loss. Inspect each plant for mature fruit by gently moving branches and leaves to reveal hidden peppers (Figure 4). Remove peppers by hand and place them in a 5-gallon bucket while moving down the row.

To harvest a pepper, pull fruit gently from the stem end of the pepper, taking care not to break either the stem or the branch holding the fruit. Many varieties can be harvested with a single hand by placing the thumb near the zone of abscission (the point where the stem attaches to the branch) while gently pulling at an angle to separate the fruit from the branch (Figure 5). This takes practice! Some varieties require two hands and significant care to harvest successfully.

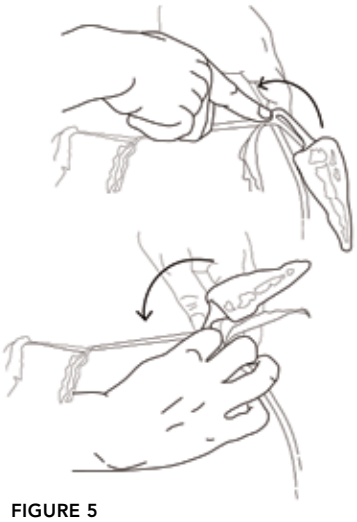

FIGURE 5

During the harvest, remove any unmarketable fruit (e.g., misshapen, insect-damaged, sunburned, rotten) from the plant and leave it in the field. This maximizes future harvest efficiency. Early fruit often sets between branches where it will become deformed as it grows; such fruit should be removed and discarded. Most fruit that contacts the soil will develop a rot spot at the point of contact; this too, must be discarded.

Harvesting small-fruited varieties (e.g., padrons) requires significant labor, not only because of their size, but because they are harvested at a relatively immature stage for optimum market quality, and thus must be harvested more frequently than larger varieties. Leaves easily camouflage the dark green 'Padron' variety, requiring significant "searching" to harvest them properly.

Other varieties can be harvested when fully sized and still green; most can also be left on the plant to mature and color up. Colored peppers (orange, red, yellow, brown) sell for a premium price. However, because of the additional time needed to reach full maturity, there is significant risk in getting a marketable fruit at the fully mature and colored stage, since this growth stage is much more prone to sunburn and insect feeding.

Post-harvest handling, storage

Weigh and pack harvested peppers into crates or boxes (no washing necessary, Figure 6). Peppers will store well in the cooler for 7–10 days if not marketed immediately.





FIGURE 6. Bell peppers harvested for UCSC Dining, UCSC Farm. *Photo: Martha Brown*

Post-harvest field care

Following the final harvest, pull the drip lines, mow the plants, and disc the field in preparation for a subsequent crop or cover crop. Pepper plants are easily chopped up by the mower, producing minimal biomass and a clean seed bed for cover crops. A single pass with a disc is more than adequate.

Crop rotation

Rotate peppers from other solanums and strawberries every four years, if possible, to minimize buildup of soil-borne fungal disease pathogens. Plant peppers into production blocks that are free of perennial weeds and grasses, are relatively high in fertility, and have good soil tilth and drainage—in other words, plant peppers in your best ground, whenever possible.

Pests and Diseases

Before you select varieties and plant your pepper crop, look up common pests and diseases that affect the crop in your area. Learn about pest and disease life cycles, prevention practices, and possible treatments using resources such as the UC IPM website (ucipm.edu), your county Cooperative Extension offices, ATTRA's Biorationals: Ecological Pest Management Database (www.ncat.org/attra-pub/biorationals), neighboring farmers, and other knowledgeable professionals.

The main pepper arthropod pests in the Central Coast region are:

- Thrips. Western flower thrips, *Frankliniella occidentalis*. Onion thrips, *Thrips tabaci*. Chili thrips, *Scirtothrips dorsalis* and other species: can be vectors of Tomato Spotted Wilt Virus (TSWV; see below).
- Aphids: Green peach aphid, *Myzus persicae*: feed on plant juices and can transmit viruses; exude honeydew that can coat fruit and be difficult to remove.
- Cucumber beetle: Western spotted cucumber beetle, *Diabrotica undecimpunctata undecimpunctata*. Western striped cucumber beetle, *Acalymma trivittatum*: feed on foliage and fruit calyxes.

The main pepper diseases in the Central Coast region are:

- Powdery mildew caused by *Leveillula taurica* (*Oidiopsis taurica*): infected leaves curl up and leave fruit vulnerable to sunburn.
- Tomato spotted wilt virus (TSWV) in the tospovirus group: symptoms vary with the stage of growth infected, the cultivar, other viruses, and environmental conditions, but typically include spotting, bronzing, dying leaves, and ringspots on fruit. Affected fruit is not marketable.

Please see *Organic Pest and Disease Management in Selected Crops on California's Central Coast* in this **Grower Guide** series for information on the pests and diseases listed here, and suggestions for their control.

ADDITIONAL RESOURCES

ATTRA question of the week: What do I need to know about organic sweet pepper production and where can I get the information? attra.ncat.org/calendar/question.php/what_do_i_need_to_know_about_organic_swe

Introduction to weed management in a small-scale organic production system (video). Produced by the Center for Agroecology & Sustainable Food Systems. www.youtube.com/user/casfsvideo

Knock weeds out at critical times, by Mark Schonbeck. eOrganic, 2010. articles.extension.org/pages/18882/knock-weeds-out-at-critical-times

Resource guide to organic and sustainable vegetable production, by Steve Diver et al. ATTRA 2001; updated 2012. NCAT IP188. attra.ncat.org/attra-pub/summaries/summary.php?pub=19

UC IPM pest management guidelines: Peppers. University of California, DANR Publication 3339. ipm.ucanr.edu/PMG/selectnewpest.peppers.html

Organic Pepper Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers by Jim Leap, Orin Martin, Darryl Wong, and Kirstin Yogg-Comerchero, with contributions from Ann Baier and Doug O'Brien. Edited by Martha Brown and Ann Baier.

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This publication was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

Photo, p. 1, left: Elizabeth Birnbaum. Illustrations, pp. 3 and 6, Laura Vollset.

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APPENDIX: PRODUCTION SCHEDULE, ECONOMIC DATA

Crop day	# beds (1 bed = .02ac)	Action	work rate (hr/ac)	fixed rate (hrs)	Total labor cost @ $16.10/hr	Total machine cost @ $21.70/hr	Harvest Week	% total harvest	Harvest Amt.	Harvest Value
-25	10	Flail Mow:heavy	2.50	0.2		$15.19				
-25	10	Spade	4.80	0.2		$25.17				
-11	10	Mark Lines	2.00	0.2		$13.02				
-11	10	List	1.25	0.2		$9.77				
-11	10	Overhead Irr:set up	3.75		$12.08					
-10	10	Overhead Irr:run		0.5	$8.05					
-1	10	Light cultivation	1.25	0.2		$9.77				
-1	10	Shape	2.00	0.2		$13.02				
0	10	Transplant:1 line	58.00	0.5	$194.81					
0	10	Overhead Irr:run		0.5	$8.05					
1	10	Overhead Irr:run		0.5	$8.05					
4	10	Overhead Irr:run		0.5	$8.05					
7	10	Overhead Irr:run		0.5	$8.05					
11	10	Overhead Irr:break down	3.75		$12.08					
11	10	Cultivate	2.00	0.2		$13.02				
11	10	Drip:set up	10.00	0.25	$36.23					
11	10	Hoe:1 line	36.00		$115.92					
12-169	10	Drip:run x 2/wk @ 22 weeks		0.3	$106.26					
35	10	Hand Weed:big weeds	8.00	0.2	$28.98					
65	10	Hand Weed:big weeds	8.00	0.2	$28.98					
120	10	Harvest x 2	532.40		$171.43		1	10%	799	$1,197.90
127	10	Harvest x 2	532.40		$171.43		2	10%	799	$1,197.90
134	10	Harvest x 2	532.40		$171.43		3	10%	799	$1,197.90
141	10	Harvest x 2	532.40		$257.15		4	15%	1,198	$1,796.85
148	10	Harvest x 2	532.40		$257.15		5	15%	1,198	$1,796.85
155	10	Harvest x 2	532.40		$342.87		6	20%	1,597	$2,395.80
162	10	Harvest x 2	532.40		$171.43		7	10%	799	$1,197.90
169	10	Harvest x 2	532.40		$171.43		8	10%	799	$1,197.90
175	10	Flail Mow:light	1.25	0.2		$9.77				
-	10	Drill/Cover Crop	1.60	0.2		$11.28				
				Sub-total:	$2,289.90	$120.00				

Labor + Machine Cost ($)	
Per Block (.2 Acres):	***$2,409.90***
Per Acre:	***$12,049.52***

Yield		
Per Block (.2 Acres):	**7,986**	***$11,979.00***
Per Acre:	**39,930**	***$59,895.00***

Harvest Assumptions	
Harvest (#/acre)	39,930
Harvest (#/row')	2.75
Harvest Rate (#/hr)	75
Harvest (hr/ac)	532.4
Price ($/#)	1.5

Item	*Cost per unit*	*Cost per acre*	*Notes*
Starts	$.025/plant	$363.00	1 row/bed; 14520 row'/ac; 1' spacing
Drip Tape	$120/7500'	$232.32	1 row/bed; 14520 row'/ac; $.016/row'
Boxes	$2.067/bx	$4,878.12	20#/box; 47190#/ac; 2360 box/ac
Total Expenses (per acre):		***$5,473.44***	

Per Acre Totals	
Income:	$59,895.00
Labor + Machine Cost ($)	-$12,049.52
Expenses	-$5,473.44
Production Profit:	**$42,372.04**

Complete irrigation schedule available online at casfs.ucsc.edu/about/publications/growerguides. Data reflect direct field production costs and do not include other potential overhead (e.g., water, electricity, land rent).

ORGANIC WINTER SQUASH PRODUCTION ON CALIFORNIA'S CENTRAL COAST:
A Guide for Beginning Specialty Crop Growers





Introduction

Winter squash production can be done with low capital investment and simple infrastructure. Squash has low seed cost, modest fertility needs, and relatively little labor requirements during the growing season. The broad leaf canopy minimizes weed pressure, and many varieties are fairly resistant to pests and diseases. "Winter" or "hard" squash is grown in the warm season and can be stored for some months (through the winter). Unlike "summer" squash (zucchini and other "soft" squashes) that must be harvested daily and stored in a cooler, winter squash has a flexible window of harvest and sale (with proper dry storage). These characteristics make winter squash a viable crop for beginning specialty crop growers.

Growing a mix of varieties provides an assortment of colors, textures, and flavors to diversify marketing opportunities or add variety to a Community Supported Agriculture (CSA) program.

Depending on markets, varieties, and yields, winter squash can provide excellent cash returns. Adequate dry storage allows sales to be spread over a period of two to four months for best price.

This guide addresses the steps involved in growing winter squash organically on the Central Coast of California, with a focus on planting to moisture to minimize weed pressure.

Features of winter squash production

- Winter squash grows well in cooler coastal areas as well as the warmer inland valley locations (it has few climatic limitations in the Central Coast region)
- Requires little labor throughout the growing season
- Stores well with minimal infrastructure (dry storage only; no cooler needed), which is useful for extending direct sales/CSA season
- Resists or tolerates pests and diseases
- Grows well in most soil types and requires only moderate soil fertility levels
- Produces reasonable yields with relatively little irrigation; can be dry farmed in the right climate and soil type (see Dry-Farmed Tomato Grower Guide)
- Provides for excellent crop rotation to improve soil quality and decrease weed pressure for future crops

PRODUCTION PRACTICES — SUMMARY

Soil type and pH

- Does well on a range of soil types but grows best on well-drained sandy loam soil with pH 5.8 – 6.5.

Site selection

- Avoid planting where infestations of cucumber beetle have been heavy or common.
- Plant upwind and separated from older sequential blocks, and other crops highly susceptible to cucumber beetles, such as potatoes, cucurbits, beans and corn.

Fertility requirements

- Fall/winter cover crop (bell beans, triticale, vetch).
- Compost, as needed (5–7 tons/acre).
- Post-plant fertility may be needed on sandy soils with minimal residual fertility and low CEC (cation exchange capacity).

Soil temperature

- Optimum soil temperature is 60°F or higher at planting depth.

Amount of seed needed

- 2–3 lbs/acre.

Plants per acre

- 3,000 – 4,000 (vining types).
- 6,000 – 8,000 (bush types).

Planting date

- Mid May through early July, depending on variety.

Planting technique

- Sow directly into moisture.
- Plant in beds or on the flat.
- Can be transplanted (intensive garden system) but are rarely transplanted on a field scale system.



Plant and row spacing

- Bush types: 36–60" between rows; plants should be 24" apart.
- Vining types: 60–80" between rows; plants should be 36–48" apart.
- Plant closer and thin to the desired spacing in the row to ensure a uniform stand of healthy plants.

Planting depth

- Bush types (typically smaller seed size): up to 1" deep depending on soil type and depth to moisture
- Vining types (typically larger seed size): up to 2" deep depending on soil type and depth to moisture

Irrigation

- May be planted to moisture and dry farmed.
- If planted to moisture and irrigated, lay drip lines following the first cultivation and hold off as long as possible before the first irrigation.
- Note that some growers use overhead irrigation early in the production cycle to minimize powdery mildew.

Days to maturity

- 85–110 days depending on variety and weather conditions.

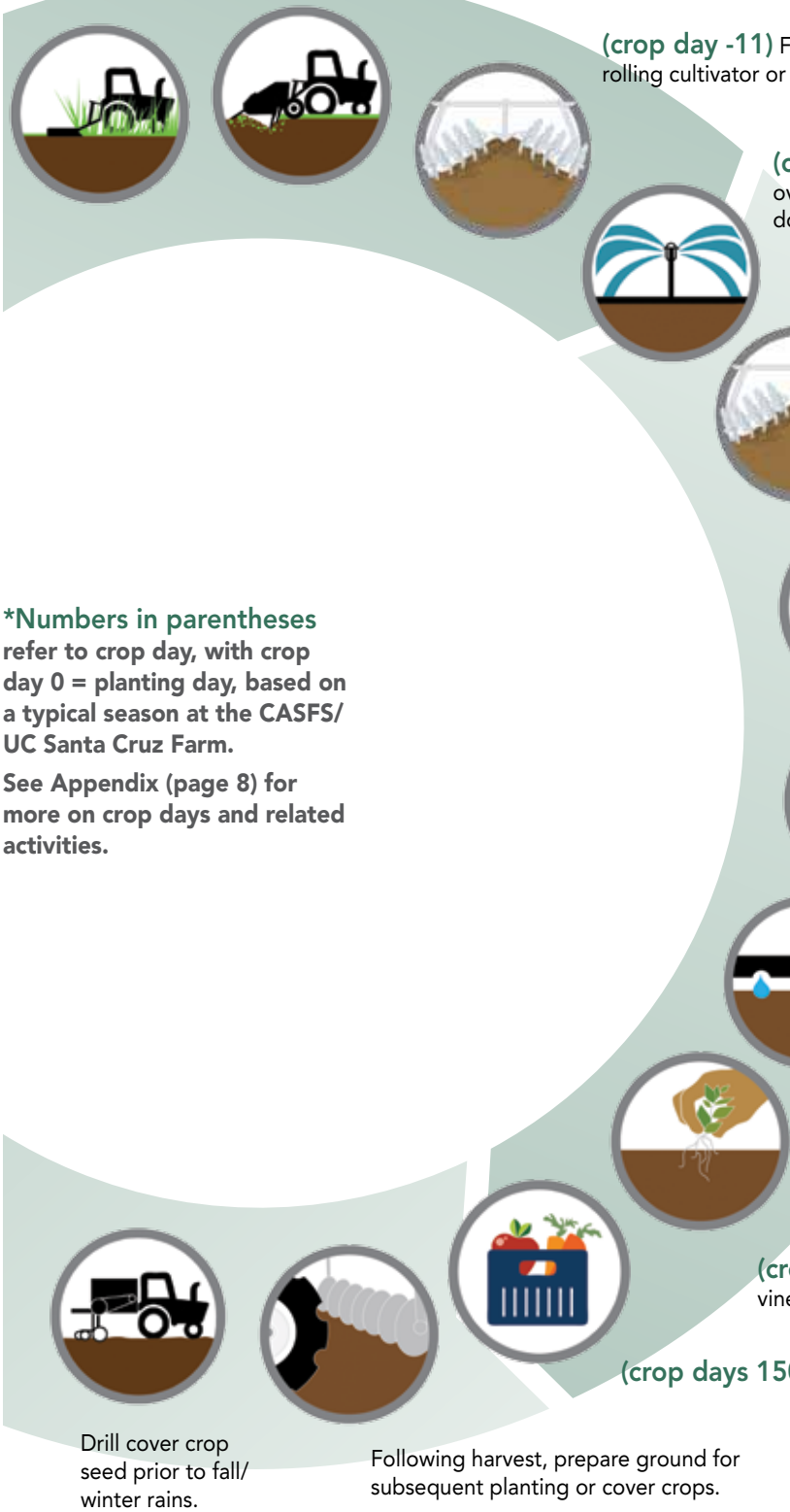
Harvest/Post-harvest handling

- Leave squash on vines until plants begin to senesce (die after maturing) .
- Cut squash with hand-held clippers, leaving a short stalk once foliage dies back and the tendril begins to dry (opposite the squash attachment stem on the main vine).
- Windrow in field to facilitate pick up.
- Store for short periods of time in cardboard bins.

Crop rotation

- Managed well, a winter squash crop will suppress weeds and scavenge fertility, making it a good crop to follow more intensive mixed vegetables that require higher fertility inputs. Few weeds grow or set seed among a squash crop that is planted to moisture and drip irrigated once full crop canopy is established. This reduces weed seed in that field, to the benefit of subsequent crops.
- Prepare fields with relative ease and minimal tillage for subsequent crops or cover crops; winter squash residue breaks down well.
- Where Verticillium wilt *(Verticillium dahliae)* is present, use long rotations (2–3 years or more) out of susceptible crops such as cucurbits, solanums, and strawberries to non-susceptible crops, such as grasses and legumes.

PRODUCTION SEQUENCE — OVERVIEW



(crop day -25*) In spring, mow cover crop to facilitate breakdown.

(crop day -25) Incorporate cover crop residue.

(crop day -11) Form beds with rolling cultivator or listing shovels.

(crop day -10) Pre-irrigate beds with overhead irrigation (1–1.5"). Wait for dry down and weed emergence.

(crop day -1) Work bed surface lightly with cultivator to terminate weeds, re-form beds, and create "dust mulch" to trap subsoil moisture.

(crop day 0) Direct seed squash seeds with a JD 71 planter (or equivalent).**

(crop day 20) Cultivate for additional weed control using standard 3-bar cultivator with sweeps, knives, and disc hillers.

(crop day 21) Lay drip lines.

Apply drip irrigation once canopy forms and continue weekly.

Hand weed large weeds as needed.

(crop days 120, 140) Clip squash from vines, let cure in field.

(crop days 150, 160) Harvest.

Following harvest, prepare ground for subsequent planting or cover crops.

Drill cover crop seed prior to fall/ winter rains.

***Numbers in parentheses refer to crop day, with crop day 0 = planting day, based on a typical season at the CASFS/ UC Santa Cruz Farm.**

See Appendix (page 8) for more on crop days and related activities.

** On garden scale, plant transplants

Production Practices — Additional Details

Pre-plant fertility

A legume/cereal mix cover crop incorporated prior to bed preparation should provide adequate fertility for winter squash on most soil types. If additional fertility is required, apply high quality compost (5–7 tons/acre) at time of cover crop incorporation. Supplemental post-plant fertility is seldom needed, although winter squash grown on very low CEC (cation exchange capacity) sand with minimal residual fertility may require additional nutrients, which can be applied via drip injection.

Bed preparation and planting

Although winter squash can be planted "on the flat" (i.e., without forming beds), a bedded system improves moisture retention and weed management.

Perform standard tillage practices to incorporate crop or cover crop residue (Figure 1), break compaction, and adequately loosen soil. Then, form the planting beds using bedding shovels or a rolling cultivator.

If there is no rainfall following bed formation in the spring, pre-irrigate (1–1.5") with overhead irrigation to wet the root zone and germinate weeds prior to planting. This pre-irrigation further improves soil conditions and tilth by breaking down soil clods or clumps of cover crop residue, leaving the soil loose, moist, and friable.

Following the pre-irrigation (or spring rainfall of 1–2"), eliminate newly germinated weeds with a rolling cultivator or other suitable cultivation technique. If timing is good and the moisture is uniform, such a run can work wonders. This initial cultivation breaks surface crusting and provides a "soil mulch" to slow evaporative loss of deeper soil moisture.

Once crop or cover crop residue is adequately decomposed (residues brown, leaves no longer recognizable) and soil temperatures are above 60°F, use a suitable planter (see below) to push aside the drier soil on the bed tops and plant the squash seeds into the deeper moisture in the bed.

Timing of planting

In general, winter squash can be planted from mid-May through June on California's Central Coast. Shorter-maturing varieties can be planted in early July. Planting dates are based on timing of adequate seedbed preparation (allowing for thorough cover crop residue decomposition), soil moisture (adequate for germination), and optimal soil temperature (>60°F).



FIGURE 1. A spader can be used to incorporate cover crops. *Photo: Elizabeth Birnbaum*



FIGURE 2. John Deere 71 "flexi" planter. *Photo: Jim Leap*

Plant late enough in spring to allow for rapid plant growth; this will help limit cucumber beetle and other herbivore damage to seedlings. Planting dates must be early enough to allow the crop to mature and adequately field cure before fall rains, heavy dew, or frost.

Planting to moisture

Winter squash seed can be planted to moisture by hand with a shovel or trowel. There are also "seed stick" planters that are very effective for planting winter squash. Push planters such as the Planet Jr. are effective for garden-scale production, but require a special "deep" opening shoe to get the seed far enough into moist soil.

On larger field-scale blocks (>.25 acres), use a tractor-mounted planter such as the John Deere 71 "flexi" planter or other similar plate-type planter (Figure 2). The planter's double disc openers cut through residual cover crop or crop residue. Adjust planting depth with a rotating cam on the side of the planter, which changes the angle of the press wheel in relation to the disc openers. For mixed blocks (multiple varieties) of winter squash on relatively small plots, the planter hopper can be removed and the seeds hand dropped into the drop tube. This circumvents the need for multiple seed plates to match each variety.

Note that it is better to plant into soil on the drier side. On many soil types, if the soil is too wet at planting, soil surface crusting can impede successful crop emergence. Squash plants that struggle to break through crusted soil may remain stunted.

In cases when the soil is either too wet or too dry, you can form a "cap" of soil over the seed line to either minimize crusting (too wet) or to minimize further evaporative loss (too dry). Run soil cappers behind the planter to create a loose cap of soil right over the seed line behind the planter's pack wheel (Figure 3).

With optimum soil conditions (>60°F and minimal crusting) and planting depths, plants should emerge in 7–10 days. Uniform emergence is the best sign of optimal planting conditions and potential for a successful crop.

The most critical aspect of effectively "planting to moisture" is your ability to judge soil moisture and decide on seed depth. Decisions related to seed depth will vary depending on soil type, seed size, and weather and soil conditions at the time of planting. Because of the challenges associated with planting to moisture,



FIGURE 3. Soil cappers run behind the pack wheel create a loose "cap" of soil over the seed line. *Photo: Jim Leap*

less experienced growers may opt to irrigate up their newly planted squash seed. This practice is effective and will ensure a good stand, but results in more weed competition and management costs. Please see the publication *Tillage, Bed Formation, and Planting to Moisture* in this Grower Guide series for additional details.

Thinning

Thin winter squash to the desired spacing once plants are fully emerged and well established but still relatively small. As needed, weed in the plant line at the time of thinning (by hand or with a hoe).

Irrigation

Drip irrigation minimizes weed pressure, although some growers use overhead irrigation prior to fruit set to help control powdery mildew.

Timing of the first drip irrigation depends on the water-holding capacity of the soil, the initial soil preparation, the amount of winter rainfall, and the amount and timing of any pre-irrigation. Lay out drip lines when the plants have been thinned but are still small, and the first cultivation is complete (Figure 4). Delay irrigation as long as possible to encourage deep rooting of the squash plants. To minimize weed pressure, the first irrigation ideally would take place once squash leaves grow a full canopy to shade out weeds that may emerge once irrigation is initiated.

From this point on, use evapotranspiration (Et) estimates from your local CIMIS station (cimis.water.ca.gov) or another source to inform irrigation decisions. Irrigation rates will likely range from 1–2" per week for the duration of the crop's development. Once the squash fruits are sized there is no need for further irrigation and the water can be cut.

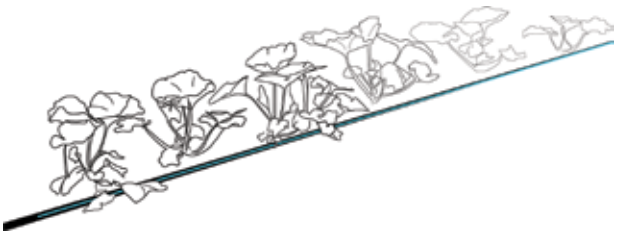


FIGURE 4. Lay drip tape when plants are still small, following first cultivation. *Illutration: Laura Vollset*

VARIETAL OVERVIEW: Popular winter squash varieties

Acorn ***(Cucurbito pepo)*****:** A small, green, thin-skinned type with sweet "caramelized sugar" flavor and smooth flesh. Short storage window (~1 month). To maintain best flavor and texture, skip field cure and bring them into cool storage once they have colored up. This type keeps best at slightly cooler storage than other winter squash. **VARIETIES: Sweet Reba, Table Queen, Carnival (Acorn x Sweet Dumpling)**

Delicata ***(C. pepo)*****:** A mild, sweet, early season, small (1–2 pounds), thin-skinned type with very sweet, smooth yellow flesh. As it ripens, color goes from white with green striping to pale yellow with orange and green striping. Storage life is longer than acorn but become drier and starchier in the 2nd–3rd month of storage. Skin is edible. **VARIETIES: Zeppelin Delicata, Sweet Dumpling**

Butternut ***(C. moschata)*****:** A bell-shaped fruit with thin tan skin. Widely grown for its bright orange, sweet, moist flesh, this type has a long storage life (~6–8 months), and seems to get better with age. **VARIETY: Waltham**

Spaghetti ***(C. pepo)*****:** A large, oblong fruit. The pale yellow flesh is quite mild, only slightly sweet, and breaks apart to look like strands of spaghetti when cooked. It has a short storage life (~4–6 weeks).

Hubbard ***(C. maxima)*****:** A large, hard-skinned, tear drop-shaped type with several color varieties, from pale blue to bright orange skin, with pale yellow to deep orange flesh, which is sweet and savory. Great as a pie filling or puree. Can be stored up to 6 months in proper conditions. **VARIETIES: Red Kuri, Blue Ballet**

Kabocha ***(C. maxima)*****:** A squat-shaped Japanese type with rough, thick skin in several colors, with dark green most common, but also in shades of gray to light blue, or bright orange. The flesh is distinctively dry and flaky with a rich, nutty flavor. Long storage life (~6–8 months). **VARIETIES: Sunshine (bright orange-red), Cha-Cha (dark green)**

Buttercup ***(C. maxima)*****:** Compact and green, closely resembles a kabocha type, but is distinguished by a round ridge on the bottom. The flesh is dense, firm, and somewhat dry. **VARIETIES: Burgess, Bush** ***(compact plants, good for garden scale)***

NOTE that some varieties are resistant to powdery mildew, a major disease of winter squash. When you search seed catalogs, look for the abbreviations "PMT" for Powdery Mildew Tolerant.



Clockwise from top left: Red Kuri, Winter Luxury (pumpkin), Sweet Reba, Zeppelin, Sunshine. *Photo: Elizabeth Birnbaum*



FIGURE 6. The squash canopy shades out weeds as fruit develops.
Photo: Elizabeth Birnbaum

Winter squash commonly show signs of wilting on hot afternoons. This is not always related to lack of available water, so don't use the afternoon wilt symptom as a guide for irrigation frequency. If the plants appear wilted in the morning, then the plants are water stressed and you need to irrigate.

Weed control

When squash seeds are planted to moisture, late season rains are minimal, and drip irrigation can be delayed until there is a full canopy of leaves between plants within the row, there may be no weeding necessary during the entire cropping cycle. This type of management can significantly reduce production costs, keep the field clean of unnecessary weed seed, and maintain profitability.

If between-row weed management is needed after thinning and in-row weeding, use a three-bar cultivator mounted with disc hillers, sweeps, and knives. Because of the low growing point of squash plants, it is not advisable to move soil towards the plant following emergence. Rolling cultivators are therefore not an appropriate tool to effectively manage weeds in winter squash.

Run shallow chisels behind the tractor tires to break tractor tire wheel compaction, especially in situations where soil moisture is high at the time of cultivation. This will aid fall tillage and minimize clod formation. Generally, only one or two cultivations are needed for weed management in winter squash. The few weeds that escape cultivation can be hand pulled once the squash is in full bloom. After that, the canopy should prevent further weed germination or growth (Figure 6). Additional passes may be needed to control bindweed or other perennial weeds.

Harvest

Color is probably the best indicator of harvest timing. Most varieties will develop a deep color as the stems dry down, the rind loses its sheen, and the fruit hardens. For example, Butternut will go from light green to deep tan; Sweet Dumpling and Delicata will go from white/green to deep yellow/orange

Once the squash foliage has fully senesced, cut the squash from the vine with hand-held clippers, leaving a short stalk on the fruit. Take care not to break off the stem as early post-harvest decay can develop at the point of detachment. Windrow the harvested squash in the field to facilitate pick up after curing (Figure 7). Field curing—leaving squash in the sun for 1–2 two weeks (depending on weather)— allows fruit to shed some moisture, concentrates sugars, hardens the skin, and slows respiration, allowing for better long-term storage. Curing for more than two weeks may cause sunburn and make fruit susceptible to insect damage. If rain or a heat wave (temperatures over 95°F) is forecast, squash should be picked up and stored.

Cardboard bins may be used for field removal and temporary storage. Handle squash carefully to avoid cutting or bruising the skin. Remove dirt from squash and cull damaged fruit while filling bins; do final quality assessment and grading when packing boxes from the bins for market. Bins on pallets may be moved with a three-point forklift attachment on a tractor, or a forklift. Store squash in a shady, covered area.

Post-harvest considerations

When kept dry and rodent free, most winter squash varieties will store well at ambient temperatures for 2–5 months, and some varieties (e.g., Butternut, Hubbard) will store for up to 8 months or longer. Consult seed catalogues and post-harvest storage charts (see Additional Resources) for optimal storage temperatures of the squash varieties you grow.

Post-harvest field care

Shortly after harvest, retrieve all drip lines and prepare the ground for a subsequent cash crop or winter cover crop. Mow the squash vines after harvest to eliminate large clumps of plant material prior to discing. If left intact, large vine pieces can cause "wrapping" and "gathering" problems with some follow-up tillage implements (e.g., chisels and spring tooth harrows).

Because squash requires minimal tractor and foot traffic on moist ground during the cropping cycle, the soil should be easy to work following harvest. Typically the winter squash field will only need mowing and one or two passes with a disc to adequately prepare the ground for planting. Optimal soil conditions support good cover crop stands and rainwater infiltration rates.



FIGURE 7. Windrowed winter squash curing at the UCSC Farm.
Photo: Elizabeth Birnbaum

DRY FARMING WINTER SQUASH

Many varieties of winter squash are well suited to dry farming in California's Central Coast region, especially in areas with marine influence and generally cooler daytime highs. Primary considerations for dry farming winter squash include:

- Minimum 20" of winter rainfall.
- Deep soils with high clay content in lower horizons.
- Timely (early) incorporation of cover crop to minimize loss of deeper soil moisture due to transpiration by the cover crop.
- Tillage practices that promote water holding and minimize loss of moisture through surface evaporative.
- Use of wider-than-standard plant spacings to allow for greater soil/water volume for each plant. Wider spacing means fewer plants and lower yields.

Pests and Diseases

Before you select varieties and plant your winter squash crop, look up common pests and diseases that affect the crop in your area. Learn about pest and disease life cycles, preventive practices, and possible treatments using resources such as the UC IPM website (ucipm.edu), your county Cooperative Extension offices, ATTRA's Biorationals: Ecological Pest Management Database www.ncat.org/attra-pub/biorationals, neighboring farmers, and other knowledgeable professionals.

The main winter squash arthropod pests in the Central Coast region are:

- Cucumber beetle: Western spotted cucumber beetle, *Diabrotica undecimpunctata undecimpunctata*; Western striped cucumber beetle, *Acalymma trivittatum*: feed on foliage and fruit.
- Melon Aphid, *Aphis gossypii* and other aphids: transmit plant viruses, feed on leaves of older plants, honeydew can lead to mold infections.

The main winter squash diseases in the Central Coast region are:

- Powdery mildew: *Sphaerotheca fuliginea* (=*Podosphaera xanthii*) and *Erysiphe cichoracearum* (=*Golovinomyces cichoracearum*): affects leaves and stems of older, fruit-bearing plants.
- Verticillium Wilt, *Verticillium dahliae*: interferes with water transport, can reduce fruit yield and quality, or kill plant.

Please see *Organic Pest and Disease Management in Selected Crops on California's Central Coast* in this **Grower Guide** series for information on the pests and diseases listed here, and suggestions for their control in winter squash.

ADDITIONAL RESOURCES

Introduction to weed management in a small scale organic production system (video). Produced by the Center for Agroecology & Sustainable Food Systems. www.youtube.com/user/casfsvideo

Knock weeds out at critical times, by Mark Schonbeck. eOrganic, 2010. articles.extension.org/pages/18882/knock-weeds-out-at-critical-times

Organic pumpkin and winter squash marketing and production, by Janet Bachmann and Katherine Adam. NCAT IP371, 2010. attra.ncat.org/attra-pub/summaries/summary.php?pub=30

Powdery mildew resistant winter squash varieties are valuable addition to management program. Vegetable MD Online, Cornell University. vegetablemdonline.ppath.cornell.edu/NewsArticles/Winter_PM_Resistant.html

UC Davis postharvest technology postharvest.ucdavis.edu/Commodity_Resources/Fact_Sheets/(see Pumpkins)

Organic Winter Squash Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers by Jim Leap, Darryl Wong, and Kirstin Yogg-Comerchero, with contributions from Ann Baier and Doug O'Brien. Edited by and Martha Brown and Ann Baier.

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This publication was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA. Mention of commercial products does not constitute an endorsement.

Photos, p. 1: Elizabeth Birnbaum. Icon illustrations, p. 3, Laura Vollset.

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APPENDIX: PRODUCTION SCHEDULE, ECONOMIC DATA

Crop day	sub crop	# beds (1 bed = .02ac)	Action	work rate (hr/ac)	fixed rate (hrs)	Total labor cost @ $16.10/hr	Total machine cost @ $21.70/hr	Harvest Amt.(#)	Harvest Value($)
-25		10	Flail Mow:heavy	2.5	0.2		$15.19		
-25		10	Spade	4.8	0.2		$25.17		
-11		10	Mark Lines	2	0.2		$13.02		
-11		10	List	1.25	0.2		$9.77		
-11		10	Overhead Irr:set up	3.75		$12.08			
-10		10	Overhead Irr:run		0.5	$8.05			
-1		10	Light cultivation	1.25	0.2		$9.77		
-1		10	JD 71 Seed	4.82	0.2		$25.26		
0		10	Plant:drop seeds	9.64	0.2	$34.26			
18		10	Thin plants	2		$6.44			
20		10	Cultivate	2	0.2		$13.02		
21		10	Drip:set up	10	0.25	$36.23			
21-119		10	Drip:run x 1/wk; @ 15wks		2.25	$36.23			
45		10	Hand Weed:big weeds	8	0.2	$28.98			
70		10	Hand Weed:big weeds	8	0.2	$28.98			
120	Red kuri	2	Clip	6		$3.86			
120	Delicata	4	Clip	6		$7.73			
140	Butternut	4	Clip	6		$7.73			
150	Red kuri	2	Harvest	37.23		$23.98		1,162	$871.20
150	Delicata	4	Harvest	14.17		$18.25		884	$663.00
160	Butternut	4	Harvest	23.27		$29.97		1,452	$1,089.00
			Pack						
-		10	Drill/Cover Crop	1.6	0.2		$11.28		
					Sub-total:	$282.75	$122.47		

Harvest Assumptions	
Harvest (#/acre)	
Delicata	18,000
Butternut	29,000
Red Kuri	22,000
Harvest (#/hr)	780
Harvest Rate (hr/ac)	
Delicata	14.17
Butternut	23.27
Red Kuri	37.23
Price ($/#)	0.75

Labor + Machine Cost ($)	
Per Block (.2 Acres):	$405.23
Per Acre:	$2,026.15

Yield		
Per Block (.2 Acres):	3498	$2,623.20
Per Acre:	17488	$13,116.00

Item	Cost per unit	Cost per acre	Notes
Drip Tape	$120/7500'	$232.32	1 row/bed; 14520 row'/ac; $.016/row'
Seeds	-	$200.00	Seed cost per acre: butternut $70; Delicata $140; Red Kuri $580
Boxes	$.98/box	$490.00	.98/bx; 35#/box; 500 box/ac
Total Expenses (per acre):		**$922.32**	

Per Acre Totals	
Income:	$13,116.00
Labor + Machine Cost:	-$2,026.15
Expenses:	-$922.32
Production Profit:	**$10,167.53**

Complete irrigation schedule available online at casfs.ucsc.edu/about/publications/growerguides. Data reflect direct field production costs and do not include other potential overhead (e.g., water, electricity, land rent).

FRESH MARKET AND DRY BEAN PRODUCTION: A Guide for Beginning Specialty Crop Growers







Introduction

Fresh market round and flat pod bush beans can be a productive and profitable market crop, as well as a beneficial rotational crop in diverse, small- to medium-scale, mixed specialty crop systems in California.

The primary advantages of beans include their relatively low cost of production until the time of harvest (which requires more labor), as well as a short production window that eliminates a significant amount of financial risk compared to most other vegetable crops. Bush beans can also be grown as shell or dry beans, adding another dimension to a specialty crop grower's product mix.

This guide describes the steps involved in growing bush beans organically with a focus on planting to moisture for weed control, and reviews options for planters to use at various scales.

Features of bush bean production

- Managed well, bean crops grow quickly, form a canopy, and incur little or no labor costs for weed management
- Relatively deep-rooted, efficient nutrient scavengers that require little or no supplemental fertility
- Minimal pest and disease pressures
- Self-pollinate; seed can be easily saved, reducing production costs
- Well suited to drip irrigation, which minimizes water use and reduces soil compaction from harvest crew
- Offers potential for multiple, staggered crops to take advantage of seasonal market prices
- Can be grown as dry beans (allowed to mature) to extend marketing opportunities
- Low crop residue facilitates easy seedbed preparation for subsequent crops or cover crops
- Good crop cover and weed management can significantly reduce weed seed bank and weed pressure in subsequent crops

SUMMARY OF PRODUCTION PRACTICES

Soil type

- Grow well on loamy sands to clay loams
- Sandy loam soils are optimal for maximum production and ease of management
- Soils with low CEC (e.g., loamy sands) may require supplemental fertility

Fertility requirements

- Fall/winter cover crop (bell beans, triticale, vetch)
- Compost, as needed (5–7 tons/acre)

Soil temperature

- Plant when soil temperatures reach 60° F minimum at planting depth

Plants per acre

- Roughly 130,000

Planting technique

- Direct seeded
- Planted to moisture

Bed spacing

- Single line on beds spaced 30–36" center to center for green bean harvest
- Double lines on 40" beds for combine-harvested dry beans

Plant spacing

- Optimum row spacing: 30–36" between seed lines
- Plant spacing: 1.5–2" apart in the seed line
- Single line configuration optimizes mechanical weed management and harvest efficiency.

Planting depth

- 1–1.5" depending on soil type, moisture levels and weather conditions.
- Can be planted deeper (up to 2") on lighter textured (sandier) soils

Irrigation

- Drip tape facilitates uniform water application, saves on water costs, and minimizes both weed and disease pressure

Days to maturity

- Most fresh market round and flat pod bean varieties take 50 days from planting to harvest.
- Dry beans take roughly 4–5 months from planting to harvest, depending on variety. Harvest timing is determined by a balance of maturity and dry down; harvest the beans before the pods start splitting open (shattering).

Harvest

- Irrigate prior to harvest to ensure green beans are turgid (juicy/snappy, not dry/limp)
- Harvest in the morning while temperatures are cool
- Avoid rough handling; pack gently to avoid bruising
- Remove all mature beans from a plant
- Cull (toss out) any broken or damaged beans, and those that have had soil contact

Post-harvest handling

- Avoid over-handling freshly harvested beans; bruising impacts market quality
- Keep harvested beans in a shaded spot to reduce respiration and maintain freshness
- As soon as possible after harvest (within 1 or 2 hours), cool beans with clean water to remove field heat and to keep them fresh and turgid.



PRODUCTION SEQUENCE — SUMMARY



(crop day -25*) In spring, mow cover crop to facilitate breakdown.



(crop day -25) Incorporate cover crop residue.



(crop day-11) Form beds with rolling cultivator or listing shovels.



(crop day -10) Pre-irrigate beds with overhead irrigation (1–1.5"). Wait for dry down and weed emergence.



(crop day -1) Work bed surface lightly with cultivator to terminate weeds, re-form beds, and create "dust mulch" to trap subsoil moisture.



(crop day 0) Direct seed bean seeds with a JD 71 planter (or equivalent).



(crop day 20) Cultivate for weed control using standard 3-bar cultivator with sweeps, knives, and disc hillers.

(crop day 20) Lay drip lines in seed lines.



(crop day 21–30) Cultivate with rolling cultivator when beans are greater than 12" in height to smother weeds in seed line and cover drip line.



(crop day 30) Apply drip irrigation when beans start to show signs of water stress.



Spot weed large flowering weeds.



(crop day ~60) Pick for market quality every 2–3 days, depending on weather and crop development**



Plant successions of fresh market beans approximately every 10 days with a JD 71 planter.



Prepare ground for subsequent planting or cover crops.



Drill cover crop seed prior to fall/winter rains.

Numbers in parentheses refer to crop day, with crop day 0 = planting day, based on a typical season at the CASFS/ UC Santa Cruz Farm.

**If growing for dry beans, harvest before seed pods begin to "shatter"

Production Practices — Additional Details

Timing

In cooler coastal production areas you can plants beans from April through August, and even into September, depending on the potential for early frost. Because production costs are low (cost of crop failure is not devastating), growers can risk early or late plantings to have beans in the market when supply is lower and prices are higher. Plant beans grown for harvest as dry beans by mid May on California's Central Coast.

In warmer inland valleys it is best to plant early (April and May) while daytime temperatures are relatively moderate. Avoid June and July plantings, since fresh market bean quality and quantity will be significantly reduced when daytime temperatures are much above 95°F (35°C). Beans can then be planted again in the late summer (August and September) to allow for good production until the first frost.

On soils with relatively good water holding capacity, large areas can be bedded, pre-irrigated, and then worked with a rolling cultivator following weed seed emergence. The cultivation will effectively hold soil moisture for 30 days or longer, allowing for successive plantings over time with minimal effort. To ensure harvest continuity for staggered plantings, plant the next round of beans when the prior planting is in the "crook" stage (see below), approximately every 10 days.



FIGURE 1. Planting bean seeds to moisture. *Photo: Martha Brown*

Planting

When produced on a commercial scale, beans should always be planted to moisture rather than irrigated up. If you plant beans into dry soils and then irrigate them to initiate germination, weed seeds will germinate at the same time as the newly planted beans. In most cases weeds will quickly outcompete the beans and compromise effective weed management. It is not possible to cover labor costs, through sale of the crop, for hand weeding when weed pressure is high. See the publication *Tillage, Bed Formation, and Planting to Moisture* in this Grower Guide series for additional details.

When planting to moisture, use a wide "Alabama" shovel mounted on the planter to run ahead and push off the dry dirt on top of the bed. Set the shovel so that it goes deep enough to get into the sub-surface moisture. When set correctly, the shovel leaves a flat "V" pattern down the center of the bed. On most soil types, as long as you can see some slight darkening of the soil that is exposed when the bed top is knocked off compared to the drier surface soil, there should be enough residual pre-irrigation (or rain) moisture in the soil at the bottom of the "V" to initiate germination of the newly planted bean seed. Plant beans at the low point in the middle of the bed to conserve moisture deeper in the soil (Figure 1).

In most cases 1–1.5" is a good planting depth for strong germination, although beans can emerge when planted 2" deep as long as the soil is "loose" and not compacted above the seed. Loose soil above the seed line also limits evaporative loss. When beans seeds all emerge at roughly the same time, you know you have done a good job of planting them.

Note that most bean planters are designed to drop seed into a small trench that is then covered with soil and firmed up with the planter press wheel. Avoid planting when the soil is too wet as the press wheel can create a compacted layer over the seed that dries into a firm crust, which can significantly impede successful bean seed emergence.

Planters

When choosing a tool-bar-mounted planter for larger-scale bean plantings (greater than 1/10 acre plots), select a planter that singulates the seed, has double disc openers that cut deep into the soil (4" minimum), and has a press/tamp wheel. Options include the Clean Seeder TP (www.suttonag.com/clean_seeder_tp.html), the John Deere 71 "flexi" planter (Figure 2;), and the International 185 planter (similar to the John Deere 71) planter. Note that on smaller farms, the cost of this type of planter can be a significant capital expense.

Although no longer available new, the John Deere 71 "flexi" planter is still one of the more common planters used on the Central Coast for planting beans (many parts are still available). It is called a "flexi" planter because it is designed to "flex" or "float" over heavy residue. This design feature makes it an ideal planter for planting beans (and many other large seeded crops) following cover crop incorporation in the spring.

The Clean Seeder TP and John Deere 71 planters have double disc openers that create a very narrow opening in the soi lFigure 2). The seed falls into the opening while the sides of the opening are being held open by the discs. The small trench created by the openers easily collapses once the disc openers pass. The press wheel on the planter firms the soil over the seed and helps to reestablish capillarity, which improves soil moisture movement from lower in the soil horizon. If you question whether there is adequate soil moisture, assess moisture early the next day after planting. Soil moisture typically improves overnight as a result of the light compaction (and improved capillarity) created by the press wheel.

The advantage of double disc openers (common on most grain drills) is that they can easily cut through or roll over residual cover crop or crop residue. In comparison, Planet Jr. planters use a fixed opener shoe, which gathers field trash when used to plant at depths greater than 1 inch. When residual crop residue wraps on a fixed shoe, it pushes soil away from the seed line, causing skips in planting and an uneven surface.

Plate planters such as the Clean Seeder TP-TB, John Deere 71, and International 185 do an excellent job of "singulation" of the bean seed. Driven by the press wheel, the seed plate rotates in the bottom of the seed hopper. The holes in the plate allow single seeds to drop into the hopper cells. The cells rotate over an opening in the bottom of the hopper, and with the help of a "knocker," drop the seed at a selected spacing as the planter moves through the field.

Planting depth can be adjusted with a rotating cam on the side of the planter, which changes the angle of the press wheel in relation to the disc openers. Seed spacing is set based on the number of holes in the seed plate, as well as gearing, which is easily changed. Select seed plates carefully to match varieties, since bean varieties vary significantly in size and shape.

Germination

When beans germinate, they lift the two seed halves (cotyledons) above the soil surface. This is referred to as "epigeal" germination. The emerging beans will first push through the soil with the stem (hypocotyl) in a "crook" position and then



FIGURE 2. A John Deere 71 "flexi" planter set up for direct seeding bush beans. *Photo: Jim Leap*

the cotyledons will emerge, followed by the first true leaves as the hypocotyl straightens out following emergence. The early stage of germination when the stem first appears above ground is referred to as "in the crook" (Figure 3).



FIGURE 3. An emerging bean "in the crook." *Illustration: Laura Vollset*

Emerging beans are very susceptible to heat damage at the soil surface as they push upward. When planting in late summer (August or September for fall production), farmers in warmer inland valleys of California commonly put a "soil cap" on the bean seed line with small disc hillers (Figure 4). The hillers are attached to, and run directly behind the planter to form a small mound of loose soil directly over the seed line. During times of high daytime temperatures, growers dig up the embibed seeds daily until they see uniform radical emergence. They then mechanically knock off the cap. If timing is good, the beans will emerge through the soil during the cool of the evening, thus avoiding the issue of stand loss due to high soil temperatures.

In cooler coastal production areas you do not need to cap the seed lines. However, a very light soil cap (which does not need to be removed) helps keep the soil loose and moist. This can improve ease of emergence and stand uniformity in both extremes—when the soil is either slightly too wet or too dry.



FIGURE 4. Disc hillers create a soil cap over the seed line.
Photo: Jim Leap

Weed control

When soil moisture is optimal, planting to moisture allows the beans to germinate but limits weed germination, as most weed seeds require more moisture to trigger germination compared to the large bean seed. The beans emerge in a small trench in the middle of the bed, where vigorously growing beans will easily outgrow most weeds (Figure 5).

Let the beans grow as long as possible without irrigation to allow them to root deeply and to minimize weed competition. In most climate zones on soils with decent water-holding capacity, the beans can grow to full bloom before you need to irrigate (see Irrigation, next page).

Once beans are 5–6" tall, do a first cultivation. Use a standard 3-bar cultivator with a set of reverse disc hillers running along each side of the plant line, side knives along the sides of the beds, and sweeps in the furrows. Run small chisels behind the tractor tires to a depth of about 4" to break tractor tire compaction and facilitate subsequent cultivations. This first cultivation will effectively terminate most newly germinated weeds from seed line to seed line. Then lay drip tape along the seed line.

As the beans continue to elongate, use a rolling cultivator for the second—and most effective—cultivation. Properly set, the cultivator will gently return the dirt that was pushed off the bed top at time of planting to the middle of the bed (Figure 6). The bed should end up looking just like it did prior to planting. If bean stems are long enough, this "dirting" cultivation will effectively cover both the drip line and smother any weeds that have emerged in the seed line while covering only the lower stem of the bean plant.

This last cultivation, or "dirting," leading up to harvest is commonly practiced on large acreages of many agronomic crops that are planted to moisture in situations where herbicides are not used. To perform this cultivation successfully requires specific and tightly adjusted implements, and a significant level of tractor skill. As small farms scale-up to mid-sized farms and larger acreages, planting to moisture and dirting can significantly reduce the labor required for weed control.



FIGURE 5. Newly emerged beans in trench.



FIGURE 6. A rolling cultivator re-forms planting beds and "dirts" growing beans, burying the drip lines and any weeds.

Other options for planting and weed management

On small plots (100 bed-feet or fewer), you can easily plant beans to moisture by hand. Pre-irrigate your beds, and use hand tools to take out the newly germinated weeds. Push the bean seed into the deeper moisture by hand. Any subsequent weed growth can be handled with a wheel hoe or hula hoe.

On larger plots (greater than 100 feet), plant beans to moisture with simple tools. Use a rototiller (either walk behind or three-point, mounted behind a small tractor) following pre-irrigation to terminate weeds and form a soil or "dust" mulch. Form a planting trench with a small furrowing shovel mounted on a wheel hoe to access deeper soil moisture. Plant with a Planet Junior push seeder using the general purpose "deep" shoe, or the Jang (clean seeder) large seed push seeder (Figure 7). On this scale, weeds can be managed using hand tools or wheel hoes.

Irrigation

Time the first post-emergence irrigation based on subtle signs of water stress in the bean plants during warmer days—especially later in the day. Pay attention to slight changes in the color of the bean plants: a plant with adequate soil moisture appears dark green; when stressed, the green color shows hints of gray. Following emergence of the first true leaves, water stress will be very evident as a stressed plant tends to push the first true leaves together and upright. These stress symptoms typically show up on field edges where pre-irrigation coverage may not have been adequate, or where soil is more compacted.



FIGURE 7. Push seeder.

Monitor stress daily and (although this can be challenging for many growers) wait as long as possible before the first irrigation to allow for deep rooting, promote early and uniform flowering, and inhibit weed competition.

Apply about an inch of water with the first drip irrigation. Subsequent irrigations should be scheduled using evapotranspiration (Et) data from your local CIMIS station or another sources (cimis.water.ca.gov), and based on the percent canopy of the bean plants at time of irrigation.

Harvest

Fresh market beans are at their best when the seeds inside the pod are still very small and the bean is still tender. Bean pods form quickly; the harvest must be timed well to avoid harvesting any beans that are "over-mature." On many fresh market "round pod" bean varieties, you shouldn't be able to see bumps in the pod indicating seed development. Open random beans to check for over-maturation. Another good field test to determine market quality is to break the beans in half—they should break easily (snap) and not bend.

Harvest in the morning when the temperature is cooler. Harvest efficiency is related to the picker's ability to grab as many beans as possible in a single handful and pull them off the plant with enough care not to break any beans at the stem end. Efficient bean harvest is a fine art that takes a strong back, practice, and fast hands. A good bean picker is able to pick 50 lbs., or roughly two 5-gallon buckets per hour. This rate is only possible when the beans are heavily laden with evenly mature green beans. Sorting beans when harvesting is simply not economically viable.

Depending on variety and uniformity of maturation, a stand of beans can be harvested one, two, or three times. The longer the planting is harvested the greater the likelihood of missing over-mature pods during the prior pick. The over-mature pods from extended harvest need to be sorted out, and this task is simply not economical. When the next succession is ready to go it is time to walk away from the last planting.

Dry Beans

Small scale harvesting and processing of dry beans (.25 acres or less)

Dry bean harvesting for direct market sales ($4–$6 per pound) can be easily and economically accomplished with minimal capital investment. The most common method used on the Central Coast to harvest small dry bean plots is to hand cut the entire plant when pods are mature (dry), but not yet shattering (Figure 8), and place them on tarps fully exposed to sun to allow them to continue to dry to the point of shatter.



FIGURE 8. Dry beans ready for harvest. *Photo: Elizabeth Birnbaum*

Once the pods begin to shatter easily they can be "threshed" by either walking on them or by rolling over them with anything heavy enough to shatter the pod but not so heavy that it breaks the bean seed. Some growers on the Central Coast put the bean plants in burlap bags and drive over them with a light vehicle, such as small field utility "gator."

Once the beans are threshed, remove the bean plant residue with a pitchfork and collect the beans on the tarp. Sort the beans from the remaining small plant residue by screening (to remove rocks and small dirt clods), and winnowing in the wind or in front of a fan. Simple technologies to streamline this process may include multiple screen sizes in frames that fit over a wheelbarrow. For larger-scale dry bean production (greater than .25 acres), use a small combine or fanning mill-type seed cleaner.

Pests and Diseases

Before you select varieties and plant your bean crop, look up common pests and diseases that affect the crop in your area. Learn about pest and disease life cycles, preventive practices, and possible treatments using resources such as the UC IPM website (ucipm.edu), your county Cooperative Extension offices, ATTRA's Biorationals: Ecological Pest Management Database www.ncat.org/attra-pub/biorationals, neighboring farmers, and other knowledgeable professionals.

The main bean arthropod pests in the Central Coast region are:

- Aphids: Cowpea aphid, *Aphis craccivora*; Black bean aphid, *Aphis fabae*; Pea aphid, *Acyrthosiphon pisum*; Green peach aphid, *Myzus persicae*: suck plant juices, weaken and distort crops, can transmit viruses, may make crop unmarketable.
- Cucumber beetle: Western spotted cucumber beetle: *Diabrotica undecimpunctata undecimpunctata*, Western striped cucumber beetle: *Acalymma trivittatum*: damage can make beans unmarketable.

The main bean diseases in the Central Coast region are:

- Damping off caused by *Pythium* spp., *Fusarium* spp., *Rhizoctonia solani*, and *Thielaviopsis basicola*: causes pre-emergent rot of whole seed, emerging plant, or first true leaves.
- Powdery mildew caused by *Erysiphe polygoni*: severe infestation reduces yield, shortens productive life of plants.

Please see *Organic Management of Select Specialty Crop Pests and Diseases* in this **Grower Guide** series for information on the pests and diseases listed here, and suggestions for their control in beans.

ADDITIONAL RESOURCES

Common dry bean production in California, by Rachel Long et al, 2010. University of California Agriculture and Natural Resources, Publication 8402. anrcatalog.ucanr.edu/pdf/8402.pdf (not an organic guide, but lots of useful information)

How to manage pests: Dry beans UC IPM, Statewide Integrated Pest Management Program. ipm.ucanr.edu/PMG/selectnewpest.beans.html

Introduction to weed management in a small scale organic production system (video). Produced by the Center for Agroecology & Sustainable Food Systems. www.youtube.com/user/casfsvideo

Knock weeds out at critical times, by Mark Schonbeck. eOrganic, 2010. articles.extension.org/pages/18882/knock-weeds-out-at-critical-times

Organic Bush Bean Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers by Jim Leap, Darryl Wong, and Kirstin Yogg-Comerchero, with contributions from Ann Baier and Doug O'Brien. Edited by Martha Brown and Ann Baier.

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This publication was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA. Mention of commercial products does not constitute an endorsement.

Photos, p. 1: Left, Martha Brown; top right, CASFS, bottom right, Fifth Crow Farm. Icon illustrations, p. 3, Laura Vollset.

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ORGANIC MIXED PRODUCTION BLOCKS FOR DIRECT MARKETS ON CALIFORNIA'S CENTRAL COAST: A Guide for Beginning Specialty Crop Growers





Introduction

Crop diversity on small-scale farms is key to direct marketing strategies such as Community Supported Agriculture (CSA), farmers' markets, farm stands, and restaurant accounts. Crop diversity also benefits on-farm ecology, risk management, and economic viability. However, managing a diverse cropping system requires significant experience and planning for the farm operation to be productive, competitive, and financially viable.

This guide focuses on producing mixed blocks of 30- to 60-day, direct sown and transplanted crops suitable for CSA and direct market sales, with the goal of improving cropping system efficiencies and economic viability. Note that the guide does not address specific crop information, but focuses instead on managing the mixed crop production block as a whole.

Although not covered in detail in this guide, the same planning and management principles apply to crops with an extended harvest (and possibly successional plantings), such as tomatoes, beans, and zucchinis. Single planting/single harvest storage crops such as onions, potatoes, and winter squash can also be managed in production blocks. These three main types of blocks—short season, extended season, and single harvest storage crops—can complement each other in CSA and other direct marketing efforts.

Features of mixed crop blocks

- Simplify bed preparation, planting, and harvesting
- Diversify products available for direct marketing
- Supply a continuous harvest of crops throughout the season

Features of CSA marketing

- Provides a guaranteed market and up-front capital at start of season
- Offers growers and customers an opportunity to connect directly with each other
- Provides consumers the chance to directly support farmers and their farms
- Allows for creative community partnerships, e.g., with schools, businesses, faith-based groups

PRODUCTION SEQUENCE – SUMMARY

(crop day -25*) In spring, mow cover crop to facilitate breakdown.



(crop day -25) Incorporate cover crop residue.



(crop day -11) Form beds with rolling cultivator or listing shovels.

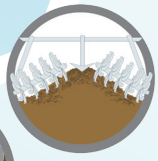


(crop day -10) Pre-irrigate beds with overhead irrigation (1.5"). Wait for dry down and weed emergence.



(crop day -1) Work bed surface lightly to terminate weeds and re-form beds.

(crop day -1) Shape beds using bed shaper or rototiller/shaper combination. Mark planting rows.





(crop days -1, 0) Plant direct seeded crops and transplants (if planting takes place over two days, plant transplants last).



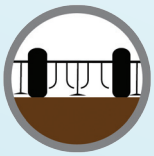


(crop days 0, 1, 4, 7) Irrigate (overhead) to water in and establish transplants.



(crop day 11) Cultivate for weed management.

Lay drip lines.



(crop day 11) Hoe out small weeds.



(crop day 12) Initiate drip irrigation.



(crop day 21) Thin carrots and beets.



(crop day 21) Hand weed direct sown and transplanted crops.



(crop day 35) Initiate harvests.

Following completion of harvests, remove drip lines from field, mow crop residue, and undercut beds.





Prepare ground for subsequent planting or cover crops.

***Numbers in parentheses refer to crop day, with crop day 0 = planting day, based on a typical season at the CASFS/ UC Santa Cruz Farm.**

See Appendix (page 8) for more on crop days and related activities.

Mixed Production Blocks

What this guide refers to as "CSA blocks" or "mixed production blocks" are crop areas within the farm specifically designated to grow a set of short season crops (30–60 days to maturity), e.g., lettuces, leafy greens such as spinach and chard; short season brassicas such as kale, turnips, kohlrabi, broccoli, and cauliflower; as well as carrots, bunching onions, beets, fennel, basil, and cilantro. Staggered plantings of these crops are essential for providing a consistent supply of diverse products throughout the season to a CSA project and/or other direct markets.

The practice of "blocking" production areas on diverse small-scale farms is a critical component of a well-thought-out production system. Crop blocking is the basis for improved management efficiencies related to fertility, tillage operations, weed control, irrigation management, and harvest operations.

At the UCSC Farm, ten 300'-long beds on 3' centers make up each production block of 30' x 300' (Figure 1). This size is based on two factors:

- **Irrigation management:** The field block can be irrigated using a 30'-long irrigation pipe running along the top of the beds and ten 30' pipes placed down either side of the block for pre-irrigation and post plant out irrigation sets.
- **Production quantity:** The average yield per block supplies the needs of the farm's marketing outlets (125-member CSA and other direct sales).

Adjust your block size and design according to your field size, preferred bed size, and equipment settings. Based on a 6' center to center tractor system, blocks could consist of either six 60" beds or twelve 30" beds.

Number of plant lines per bed depends on bed size and crop. Beets, lettuces, chard, and other small crops are usually planted in at least 2 lines in a narrow bed, and up to 8 lines in a 60" bed. Broccoli and cauliflower may be transplanted in a single or double line. Potatoes must be planted in a single line to allow for hilling. The planting arrangement needs to maximize productivity and efficiency, as well as yield and ease of weed management.

Planning and managing mixed crop blocks

Blocks of short-season crops are managed with a single set of practices during the establishment phase. All the crops within the block should be either direct sown or transplanted on the same day (or over a period of two days). They can then be irrigated and cultivated on a schedule consistent with single crop management until the time of harvest. The one difference is that, often, direct sown crops require thinning.

Mixed production blocks typically include both transplanted and direct sown crops. For example, broccoli, cabbage, cauliflower, kohlrabi, collards, fennel root, bunching onions, and head lettuces are typically transplanted, either by hand or with a mechanical transplanter. Beets, spinach, salad mix, radishes, turnips, and carrots are direct seeded. Figure 2 shows a typical mixed production block schematic at the UCSC Farm.



FIGURE 1. Spring-planted crop blocks at the UCSC Farm (above and below).
Photos: Martha Brown



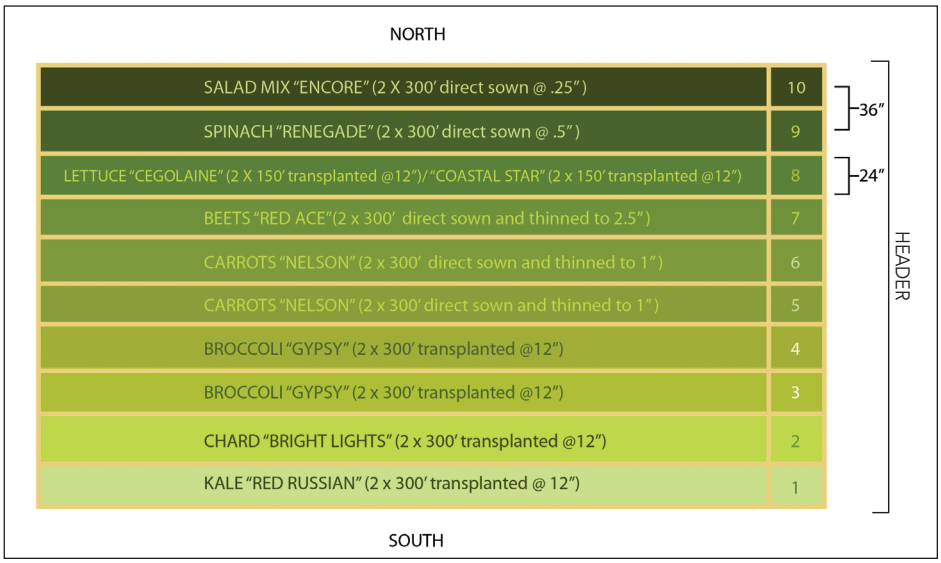


FIGURE 2. Crop block schematic, UCSC Farm.

TABLE 1: MIXED PRODUCTION BLOCK CROPS MATURATION CHART

CROP	DAYS TO MATURITY (APPROX)	PLANTING METHOD	MULTIPLE HARVEST
arugula	30	direct sown	
asian greens	60	direct sown	
beets	60	direct sown	
broccoli	60	transplant	
bunching onions	60	transplant	
cabbage	90	transplant	
carrots	60	direct sown	
cauliflower	90	transplant	
chard	60	transplant	
collards	70	transplant	yes
kale	60	transplant	yes
kohlrabi	60	transplant	
lettuce	60	transplant	
salad mix	30	direct sown	yes
spinach	40	direct sown	
radish	30	direct sown	
turnips	40	direct sown	

Mixed crop production blocks can also include a beneficial insectary row, depending on aphid pressure and surrounding habitat. A fast-blooming crop such as alyssum (transplanted) or annual buckwheat (direct sown) provides a nearby nectar source and habitat for beneficial insects as the crops mature.

Some tips for planning a mixed crop block:

- Designate an entire bed to each specific crop within the block. Although this can be challenging, especially when dealing with small lots of transplants, it will greatly facilitate irrigation uniformity and harvest efficiency.
- If you plant a mix of varieties of specific crops in a single bed (for example red, golden, and striped beets), use flags or other markers to delineate varieties.
- Put crops with similar days to maturity or harvest methods next to each other for ease of mowing and undercutting following harvest (Table 1).

To keep pace with product demand, plant a new mixed crop block every 10 to 14 days during the production season. Good recordkeeping facilitates future planting selections and schedules to meet specific harvest windows and to ensure consistent product flow. Track your production (harvest dates, yield) and how closely it meets your marketing plans and needs (for example, see Appendix, page 8). Keep notes on weather and other factors that influence crop growth, maturity dates, and product quality.

Other considerations in managing mixed crop blocks

Bed preparation and early season planting

When preparing beds for mixed production blocks, use the standard pre-irrigation and weed control sequence (e.g., Production Sequence — Summary, page 2). See the publication *Tillage, Bed Formation, and Planting to Moisture* in this Grower Guide series for additional details.

Note that early season production on California's Central Coast can be challenging during wet years, especially on heavier soils. Incorporating heavy residue legume/cereal cover crops and waiting for them to decompose can significantly delay initial plantings.

There are several ways to facilitate early plantings:

- Select locations on the farm that dry down early for initial block planting.

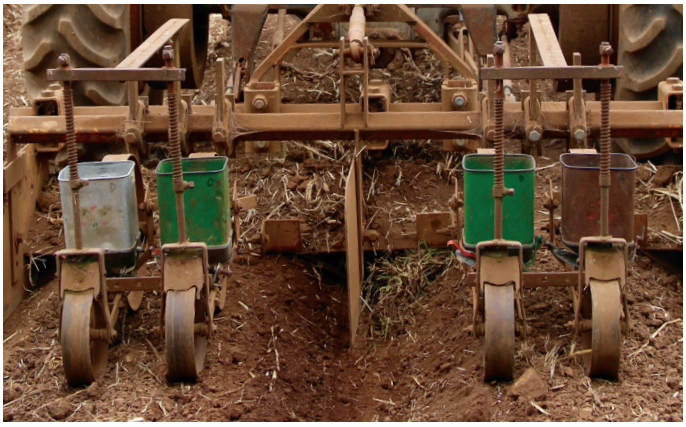


FIGURE 3. Planet Jr. tractor-drawn seeder (above) and push seeder (below) used for direct-sown crops. *Photos: Martha Brown*



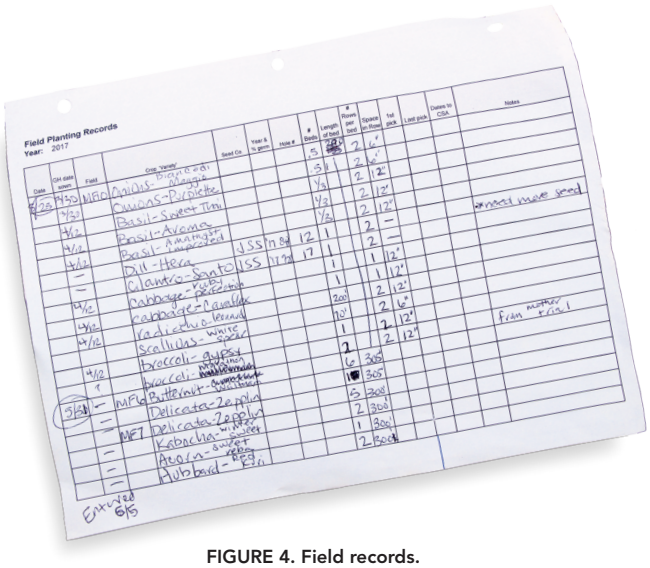


FIGURE 4. Field records.

- Use a winter cover crop that produces less biomass such as legumes or mustards that break down more quickly than mixes that include cereals.
- Use high tunnels for springtime season extension as a way to start the season earlier.

Direct sowing and transplanting

Depending on your scale of production, you can direct sow seeds using tractor-mounted or push-behind seeders designed to plant from one to six rows at a pass, e.g.:

- Planet Jr., one of the most commonly used and most versatile (Figure 3)
- Clean Seeder AP or Jang JP Series, best suited to precision planting of coated carrot seed
- Earthway seeder, very lightweight and inexpensive

Besides good seedbed preparation, two critical aspects of the direct sowing process are proper seed spacing to minimize thinning, and appropriate planting depth to ensure quick and uniform seedling emergence. Write down what you do so you can build on your own experience and inform future decisions: record the depth setting, the type of opening shoe used, and the plate hole size for all of the different seeds being direct sown (Figures 4, 5).

Transplanted crops need good root ball placement for even stand establishment. Small-scale farms can transplant seedlings by hand (Figure 6). As farms scale up, investment in equipment to increase transplanting efficiencies can be worth the cost. One of the simplest to set up is a transplant "sled" that consists of seats and plant tray holders on a three point mounted tool bar run behind a tractor (Figure 7). The unit provides a mark or an opening to drop the plants. Operators seated close to the beds drop the plants by hand into lines as the tractor moves slowly down the row.

The next step up in mechanization is a commercially available mechanical transplanter. These units are expensive, can be difficult to field adjust, and are therefore better suited to larger-scale production systems.



FIGURE 5. Selecting seed plates for direct sowing. *Photo: Martha Brown*



FIGURE 6. Transplanting seedlings at the UCSC Farm. *Photo: Martha Brown*



FIGURE 7. Transplant sled with seats.



Irrigation

Ideally, each mixed crop block has access to a dedicated irrigation riser with the capacity to supply adequate flow and pressure to run either overhead or drip irrigation. Overhead irrigation is most effective for pre-irrigating beds and "watering in" crops immediately following planting because it wets the soil quickly, but if water is limited, direct sown and transplanted crops can be watered in using only drip irrigation.

Apply water as soon as possible following transplanting to limit transplant shock and get the seedlings off to a good start; when planting out a block that has both direct sown crops and transplants, do the direct sowings first. Assuming there is adequate moisture deeper in the soil, once the crops are established, remove the overhead irrigation lines and initiate weed management strategies prior to installing drip tape—by 2 weeks after planting and initial irrigation.

A common mistake made by inexperienced growers is to apply excess irrigation water during the initial establishment phase of the mixed crop block. Over-watering has the potential to:

- increase production costs (especially where the cost of water is high)
- create surface crusting, which limits plant emergence and growth, and impedes good weed management
- increase weed emergence
- leach nutrients below the root zone—especially on lighter-textured soils

Irrigate initially just enough to get good emergence on the direct-sown crops and root establishment on the transplanted crops; 2–3 waterings per week until plants are well established. Irrigation frequency will depend on soil and weather conditions.

Once plants are established, irrigation within the block is set at two different schedules. Direct-sown crops need shorter but more frequent irrigations (2–5 day intervals, with water quantity and interval gradually increasing as the crop matures). Transplanted crops receive 25% of evapotranspiration (Et) for a week or two and then 50% of Et (see cimis.water.ca.gov for local Et rates). At full canopy, a typical mixed crop block crop in the Central Coast region uses no more than 1.5" of water per week.

Another common mistake is to under apply irrigation water to crops in full canopy. Superficial watering limits the crop's ability to access water and nutrients deeper in the soil profile. Use a soil probe to check moisture in the root zone of deeper rooting crops.

Initial weed management

As direct-sown crops emerge, annual weeds also come up in response to irrigation. Use stirrup hoes (hula hoes) to eliminate newly emerged weeds on the bed tops while they are still very small (Figure 8). If soil conditions are right (soil relatively dry and friable), a weeding crew can quickly move through the field and eliminate all of the weeds in and around the growing crops. Follow this hand weeding with mechanical cultivation of furrows and bed sides to eliminate weeds.

The best option for mechanized weed management is a tractor-mounted, three-point or belly bar cultivator (or both) to undercut weeds in the furrow bottoms, bed sides, and even the bed top using precisely adjusted knives and sweeps. Depending on soil type, you may need crust breakers to break soil crust ahead of knives. This mechanical cultivator set up, adjustment, and operation takes time, skill, and care, but will save many hours of tedious hand work. During this cultivation, run small furrow chisels behind the tractor tires to mitigate potential soil compaction issues in the furrows that receive tire traffic. Crops tend to respond favorably to the shallow soil disturbance that results from cultivation. See the *Introduction to weed management in a small scale organic production system* video in Additional Resources for an example of this type of weed management.

Once the hand weeding and tractor cultivation are complete, wait for at least a day of sunny weather to ensure desiccation and effective "kill" of the recently undercut annual weeds, then install and run the drip irrigation lines. On most soil types, a single line of drip tape between plant lines set 10–14" apart is adequate, assuming establishment was achieved with overhead irrigation (Figure 9). The crop canopy will close quickly and, assuming your weeding was effective, there should be only minimal weed pressure throughout the



FIGURE 8. Use hula hoes to control weeds on bed tops when they are still small (bottom). *Photo: Jim Clark*



FIGURE 9. Drip tape on beets and kale at the UCSC Farm. *Photo: Martha Brown*

remainder of the crop cycle. Note that if perennial weeds and/or grasses are present, additional hand and tractor work may be needed to keep them in check and to minimize crop-weed competition.

Post harvest weed management

Following harvest of some of the earlier-maturing crops in the mixed crop block (e.g., spinach, salad mix, radishes), stop irrigation on those beds, remove the drip line, mow the remaining crop residue, and undercut the bed with a "weeder" bar to terminate any weed growth and minimize the chance of weed seed set.

Once harvest is complete, the entire block can be tilled and prepared for the subsequent crop cycle or cover crop. When cultivating, run chisels in the furrows to break up tractor tire compaction. This will facilitate all follow-up undercutting and tillage operations, minimize clod formation, and improve water-holding capacity.

ADDITIONAL RESOURCES

Introduction to weed management in a small scale organic production system (video). Produced by the Center for Agroecology & Sustainable Food Systems. www.youtube.com/user/casfsvideo

Knock weeds out at critical times, by Mark Schonbeck. eOrganic, 2010. articles.extension.org/pages/18882/knock-weeds-out-at-critical-times

Quick and easy annual insectary rows, Jane Kuhn, May 8, 2016, Tend blog website www.tend.ag/blog/quick-easy-annual-insectary-rows.html

Teaching direct marketing and small farm viability: Resources for instructors, edited by Jan Perez, Martha Brown, and Albie Miles. 2015. See Unit 3: Community Supported Agriculture (CSA) for details on crop planning. casfs.ucsc.edu/about/publications

Organic Mixed Production Blocks for Direct Markets on California's Central Coast: A Guide for Beginning Specialty Crop Growers by Jim Leap, Kirstin Yogg-Comerchero, and Darryl Wong. Edited by Ann Baier and Martha Brown.

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Additional Grower Guides are available online at casfs.ucsc.edu/about/publications. This publication was supported by the Specialty Crop Block Grant Program at the U.S. Departmentof Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

Photos, p. 1: Elizabeth Birnbaum (left), Abigail Huetter (right)

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APPENDIX: PRODUCTION SCHEDULE, ECONOMIC DATA

Crop day	Sub Crop	# beds (1 bed = .02ac)	Action	work rate (hr/ac)	fixed rate (hrs)	Total labor cost @ $16.10/hr	Total machine cost @ $21.70/hr	Harvest Amt.	Harvest Value
-25		10	Flail Mow:heavy	2.5	0.2		$15.19		
-25		10	Spade	4.8	0.2		$25.17		
-11		10	Mark Lines	2.0	0.2		$13.02		
-11		10	List	1.3	0.2		$9.77		
-11		10	Overhead Irr:set up	3.8		$12.08			
-10		10	Overhead Irr:run		0.5	$8.05			
-1		10	Light cultivation	1.3	0.2		$9.77		
-1		10	Shape/Seed CSA	3.0	0.2		$17.36		
0	Transplants	5	Transplant:2 line	116.0	0.5	$194.81			
0		10	Overhead Irr:run		0.5	$8.05			
1		10	Overhead Irr:run		0.5	$8.05			
4		10	Overhead Irr:run		0.5	$8.05			
7		10	Overhead Irr:run		0.5	$8.05			
11		10	Overhead Irr:break down	3.8		$12.08			
11		10	Cultivate	2.0	0.2		$13.02		
11		10	Drip:set up	10.0	0.25	$36.23			
11		10	Hoe:2 line	72.6		$233.77			
12-50	Salad Mix/Spinach/Lettuce	3	Drip:run x 2/wk @ 5 wks		0.3	$24.15			
12-70	Broccoli	2	Drip:run x 2/wk @ 8 wks		0.3	$38.64			
12-90	Beets/Carrots/Chard/Kale	5	Drip:run x 2/wk @ 11 wks		0.3	$53.13			
21	Beets/Carrots	3	Thin	121.0		$116.89			
21	Salad Mix/Spinach	2	Hand Weed:small weeds	74.5		$47.98			
21	Transplants	5	Hand Weed:big weeds	8.0		$12.88			
			Week 6 Harvest						
42	Salad Mix	1	Harvest x 2	290.4	0.5	$54.80		73	$290.40
42	Spinach	1	Harvest x 2	290.4	0.5	$54.80		87	$348.48
42	Lettuce	1	Harvest x 2	193.6	0.5	$39.22		232	$348.48
42	Chard	1	Harvest x 2	121.0	0.5	$27.53		145	$363.00
			Week 7 Harvest						
49	Salad Mix	1	Harvest x 2	290.4	0.5	$54.80		73	$290.40
49	Spinach	1	Harvest x 2	290.4	0.5	$54.80		87	$348.48
49	Lettuce	1	Harvest x 2	193.6	0.5	$39.22		232	$348.48
49	Kale	1	Harvest x 2	121.0	0.5	$27.53		145	$363.00
			Week 8 Harvest						
56	Beets	1	Harvest x 2	106.5	0.5	$25.19		48	$119.79
56	Chard	1	Harvest x 2	121.0	0.5	$27.53		145	$363.00
60	Salad Mix/Spinach/Lettuce	3	Undercut	2.0	0.2		$6.94		
60	Salad Mix/Spinach/Lettuce	3	Flail Mow:light	1.3	0.2		$5.97		
			Week 9 Harvest						
63	Broccoli	2	Harvest x 2	68.5	0.5	$30.09		192	$383.33
63	Beets	1	Harvest x 2	106.5	0.5	$25.19		48	$119.79
63	Kale	1	Harvest x 2	121.0	0.5	$27.53		145	$363.00
			Week 10 Harvest						
70	Broccoli	2	Harvest x 2	68.5	0.5	$30.09		192	$383.33
70	Beets	1	Harvest x 2	106.5	0.5	$25.19		48	$119.79
70	Kale	1	Harvest x 2	121.0	0.5	$27.53		145	$363.00
70	Carrots	2	Harvest x 2	154.9	0.5	$57.92		155	$387.20
			Week 11 Harvest						
77	Beets	1	Harvest x 2	106.5	0.5	$25.19		48	$119.79
77	Kale	1	Harvest x 2	121.0	0.5	$27.53		145	$363.00
77	Carrots	2	Harvest x 2	154.9	0.5	$57.92		155	$387.20
			Week 12 Harvest						
84	Carrots	2	Harvest x 2	154.9	0.5	$57.92		155	$387.20
90	Broccoli/Chard/Kale/Beets/ Carrots	7	Flail Mow:light	1.3	0.2		$8.14		
90	Broccoli/Chard/Kale/Beets/ Carrots	7	Undercut	2.0	0.2		$10.42		
110		10	Disc:x1	0.5	0.2		$6.51		
-		10	Drill/Cover Crop	1.6	0.2		$11.28		
					Sub-total:	$1,620.43	$152.55	*Sub-total:*	$6,560.14
					Labor + Machine Cost:	***$1,772.98***			

Harvest Assumptions	*Salad Mix*	*Spinach*	*Lettuce*	*Beets*
Unit	#	#	hds	bu.
Harvest (unit/acre)	7,260	8,712	23,232	9,583
Harvest (unit/row foot)	0.25	0.3	0.8	0.33
Harvest Window (weeks)	2	2	2	4
Harvest Rate (unit/hr)	25	30	120	90
Harvest (hr/ac)	290.4	290.4	193.6	106.5
Price ($/unit)	4	4	1.5	2.5
Revenue ($/acre)	$29,040	$34,848	$34,848	$23,958

Item	***Cost per unit***	***Cost per acre***
Starts	$.025/plant	$726.00
Drip Tape	$120/7500'	$232.32
Rubber Bands	$91.25/bx	$91.25
Boxes: Broccoli	$2.067/box	$651.11
Boxes: Cilantro	$1.186/box	$474.40
Boxes: Romaine	$2.589/box	$569.58
Perforated Liners	$85.05/1000 liners	$85.05
Total Expenses (per acre):		***$2,829.71***

Per Acre Totals	
Income:	$32,800.68
Labor + Machine Cost ($)	-$8,864.92
Expenses	-$2,829.71
Production Profit:	**$21,106.05**

California Farm to Fork Mobile Farm Business Plan

California Department of Food and Agriculture
Office of Farm to Fork

January 2016

CALIFORNIA DEPARTMENT OF
FOOD & AGRICULTURE

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Executive Summary

The California Office of Farm to Fork was established in the California Department of Food and Agriculture in 2014[1]. The Office of Farm to Fork (F2F) is charged with increasing access to healthy foods for underserved communities and schools in the state of California. Currently F2F collaborates with two other state agencies, the California Department of Education (CDE) and the California Department of Public Health (CDPH). F2F also partners with many community organizations and programs that support local food systems and make healthy, nutritious food available to all residents of California.

Currently, at least 353 California school districts engage in Farm to School activities[2]. There are several organizations that work to incorporate food and nutrition education into Common Core and institute sequential standards based curriculum. One of the most effective ways to deliver this type of education is through the use of school gardens. Research has demonstrated that school gardens positively impact children's food choices by improving their preferences for vegetables and increasing their nutrition knowledge[3]. Furthermore, school gardens and structured garden-enhanced nutrition education curriculum have resulted in increases in students' fruit and vegetable consumption, improvements in student attitudes towards fruits and vegetables, increases in school meal participation and improved job satisfaction and staff retention[4].

Building and maintaining school gardens requires substantial resources. This includes time from already stressed staff, adequate space and finances. As a result, many schools, especially those in low-resourced settings, are unable to support school gardens and children are unable to receive their benefits.

In order to address this problem, F2F plans to build a Mobile Farm so that all students can benefit from hands-on learning experiences about where their food comes from, how it is grown, and other aspects involved in farming as well as tasting and learning about the nutrition of the food grown. The Mobile Farm will travel around California and provide underserved schools with an opportunity in which students can experience hands on learning they might not benefit from otherwise.

The Mobile Farm will house various interactive stations on subjects such as water, composting & vermiculture, beneficial bugs, and nutrition education. Each will have an interactive display providing information to students as well as components for hands on learning. For example, the composting & vermiculture station will have compost at various stages of breakdown for children to observe and work with. Depending on the grade level, concepts can range from very basic to more complex. If working with kindergarteners, the topic might be about compost critters, what they do and trying to identify them in the soil. More complex concepts for those in high school might take a look at the microorganisms involved in food degradation, the importance of temperature, pH, etc. and their implications for soil health.

Company Analysis
Farm to Fork has worked on various grants and projects focused on school gardens. We have worked extensively with the Pittsburg Unified School District's (PUSD) Child Nutrition Director, Matthew Belasco, to expand his now 10 school gardens as well as assist in local food procurement. F2F has worked with Belasco for the past two and a half years to help obtain funding for various farm to school activities. F2F has written several grants on behalf of PUSD to the Captain Planet Foundation, Lowe's Garden Grant, Whole Kid's Foundation Grant, etc. All but one of the grants have been funded for various garden expansion and enhancement projects like starting a hydroponic garden at the high school.

Farm to Fork recently launched the California Farmer Marketplace which is a free state-run website that helps reduce communication barriers between school food service and farmers. The Marketplace offers farmers the opportunity to post products and connect directly with school food service to increase the amount of California grown and produced foods on school lunch trays.

Farm to Fork was also involved with creating an asset map of various farm to fork activities occurring throughout California. In conjunction with USDA, F2F brought organizations together who are involved in different areas of the farm to fork movement, one of which was farm to school. This group identified and described projects taking place as well as determined gaps in this area. One of the gaps identified was lack of implementation of sequential based nutrition education in schools as well as a lack of nutrition education training educators receive. The construction of the Mobile Farm has the ability to address both of these concerns. With the Mobile Farm, we will use educational materials already developed and tested for grades K-12 in our areas of focus (see Appendix) as well as develop new materials when necessary. The F2F team and our collaborators have years of experience in the development and implementation of appropriate nutrition education for school age children. This takes the burden off of already overworked teachers trying to learn and create extensive nutrition education material.

Industry Analysis
We will make the Mobile Farm available to all California school children in K-12 -- totaling over 6.2 million students[5]-- but prioritize school children with limited access to school gardens. With the passing of the Healthy, Hunger-Free Kids Act of 2010 there has been more money directed at helping schools prepare and serve healthier school meals. Since 2012, USDA has awarded $15.1 million in grants to 221 Farm to School projects in 49 states[6]. There is also a plethora of smaller school garden grants that are available, indicating the need and desire for garden-based education. This type of consistent investment is a good indication of where the market is going in the future with other farm to school initiatives and funding sources.

The benefits of school gardens are numerous; they not only improve academic achievement but they also positively impact child health and nutrition. School gardens improve student academic achievement. Students who have school garden programs incorporated into their science curriculum score significantly higher on science achievement tests than students who are taught by strictly traditional classroom methods[7]. Studies have also shown that students involved with school gardens generally take pleasure in learning and show positive attitudes towards education[8,9]. This is important for longevity of student learning and academic achievement.

School gardens have also shown to have a positive impact on children's health in both the short and long term. Children who are familiar with growing their own food tend to eat more fruits and vegetables, and are more inclined to continue healthy eating habits through adulthood[10, 11]. The earlier school gardens are introduced to students and the longer they continue throughout their learning, the greater the impact of those benefits for their lives and the lives of others around them.

Competitive Analysis

Our primary competitors are schools that already have school gardens. Since they already have a garden present on campus, they can structure various classes around it and don't have similar needs of other schools lacking gardens. That being said, with the Mobile Farm, everything will be set up, ready to use and already have age appropriate learning stations set up for students. This mitigates the need for teachers to take up even more time out of their already hectic schedules to create or find new lesson plans. The Mobile Farm will also include stations on topics that might not be easy to implement even with a school garden, like water conservation and the use of hydroponics to grow food.

Another source of competition are other mobile learning centers focused around agriculture. One of the most well-known is the Mobile Dairy Classroom created by the Dairy Council of California. Though their lesson plans have an agricultural focus, they are fundamentally different from Farm to Fork's Mobile Farm, which will focus on specialty crops and not dairy and dairy farms. The Mobile Dairy Classroom also is only able to visit schools once every 3 years. The Mobile Farm will ideally make several trips to the same school in one year provided there is adequate funding for annual operating costs of the Mobile Farm and its support staff.

Other fieldtrip opportunities directly to farms or other agricultural focused centers are also a source of competition. Students are able to see farming in real time and have a better sense of what it looks like to grow food as well as who grows the food. The disadvantage of farm visits is that the teachers and/or parents have to coordinate the off-campus visit. The Mobile Farm comes directly to the school, with the added benefit of being able to offer multiple classrooms the opportunity to visit at different times so students get a more personalized learning experience.

Even given all of these competitors, the market is still underserved. There are enough schools without school gardens or the ability to do farm visits that given we only visit those schools, we would still not fill the need that is out there.

Customer Analysis

Our general audience is all California school children in K-12, totaling over 6.2 million students[3]. Our target audience are those children in schools that are particularly underserved. Children and youth today are less active, consume more fat and sweetened beverages, and eat fewer healthy foods, especially fruits and vegetables, than children of previous generations. Alarmingly, only 51 percent of today's children and youth eat even one serving of a fruit or vegetable each day.[4] Studies have shown that after gardening, children have more positive attitudes toward fruit and vegetable as snacks[12]. Many children also do not have a deep appreciation and understanding of where their food comes from or what it takes to be produced. School gardens are an effective solution to tackle this challenge. Children who are familiar with

growing their own food tend to eat more fruits and vegetables[10], and are more inclined to continue healthy eating habits through adulthood[11].

Marketing Plan
Farm to Fork will reach target customers (school children in K-12) through their partnership with CDE. This will be done through a mass email to all of the School Districts in California.

Another way F2F plans to market the Mobile Farm is through both of their home websites (cafarmtofork.com and cafarmermarketplace.com). The California Farmer Marketplace caters to school nutrition food service directors. The traffic to the California Farm to Fork website from January 1, 2014 to November 30, 2015 was nearly 13,000 entrances to the website. The majority of this traffic occurred from the end of April 2015 to November 30, 2015.

Farm to Fork also plans on marketing the Mobile Farm through word of mouth. F2F has strong connections with several school districts who are at the forefront of the Farm to School movement and who other school districts turn to for best practices and other information. F2F will market themselves heavily to food service directors, as well as the superintendent, of those districts to make inroads to other schools. F2F will also reach out to partner organizations like USDA's Farm to School Team for the Western Region, the California Farm to School Network and the California Foundation for Ag in the Classroom, as well as others who work with various school districts throughout California.

Management Team
The team at F2F has years of experience with farm to school activities including; developing materials and resources for best practices, procuring funding, and collaborating with other state and nonprofit agencies (see Company Analysis). F2F is also composed of several individuals with their master's in public health, registered dietitians, as well as a past organic farmer.

Operations Plan
Farm to Fork's action plan for the Mobile Farm project is to determine scholastically appropriate materials for students in K-12. There are already numerous valuable resources for teachers that meet common core standards centered on school gardens and agriculture. Therefore, F2F will select appropriate resources and design lesson plans as needed.

Once F2F decides on the curriculum and the design details, the next part of the action plan is to purchase the bus or trailer. In order to create the Mobile Farm we need a builder and visionary with experience in designing innovative interactive displays. Ideally we would also like someone with background knowledge of agriculture and how best to bring it to life in a small space.

In the long term, if we are able to obtain funding for our Mobile Farm, we would need to have someone drive the Mobile Farm to the various school sites as well as someone to help facilitate "classroom" learning. In the future we could reach out to other agencies like Food Corps and Ag in the Classroom to determine their interested in collaborating on the project.

Financial Plan
The Mobile Farm is estimated to cost anywhere from $600,000 to $1.2 million. This includes the purchase of a new bus or truck and trailer. The higher projected cost is largely incorporating

advanced cinema to introduce students to the concepts being presented at the various learning stations. The $1.2 million budget could include using recognizable voices from actors.

Estimated Costs

Bus/Trailer + Truck (new)	**$200,000**
Design & Technology Integration Plan	**$60,000**
Building Materials	**$40,000**
1. Nutrition	$10,000
a. Hydroponics	$5,000
2. Composting & Vermiculture	$10,000
3. Beneficial Bugs	$10,000
4. Water	$10,000
Advanced Cinema	**$230,000 to $750,000**
1. Televisions	$10,000
2. Other tech equipment	$20,000
3. Content development	$200,000
a. Voice overs (Hollywood)	$500,000
Operating Costs (annual)	**$100,000**
1. Gas	$10,000
2. Electricity	$9,000
3. Labor	$70,000
4. Insurance	$6,000
5. Other	$5,000
Total	**$630,000 to $1,130,000**

For this particular project we are reaching out to various high tech companies in the bay area, like Google, to help produce the video series associated with each of the exhibits for the different grade levels. If F2F were able to get time and technical resources donated, this would significantly bring down the cost of the initial investment in the Mobile Farm.

In recent years there has been a big move of technology companies into agriculture[13]. We are hoping to collaborate with such a company to help bring cutting edge information to the Mobile Farm as well incorporate tried and true lesson plans, like taste testing various produce items grown.

The yearly operating costs of the Mobile Farm are estimated to be around $100,000, depending on demand from school districts, impacting travel time and person time necessary to run the Mobile Farm. This cost could be mitigated through use of volunteers and collaboration with other agencies.

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Appendix

Educational Resources

Water	Water.org, Water Education Foundation, California Foundation for Ag in the Classroom.
Composting & Vermiculture	Collective School Garden Network, LifeLab, The Edible Schoolyard Project.
Beneficial Bugs	The Edible Schoolyard Project, California Foundation for Ag in the Classroom.
Nutrition Education	CDE, CDPH-NEOPB, Collective School Garden Network, LifeLab, USDA, Dairy Council of California, California Foundation for Ag in the Classroom, The Edible Schoolyard Project.

Wild Willow Farm Field Trip: Student Feedback

All of our tour guides were so informative and are truly passionate about what they do. A new fact I learned was that you should rotate our soil after you are done harvesting to prevent the nutrients in the soil from depleting. My group was taken to the vegetable garden where my friend got the opportunity of pulling a beet out of the ground. I was really happy to see Fennel growing there because I have used it in my culinary competition. Going into the greenhouse and seeing all the herbs got me really excited because I use Rosemary and lavender in my dishes at home. It was nice to see them in soil and inspired me to even grow my own. I enjoyed using my knife skills to cut beets for our stir fry which was delicious. I will definitely go back to volunteer in the future.

Maria Renteria- 12th grade

My experience at Wild Willow farm was an enjoyable hands-on experience. I thought it was unique in the sense that it was an educational center as well as a farm. In the culinary arts class I take at Scripps Ranch High School I've learned a lot about the importance of food and nutrition. By going on a field trip to a prosperous farm my knowledge of eating real/clean food was dramatically increased. I want to grow my own garden now, because I learned that homegrown food has a better taste than food from a local grocery store. I've been encouraged to purchase food from a local farm because it would feel much better to support a local business rather than a big corporation. The workers there work hard and our extremely knowledgeable about food, therefore, they deserve as much business as they can get.

Juliette- 12th grade

Upon arrival to the Wild Willow Farm the instructors of the educational facility were inviting and welcoming. They seemed to be very enthusiastic about educating us about the plants and produce. Prior to this experience I did not know that bats were nocturnal pollinators or that beet leaves and chard leaves were similar to one another. Every minute of the trip we were encouraged to interact with our surroundings. They even demonstrated to us how root plants such as beets depend on space for growth by allowing two of us to pull out two different “ready” beets. The smaller beet seemed ready even though it wasn’t. It simply did not have enough space to fully grow. Also, I learned that root plants should not be transported because that weakens the plants. This opportunity allowed me to not only learn about where the food I eat comes from, but also to escape my materialistic, technological world for four hours. I appreciate all the time and effort that the educators spent to teach us about our food.

Jenna Nguyen – 11th grade

We have had a couple of field trips, through culinary arts class, but this one to Wild Willows Farm will be a memorable one for years to come. As I walked out the school bus I took a deep breath in and felt a refreshing sent of nature which you do not get around the city. We were greeted by polite farmers who were full with energy. On the tour through the farm we experienced and learned many new activities that I personally have not had the opportunity of experiencing. As the trip came to an end it was surprising to taste the delicious stir fry that was prepared, due to the richness in the flavors with the fresh vegetables that were used. The most memorable part for me personally was the learning about different types of carrots that exist, most which I did not know or have heard of, and the difference in taste between store bought carrots to freshly picked ones. This trip was absolutely amazing, not only did we have fun but we learned a lot and were educated. I can say that I am proud of not taking this trip for granted like other student who chose not to attend.

Alejandro Sanchez – 11th grade

Going into this field trip I did not expect it to be like how it was. I walked into the entrance of the dining area/ kitchen and I immediately felt very materialistic for having my phone out and taking selfies on my phone. The people that were leading us in this tour seemed to be very "all natural" and in touch with the land around them. As they lead us around the farm I learned a lot about how a farm produces their food and about different tips for how to maintain a farm. We also got to pick some of the vegetables and I got to help stir fry it. This experience was beneficial and insightful because I got to learn about agriculture and about the origin of our food.

David Cha – 11th grade

SCB14021 Attachment 1

LOCAL PRODUCE PROCESSING IN THE OAKLAND UNIFIED SCHOOL DISTRICT CENTRAL KITCHEN

A Comprehensive Assessment of Local Fruit and Vegetable Sourcing, Processing and Vending Opportunities at the Oakland Unified School District Central Kitchen

Acknowledgements

The Community Alliance with Family Farmers (CAFF) would like to thank Oakland Unified School District Nutrition Services for funding and supporting this **Comprehensive Assessment of Local Fruit and Vegetable Sourcing, Processing and Vending Opportunities at the Oakland Unified School District Central Kitchen.**

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Executive Summary

Oakland Unified School District (OUSD) Nutrition Services and the Community Alliance with Family Farmers (CAFF) worked together from 2015-2017 to a) conduct an in-house produce processing feasibility study to inform the development of the OUSD Central Kitchen to maximize local produce procurement and processing, and to b) assess potential for sales from OUSD to nearby food service customers. Data was drawn from technical review, economic analysis and interviews to determine feasibility, with the goal of increasing purchases from local, family-owned farms.

Research Questions:

- What best practices and/or models are comparable Central Kitchens employing to process local produce?
- How does the produce processing machinery used in comparable Central Kitchens contrast to the processing machinery planned for the OUSD Central Kitchen? What adjustments and/or recommendations are needed to meet OUSD's needs?
- What is the existing availability and cost of local produce purchased directly from family-owned farms?
- Which produce crops are most/least affordable to process in-house? Which crops are most/least affordable to purchase pre-processed?
- What are the interests and needs of potential customers for OUSD Central Kitchen external vending?

Research Findings:

- OUSD Nutrition Services can affordably process local produce in-house at the new Central Kitchen and has the capacity to shift up to $500,000 annually to local growers.
- Processing costs vary by produce item. Certain crops, like jicama and peppers, cost less to process than other crops, like zucchini and cucumbers.
- Processing equipment specified for use in the new Central Kitchen is adequate to meet OUSD's current needs, but larger processing machines should be considered to mitigate processing costs and increase processing volume in the future.
- There is strong interest among local agricultural growers and aggregators in selling produce directly to OUSD, demonstrated by responses to a 2016 Request for Information issued by Nutrition Services. Additional direct contact is needed to build a local supply network.
- While many local Bay Area institutions are interested in purchasing processed produce from OUSD, San Francisco Unified, West Contra Costa Unified, and People's Community Market are the best-suited customers for an initial vending pilot.

Introduction

Across the United States, a movement among school districts to re-localizing their food systems seeks to expand access to fresh, high quality food for students, engage students about the agricultural origins of their meals, and support local family farms and the local economy. Farm to school programs are as critical as ever for farmers. Small family farms, which make up 90% of farms and 24% of agricultural production, are struggling; US net farm income is expected to decrease for the fourth year in a row in 2017.[1] According to the 2015 USDA Farm to School Census, 42% of school districts surveyed participate in farm to school activities, and these districts report spending $789 million locally.[2] California school districts alone purchased $168 million from California farmers in 2015, with over 50% participating in farm to school activities.[3] In turn, farmers also benefit from farm to school programs, and report up to 15-20% greater returns for school sales.

Oakland Unified School District is a long-time leader in farm to school procurement and school meal improvement in California and nationwide. OUSD has partnered with CAFF since 2009 to assess and implement programs to increase local produce and chicken procurement. Student engagement is also a top priority, and OUSD has collaborated with Berkeley-based, Center for Ecoliteracy, to develop and expand *California Thursdays*™ and taste-test farm fresh recipes with students. The District boasts weekly farmers markets at 17 schools, featuring local and often organic produce. In 2016, OUSD won a Golden Seed "Harvest" Award from the California Farm to School Network, recognizing its lasting leadership across all three pillars of farm to school (gardens, procurement and nutrition education).[4] OUSD is presently ushering in a new chapter in farm to school, with the recent adoption of the Good Food Purchasing Policy and breaking ground on the new Central Kitchen, Instructional Farm and Education Center.

About OUSD Nutrition Services and The Center

Oakland Unified School District Nutrition Services (OUSD NS) provides meal service through the National School Meal Program for 85 k-12 schools and several charter schools throughout Oakland. OUSD offers breakfast, lunch, supper, and snacks and serves almost 40,000 meals per

[1] USDA Economic Research Service Ag and Food Statistics: Farming and Farm Income, 2017. https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/farming-and-farm-income/

[2] USDA The Farm to School Census, 2015. https://farmtoschoolcensus.fns.usda.gov/

[3] USDA The Farm to School Census: California, 2015. https://farmtoschoolcensus.fns.usda.gov/find-your-school-district/california

[4] California Farm to School Network Blog Post: "Introducing Your Golden Seed Award Winners,"2016. http://www.cafarmtoschool.org/introducing-your-golden-seed-awards-winners/#more-120822

day. Nutrition Services has approximately 250 employees and works to ensure all children develop healthy lifestyles that allow them to focus on academic achievement.[5]

The Oakland Unified School District Central Kitchen, Instructional Farm and Education Center will be the hub of a new district-wide school food program that connects nutrition, education and community programs at OUSD's schools, kitchens, gardens, and produce market stands. At the central kitchen and commissary, students will observe professionally trained cooks at work and see how to prepare approximately seven million meals each year for 38,099 school children. The farm and greenhouse will serve as a learning laboratory, where students will experience urban agriculture firsthand. The teaching kitchen will provide classes for students, nutrition service staff, and the community.[6]

OUSD Produce Processing Feasibility Study

The following report summarizes research findings collected between 2015 and 2017 by CAFF and OUSD. The report is divided into four sections:

1. OUSD Produce Processing Feasibility Study (pages 4-15)
    - Central Kitchen Research; Developing Future Farm Suppliers; Cost Analysis of Central Kitchen Processing vs. Current Purchasing
2. OUSD Processed Produce External Sales Feasibility Study (pages 15-17)
    - Analysis of Potential Customers
3. Conclusion (pages 18-19)
4. Appendixes (pages 20-41)

OUSD Produce Processing Feasibility Study

Central Kitchen Research

Central Kitchen Research Goals

- Research similar central kitchens in Northern California and nationally to understand best practices.
- Assess and compare OUSD Central Kitchen design and plans to similar central kitchen models.
- Make recommendations for OUSD Central Kitchen practices and specified equipment based on case studies.

[5] OUSD Nutrition Services Overview, 2015. https://www.ousd.org/Page/934
[6] OUSD NS The Center Project Information, 2017. http://www.ousdthecenter.org/project-information.html

Interviews and tours were conducted with five local school districts and the UC Davis Dining Services Culinary Support Center (CSC), the campus central kitchen, all with diverse operations. While each had unique advantages, none were exclusively machine-processing fruits and vegetables and most were doing little prep beyond cutting oranges and apples. They each expressed similar challenges: pre-processed produce is readily available and affordable, and limits the responsibility and liability inherent in processing large volumes of whole produce.

The closest central kitchen in volume, machine processing capacity and scope to OUSD was the UC Davis CSC. The UC Davis CSC was opened in 2005 under Chef Bob Walden of Sodexo, a third-party foodservice management company. The CSC team has identified a list of produce items (local and conventional) that are more cost effective to process in-house than to purchase pre-processed. To differentiate the processing abilities of each machine, the CSC team employs a "chop guide" to categorize items processed by each machine and by hand. The team also relies heavily on the vegetable washer, and recommended all equipment in the processing area be elevated on wheels to facilitate easy cleaning and configuration. The CSC team estimates end-of-shift cleaning takes approximately one hour per day.

While the OUSD Central Kitchen and the UC Davis CSC have similar production capacities, the CSC uses a Robo Coupe CL60 and Urschel G-A, both larger than the counterparts specified in the OUSD Central Kitchen plans. OUSD Nutrition Services followed up with contracted designers and suppliers to request a comparison of the items, volumes of production and prices for the currently specified Hobart, Hallde and Robo Coupe processing machines, as well as the machines currently used at the UC Davis CSC - Robo Coupe CL60 and Urschel G-A (See Appendix A-2). While the larger processing machines would significantly add volume capacity and enable processing additional produce items, the cost of the machines is prohibitive and capacity unnecessary in the initial design phase. As a result, OUSD Nutrition Services and CAFF recommend building the electrical and layout requirements for the larger machines, and subsequently reassessing the Central Kitchen equipment budget upon opening and expansion.

In addition to the processing equipment variation described above, the UC Davis CSC uses one industrial vegetable washer, while two are planned for the OUSD Central Kitchen. The UC Davis CSC recommends reducing to one washer as a single unit has easily met their washing needs. OUSD Nutrition Services and CAFF recommend removing the additional washer from the design plans to reallocate funds to the aforementioned processing machinery and/or other needs.

Natomas Unified School District provided the best example of volume hand processing by foodservice staff in their Central Kitchen and should be consulted for future planning for the OUSD Central Kitchen. Elk Grove Unified, Davis Joint Unified, West Contra Costa Unified, and Lodi Unified were also interviewed.

Recommendations:

- Add higher volume Robo Coupe CL60 and Urschel G-A/Sprint 2 to electrical and layout designs and future investment plans.
- Shift to one large vegetable washer.

- Consider and regularly reassess machine processing capacity and variable produce pricing when determining cost comparison of pre-processed vs. central kitchen processed produce.

Developing Future Farm Suppliers

Develop Future Farm Suppliers Goals

- Determine OUSD Central Kitchen produce product list.
- Develop and publicly advertise a Request for Information for produce from local farmers and aggregators.
- Develop an extensive list of growers and support organizations to contact when seeking suppliers.
- Evaluate RFI process and potential growers for cost and future purchasing.

OUSD Nutrition Services and CAFF developed a Request for Information and outreach process to identify potential local family farms and vendors to supply the OUSD Central Kitchen with unprocessed local fruits and vegetables, as well as compare the costs of pre-processed and in-house processed produce. A Request for Information is an informational survey used to indicate interest and provide availability and pricing to be considered in future bids for selection by OUSD.

RFI language was developed to announce OUSD's intent to purchase from local farms and seek information from farms based on sourcing and operations preferences.

The RFI included:

- An explanatory announcement letter to provide background information.
- An introduction to the RFI, including a definition of "local."
- An explanation of the selection process and OUSD Nutrition Services' purchasing priorities, including: Experience, Customer Service, Quality, Food Safety, Production Specifications and Pack Sizes, Traceability (Farm Name), Delivery, Insurance, Invoicing/Payment and Competitive Pricing.
- A corresponding response section, including questions about the priority areas, including fertilizer and synthetic/chemical application.
- A "Local Produce Availability and Pricing" response section to track availability, price, and product information.

The Produce RFI was created to explicitly request information from growers and vendors that can provide grower identity, demonstrate ecologically sound growing practices and are located within 250 miles of OUSD. Food Safety Plan information was required; however, third party food safety certification was not, in an effort to expand access to potential farmer suppliers which meet State and Federal food safety requirements but are not selling in markets that require third party food safety certification.

Two RFIs were created during the project in downloadable electronic form and using an online Google Forms survey. The first had a bound timeframe and did not requiring price and volume estimates in the initial form, but were subsequently requested. After our initial outreach and

following the delay of the OUSD Central Kitchen opening from fall 2017 to fall 2018, a second RFI version was created, without a strict response deadline, which required price and volume estimates. OUSD Nutrition Services consulted with District legal counsel to ensure both RFIs complied with District, State and Federal procurement policies.

After compiling responses from the RFIs, a product list was developed from current and potential produce preferences to identify items for which farms could submit information (See Appendix A-4-1). OUSD Nutrition Services and CAFF identified 55 items and generic item categories (i.e. melons), and requested farmers submit variety, pack size, average estimate price from 2015-2016, weekly volume, and availability dates. Prices from 2015-2016 were used to standardize price comparisons against current purchasing.

In order to engage potential farmers for Central Kitchen research and future sourcing, CAFF used the following resources:

- The CAFF Farm to Cafeteria network of farmers currently selling directly to school districts.
- The CDFA California Farmers Marketplace[7] website.
- The County Agricultural Commissioners' offices for every county within a 250-mile radius of OUSD.

Over 200 farmers were contacted directly via email and follow up phone interviews were conducted with the sixteen farms that responded to the RFI. An unknown number of additional farmers were reached via various distribution lists, including Department of Agriculture and farm networks. County Departments of Agriculture maintain publicly available contact information on all registered farms in their areas, but do not maintain email addresses. Further outreach to these farms is recommended to expand the list of potential suppliers for the OUSD Central Kitchen.

Responses were received from sixteen farms, representing a total of 55 items available locally. Of the sixteen initial respondents, fifteen farms and aggregators provided volume estimates, and eight farms provided price estimates. Over 100 local California farms are represented by farm and aggregator respondents, at least 90 of which are family farms. Respondents include:

Aggregator and Food Hubs:

- ALBA Organics: Food Hub sourcing from ALBA and regional California family farms.
- Ag Link: School food hub aggregator in Ballico sourcing from California family and large-scale farms.
- Capay Organics: Grower/Aggregator of organic produce sourcing from family farms in Capay Valley and the Central Valley, California.
- Coke Farms: Grower/ Aggregator of organic produce from family farms in San Juan Bautista, California.

[7] CDFA Office of Farm to Fork, California Farmers Marketplace website, 2017. http://cafarmtofork.com/Marketplace.htm

- Top 10 Produce: Aggregator of organic produce from family farms in the Salinas Valley, California

Farms

- Bri's Greens – McArthur, CA
- Castlemont Organic Produce Farm – Oakland, CA
- JSM Organics – Royal Oaks, CA
- New Hope Farms Cooperative – Pinole, CA
- Pie Ranch – Pescadero, CA
- Rancho Azul Blueberries – Knights Ferry, CA
- Sunset Ridge Fine Fruits – Newcastle, CA
- Terra Firma Farm – Winters, CA
- Wild River Marketing – Marysville, CA

Several other farms and food hubs responded that they were interested in the RFI but were unable to provide complete information. However, the respondents represent a diverse group of regions and growers, including educational, urban and cooperative farms, and mid-scale growers.

Challenges

This RFI process illustrated the time consuming nature of providing price and availability estimates and farmers' general unfamiliarity with RFI processes. The electronic and Google Form RFI was accessible to responding farms, but added a level of formality that limited responses compared to direct contact via phone. Following the first round of outreach to growers, the Central Kitchen opening date was pushed to Fall 2018, beyond the time when many farms are able to plan and forecast. In addition, farms are expecting significant cost increases for labor and materials over the next several years, making production planning and meeting school price needs more difficult.

Recommendations

Farmer and aggregator respondents have the capacity to supply a variety of whole fruits and vegetables to the OUSD Central Kitchen. The suppliers align with OUSD's sourcing and distribution priorities and should be considered for future contracts. The RFI language and product list can be used for future OUSD Nutrition Services procurement documents. OUSD Nutrition Services should maintain relationships with respondents to update price and availability estimates. While the RFI provided an organized, streamlined process for farmers to provide information, more direct outreach, as well as coordination with food hubs, will be necessary to reach additional farmers and meet volume needs in the future.

Cost Analysis of Central Kitchen Processing vs. Current Purchasing

Analyze Central Kitchen Processing vs. Current Purchasing Goals

- Create total cost estimates for produce processed in-house using local produce available to Oakland Unified.
- Compare pricing of local produce processed in-house with prices of pre-processed produce from distributors.
- Illustrate price comparison to prioritize local produce processing in the OUSD Central Kitchen.

Analysis of 2015-2016 Target Crops

OUSD Nutrition Services and CAFF identified ten example produce crops currently purchased by OUSD to illustrate cost differences between in-house processing and pre-processed produce:

- Jicama
- Cucumber
- Onions
- Peppers
- Zucchini Squash
- Butternut Squash*
- Apples*
- Oranges*
- Lettuce*
- Melon*

Five of the ten crops (indicated with *) would be hand-processed at the Central Kitchen under current equipment specifications.

Highlights:

- Over 70% of onions, peppers, butternut squash, oranges, lettuce, and melons currently purchased by OUSD come from California, mainly from unidentified or large scale growers.
- Apples (33%), zucchini (19%) and cucumbers (29%) are the top three crops purchased from non-local sources in season by OUSD.
- Jicama (88%), cucumbers (71%) and apples (56%) are the three crops most often purchased by OUSD out of season.

Overall, OUSD's 2015-16 local California produce purchasing was strong at 63%, or over $800,000. Of this, $60,525, or 5% was purchased directly from local growers. This leaves roughly 40%, or $500,000 open to shift to California growers.

Table 1: Overall 2015-2016 Purchasing Analysis

Overall Total	Cs	$	%
Total Purchases	60409.5	$1,341,606.62	
Total L1 (Within 250 miles of OUSD)	37802	$801,755.49	60%
Total L1 Direct Purchase		$60,525.20	5%
Total L2 (Within California)	2707	$42,224.70	3%
Total CA Grown	40509	$849,761.19	63%
Total Non CA-Grown		$491,845.43	37%

Purchasing data for the five machine-processed selected crops was analyzed for seasonality and source. OUSD spent a total of $476,858 in 2015-2016 on these crops, with $290,150 (61%) purchased outside California and $105,917 (22%) purchased in season, but outside California. This $105, 917 represents the easiest purchases to shift, as the produce is available locally from family farmers in season and in alignment with the existing OUSD menu cycle.

Table 2: Example Crop Seasonality and Sourcing Analysis 2015-2016

Example Crops (See list on page 7 above)	**Cases**	**Total Purchasing ($)**	**Total Purchasing (%)**
Total Purchases	19726.5	$476,858.26	
Total L1 (Within 250 miles of OUSD)	7835	$170,731.16	36%
Total L1 Direct	-	$60,525.20	5%
Total L2 (Within California)	1064	$10,196.40	2%
Total CA Grown	8899	$186,708.56	39%
Total Non CA-Grown	10827.5	$290,149.70	61%
Potential CA Grown - Purchased in Season not CA	3905	$105,916.65	22%
Purchased Not in Season	6923.5	$184,233.05	39%

For each crop, average price per pound for pre-processed product purchased in season was tabulated. Average price for whole local produce was calculated based on responses from farmers and aggregators to the RFI (see page 6), as well as the average processing cost per pound, explained below. Total spend for currently purchased pre-processed produce in season was then compared to the estimated total average for local produce processed in the Oakland Unified Central Kitchen, as illustrated in Table 3. The total cost variance illustrates items that OUSD NS should consider processing in-house based on cost. (Least costly items highlighted in **bold green**.)

Table 3: OUSD Select Crop Analysis 2015-2016 (5 Example Crops)

Example Crops	Jicama	Cucumber	Onions	Peppers	Zucchini
Total lbs purchased in season by OUSD (processed)	400	230	6170	3780	270
Average paid for pre-processed product in season ($/lb)	$3.53	$3.70	$1.69	$3.01	$3.10
Average price for whole local produce ($/lb)	$2.00	$1.27	$2.00	$0.72	$0.72
Average OUSD Central Kitchen Processing Cost ($/lb)	$0.30	$0.28	$0.23	$0.23	$0.28
Average total price for products processed in-house based on 7,700 servings ($/lb)	$2.30	$1.55	$2.23	$0.95	$1.00
Total seasonal spend on pre-processed crop by OUSD	$1,412.25	$850.90	$10,457.25	$11,372.35	$836.25
Total seasonal average for processed product in OUSD Central Kitchen ($/lb)	$920.00	$356.50	$13,759.10	$3,591.00	$270.00
Total Cost Variance + / - ($)	$492.25	$494.40	-$3,301.85	$7,781.35	$566.25

Table 3 shows that jicama, cucumber, peppers and zucchini have the highest overall price per pound pre-processed as well as the highest total positive cost variance. Conversely, onions have the lowest cost per pound pre-processed and the greatest negative cost variance; therefore in-house processing of local product is likely to be least cost effective for onions. The prices listed in Table 3 can be compared to average local prices to understand how the OUSD Central Kitchen can evaluate and prioritize processing. Volume and type of cut was also considered within the current and future processing equipment planned for the OUSD Central Kitchen.

Prices for processed (clean) produce were compared, shown based on estimated processing volumes of both 7,700 and 12,100 servings per day. The table below shows the cost comparison for 12,100 servings, the target production volume of the OUSD Central Kitchen (See Table 5).

Processing cost for the OUSD Central Kitchen was evaluated using the following formulas:

Labor cost is based on forecasted salaries for Food Service Assistant III (FSA 3) positions at $33.49 per hour, including benefits, based on $54,658.47 per year at 204 workdays, or 1,632 hours, per year. We estimate that handling (including receiving, cleaning, and portioning) will take two people one hour each for each run at 7,700 servings and three people one hour each for each run at 12,100 servings.

<u>Central Kitchen Processing Cost Formula - 7,700 servings</u>
1 FSA3 processing at $33.49/hour

2 FSA3 handling (receiving, cleaning, portioning and packing) for 1 hour for each run at $66.98/hour
Cleaning 1 hour per shift (1/8 staff hour) at $4.19/hour

Total Cost per Hour at 7,700 servings = (raw volume processed * processing time (hours) * $33.49/hour processing)+$71.17 per run for handling and cleaning

Central Kitchen Processing Cost Formula - 12,100 servings
1 FSA3 processing at $33.49/hour
3 FSA3 handling (receiving, cleaning, portioning and packing) for 1 hour for each run at $66.98/hour
Cleaning 1 hour per shift (1/8 staff hour) at $4.19/hour

Total Cost per Hour at 12,100 servings = (raw volume processed * processing time (hours) * $33.49/hour processing)+$104.66 per run for handling and cleaning

Distribution is a major consideration of product cost in the local produce analysis, as prices from farmers are FOB, before shipping costs area added, whereas current purchasing includes distribution. Distribution can cost an additional 5%-30% to the FOB price, and is addressed later in this report.

Using the formulas above and the estimated servings per clean pound for each processed produce item[8], the following table contrasts the current average price per pound for clean pre-processed produce and the Central Kitchen local average price per pound for clean in-house processed produce. (The least costly items are highlighted in **bold green**.)

Table 4: Current vs. Local Average Prices per Pound for Clean Produce at 12,100 Servings of Production

Crop	Current Average/lb Clean Pre-Processed ($)	Local Average/lb Clean In-House Processed (12,100 servings) ($)	Variance +/- ($)	Variance +/- (%)
Jicama*	**$3.53**	**$2.28**	**-$1.25**	**35.30%**
Cucumbers Diced	**$3.70**	**$1.47**	**-$2.23**	**60.37%**
Cucumbers Sliced*	**$3.70**	**$1.56**	**-$2.14**	**57.77%**
Cucumber Strips 3" Long*	**$3.70**	**$1.55**	**-$2.15**	**58.05%**
Cucumbers Matchsticks*	**$3.70**	**$1.55**	**-$2.15**	**58.05%**

[8] Adjusted for new portion requirements. USDA Food and Nutrition Services, "Food Buying Guide for Child Nutrition Programs: Vegetables/Fruit," 2008. https://fns-prod.azureedge.net/sites/default/files/FBG_Section_2-VegFruits_2.pdf

Red Onion - Diced	$1.69	$2.17	$0.48	-28.11%
Red Onion - Sliced	$1.69	$2.25	$0.56	-33.13%
Yellow Onion - Diced	$1.69	$2.17	$0.48	-28.11%
Yellow Onion - Sliced	$1.69	$2.25	$0.56	-33.13%
Red Pepper - Diced	**$3.01**	**$0.89**	**-$2.12**	**70.37%**
Red Pepper - Sliced	**$3.01**	**$0.98**	**-$2.03**	**67.49%**
Yellow Pepper - Diced	**$3.01**	**$0.89**	**-$2.12**	**70.37%**
Yellow Pepper - Sliced	**$3.01**	**$0.98**	**-$2.03**	**67.49%**
Green Pepper - Diced	**$3.01**	**$0.89**	**-$2.12**	**70.37%**
Green Pepper - Sliced	**$3.01**	**$0.98**	**-$2.03**	**67.49%**
Zucchini - Sliced*	**$3.10**	**$1.02**	**-$2.08**	**66.94%**
Zucchini - Matchsticks*	**$3.10**	**$1.00**	**-$2.10**	**67.61%**
Yellow Zucchini - Diced	**$3.10**	**$0.86**	**-$2.24**	**72.40%**
Yellow Zucchini - Sliced	**$3.10**	**$1.02**	**-$2.08**	**66.94%**
Yellow Zucchini - Matchsticks	**$3.10**	**$1.00**	**-$2.10**	**67.61%**

Complementing the above table, Table 5 contrasts the processing cost per pound for produce purchased from distributors and produce purchased from local farmers. (The least costly items are highlighted in **bold green**.)

Table 5: Current vs. Local Processing Price per Pound for Clean Produce at 12,100 Servings of Production

Current vs. Local Average Processing Cost (12,100 servings)				
Crop	**Processing $/lb for distributor product**	**Processing (12,100 servings) $/lb for local farm product**	**Variance +/- ($)**	**Variance +/1 (%)**
Jicama*	**$0.88**	**$0.28**	**-$0.60**	**67.73%**
Cucumbers Diced	$0.18	$0.20	$0.02	-9.00%
Cucumbers Sliced*	$0.18	$0.29	$0.11	-62.59%
Cucumber Strips 3" Long*	$0.18	$0.28	$0.10	-56.82%
Cucumbers Matchsticks*	$0.18	$0.28	$0.10	-56.82%
Red Onion - Diced	**$0.18**	**$0.17**	**-$0.01**	**8.30%**
Red Onion - Sliced	$0.18	$0.25	$0.07	-38.80%
Yellow Onion - Diced	**$0.18**	**$0.17**	**-$0.01**	**8.30%**

Yellow Onion - Sliced	$0.18	$0.25	$0.07	-38.80%
Red Pepper - Diced	**$1.01**	**$0.17**	**-$0.84**	**82.97%**
Red Pepper - Sliced	**$1.01**	**$0.26**	**-$0.75**	**74.41%**
Yellow Pepper - Diced	**$1.01**	**$0.17**	**-$0.84**	**82.97%**
Yellow Pepper - Sliced	**$1.01**	**$0.26**	**-$0.75**	**74.41%**
Green Pepper - Diced	**$1.01**	**$0.17**	**-$0.84**	**82.97%**
Green Pepper - Sliced	**$1.01**	**$0.26**	**-$0.75**	**74.41%**
Zucchini - Sliced*	$0.16	$0.30	$0.14	-90.48%
Zucchini - Matchsticks*	$0.16	$0.28	$0.12	-77.50%
Yellow Zucchini - Diced	**$0.16**	**$0.14**	**-$0.02**	**15.21%**
Yellow Zucchini - Sliced	$0.16	$0.30	$0.14	-90.48%
Yellow Zucchini - Matchsticks	$0.16	$0.28	$0.12	-77.50%

The above analysis shows that jicama (68% lower cost) and peppers (75%- to 83% lower cost) will be the most cost-effective items to source locally and process at the OUSD Central Kitchen. Jicama can be processed using the machines already specified for the Central Kitchen, while peppers require the high volume Urschel machines recommended for future acquisition. Diced cucumber, diced onions and diced zucchini are also 8%-15% less costly to process in-house, although only with the Urschel processors. The 8% to 83% cost savings illustrated for jicama, peppers, cucumber, onions, and zucchini would mitigate additional distribution costs (5-30%). Also, the potential cost savings presented by processing jicama and peppers (75-83%) in-house may offset the increased cost of other processing other items, such as sliced, strip and matchstick zucchini and cucumber, as well as sliced onions, are the least-effective items to source locally and process in-house. When comparing product cost and prioritizing items to process for the OUSD Central Kitchen, processing cost should also be considered to determine whether savings in whole local product make processing affordable.

Please see Appendix A-3 for full price comparison, including current vs. central kitchen average raw prices, average clean prices and processing costs for 7,700 servings and 12,100 serving volumes.

Challenges and Limitations

Produce prices and availability are highly dynamic and variable, especially when sourcing from multiple small to mid-scale farmers. Costs of production, and therefore pricing, recently increased significantly from recent increases because of stale laws that increased overtime pay for farm workers, as well as a variety of environmental and political factors. At the same time, institutional demand for local produce is increasing. The prices from local farms and OUSD's current

distributor are aligned with current market prices; however, they are a small sample and may change in the future.

Additionally, several items included on OUSD's future menus are appropriate for processing using currently specified machinery, and require further research. These items include beets, broccoli, cabbage, carrots, daikon, parsnips, mushrooms, potatoes (mashed) and celery.

Recommendations

The cost analysis comparing Central Kitchen processing to external third party processing validates the assumption that processing cost varies by individual produce item. The most cost effective items to process in the Central Kitchen present challenges. Jicama, which can be processed using currently specified processing machinery, is not widely available in California; whereas peppers, cucumber, onions and zucchini, which are widely available in California, would require higher volume processing equipment, not currently specified for the OUSD kitchen.

Lifetime cost benefit analysis of the high volume Urschel processing machines is necessary to determine feasibility. The Urschel's 9,000 lb/day capacity far exceeds OUSD's current processing volume needs; however, this capacity may be needed in the future as Nutrition Services expands its own programs and begins vending to other school districts and institutions. As local processors continue to offer more grower identified, local fruits and vegetables, comparing these items against the cost of in-house processing (using the tools and metrics developed in this study) will enable OUSD to maximize production at the Central Kitchen, while controlling costs. Ongoing budget analysis and procurement planning which builds on this analysis are recommended.

External benefits were not within the scope of the current analysis, but should be considered, as they are in alignment with OUSD Nutrition Services mission to create an equitable food system for the Oakland Community. These benefits include, produce quality and flavor, promotion of community values and local farmers, and support for the local economy, including job-creation.

OUSD Processed Produce External Sales Feasibility Study

Goals of the OUSD Processed Produce External Sales Feasibility Study:

Survey and Assess Potential Customers Goals

- Survey and assess nearby institutional partners to understand their needs and interests in purchasing local processed produce from the OUSD Central Kitchen.

Assessment of Potential Customers

Market research was conducted, with 35 potential external customers for OUSD Central Kitchen vending identified and eight chosen for initial interviews conducted in spring 2017:

- San Leandro Unified School District
- San Lorenzo Unified School District
- Berkeley Unified School District
- Alameda Unified School District
- Albany Unified School District
- West Contra Costa Unified School District (Richmond)
- San Francisco Unified School District
- People's Community Market (Oakland)

All but Alameda Unified and San Leandro Unified were interviewed. Berkeley Unified was the only institution not at all interested in purchasing processed produce from OUSD.

The following questions were asked of the representatives from each food service operation in order to assess operational needs and purchasing motivations:

- What would be your main considerations for purchasing processed produce from the OUSD Central Kitchen?
- What pre-processed produce are you currently purchasing? Are you buying any grower identified local produce?
- Are you currently processing fruits and vegetables? Do you have plans to do so in the future?
- Would buying local, grower-identified produce from a school district add value for your community or marketing?
- Operational logistics: How many delivery sites do you have and what are your service needs from vendors?

Summary of Responses

Price, quality and reliability of service were the top three considerations for all food service representatives. OUSD will have to price compete with existing processors and deliver consistent product with strong customer service. From bidding for public contracts, to being able to work within institutions' ordering systems and making on time deliveries, OUSD will need to meet complex customers' needs.

While the institutions surveyed had varying volume needs and capacity for in-house processing, all were purchasing some source identified whole produce, but none were receiving identified processed produce from independent family farms. Supporting OUSD, purchasing from local family farms and access to educational signage and promotions were priorities for all districts, and six of the seven respondents noted that they received community demand for sustainable food. San Francisco Unified School District recently adopted the Good Food Purchasing Policy and West Contra Costa Unified is piloting organic and local sourcing through a non-profit organization called Conscious Kitchen. People's Community Market will use mostly local produce in its future grocery and café operations and Albany Unified School District has shifted to sustainable proteins.

All interviewees were interested in purchasing processed fruits and vegetables from OUSD, and all institutions interviewed are located within 15 miles of the OUSD Central Kitchen and have the capacity to ship to satellite cafeterias from a central facility, meaning distribution would be relatively easy. Because the school districts and People's Community Market use both bulk and individually packaged items, there was interest in both packaging options.

San Francisco Unified School District, West Contra Costa School District, and People's Community Market were the most well suited potential initial customers for the OUSD Central Kitchen. Whereas, San Lorenzo Unified School District was less compatible, as they currently require fixed prices for produce and next-day delivery, and have limited budget flexibility.

San Francisco Unified School District (SFUSD) and West Contra Costa School Districts (WCCSD), both large urban districts, could provide the volume demand necessary for the OUSD Central Kitchen to reach an economy of scale and offer competitively priced produce. Both SFUSD and WCCSD have growing farm to cafeteria programs and can be flexible on pricing. SFUSD has long-term plans to increase scratch cooking, but plans to purchase precut fruits and vegetables long-term, and seasonal menus align with OUSD local availability.

People's Community Market (PCM) should also be considered as a potential early customer for OUSD. PCM and OUSD are currently exploring a pilot project to enter forward contracting agreements with small family farms within the PCM network. For small farmers, forward contracting would mitigate the up-front costs associated with doing business with large institutions. PCM could benefit from cooperative purchasing with OUSD to aggregate volume and drive down prices.

Challenges

In addition to meeting the unique needs of institutional customers in a competitive market, further research is necessary to understand the health and environmental safety compliance and retail labeling regulation costs for vending outside of OUSD. The US Food and Drug Administration (FDA) and US Department of Agriculture (USDA) regulate food processing and production and various licenses and inspections are required depending on the types of product and processing taking place. Selling consumer packs for re-sale in retail environments also require meeting nutrition, allergen and commercial standards. OUSD is currently working with Ruck Shockey and Associates to design operating plans, HACCP plans, and standard operating procedures for the new Central Kitchen, which meet all necessary regulations. Liability and compliance will be major considerations for OUSD to sell to external customers.

Recommendations

Oakland Unified School District should continue to pilot co-purchasing and forward contracting with People's Community Market, and work with Ruck Shockey and Associates to understand local, state, and federal compliance requirements for external sales of processed produce. While the currently specified processing equipment can serve the needs of OUSD and PCM, the larger

Urschel machines would be necessary to service San Francisco Unified and West Contra Costa Unified School Districts, the next most compatible potential customers. Alternatively, a second shift using the specified equipment should be considered. Interviews demonstrated strong support for and interest in purchasing local produce from the OUSD Central Kitchen if price, quality and service standards can be met.

Conclusion

This assessment is a framework for understanding the considerations and methods necessary to procure, process, and resell local produce in the OUSD Central Kitchen. Research indicates that, with upfront investment in procurement planning and operational capacity, OUSD NS can affordably shift from purchasing pre-processed produce from distributors to processing local, family-farmed produce in-house. The external sales analysis demonstrates open opportunities to pilot the sale of OUSD processed produce to Bay Area institutions.

Summary of Recommendations

Central Kitchen Facilities Research Recommendations:

- Add the higher volume Robo Coupe CL60 and Urschel G-A/Sprint 2 to electrical and layout designs and future investment plans.
- Shift to from 2 to 1 large vegetable washers.
- Consider and regularly reassess machine processing capacity and variable produce pricing when comparing cost of pre-processed vs. central kitchen processed produce.

Developing Future Farm Supplier Recommendations:

- Farmer and aggregator respondents have the capacity to supply a variety of whole fruits and vegetables to the OUSD Central Kitchen. The suppliers align with OUSD's sourcing and distribution priorities and should be considered for future contracts.
- The RFI language and product list can be used for future OUSD Nutrition Services procurement documents. OUSD Nutrition Services should maintain relationships with respondents to update price and availability estimates.
- While the RFI provided an organized, streamlined process for farmers to provide information, more direct outreach, as well as coordination with food hubs, will be necessary to reach additional farmers and meet volume needs in the future.

Cost Analysis of Central Kitchen Processing vs. Current Purchasing Recommendations:

- The cost comparison between Central Kitchen processing and external third party processing validates the assumption that processing cost varies by individual produce item.

- The most cost effective items to process in the Central Kitchen present challenges. Jicama, which can be processed using currently specified processing machinery, is not widely available in California; whereas peppers, cucumber, onions and zucchini, which are widely available in California, would require higher volume processing equipment, not currently specified for the OUSD kitchen.
- Lifetime cost benefit analysis of the high volume Urschel processing machines is necessary to determine feasibility. The Urschel's 9,000 lb/day capacity far exceeds OUSD's current processing volume needs; however, this capacity may be needed in the future as Nutrition Services expands its own programs and begins vending to other school districts and institutions.
- External benefits of increasing purchases from local family farms were not within the scope of the current analysis, but should be considered, as they are in alignment with OUSD Nutrition Services' mission to create an equitable food system for the Oakland Community.

Processed Produce External Sales Feasibility Study Recommendations

- Oakland Unified School District should continue to pilot co-purchasing and forward contracting with People's Community Market (PCM), and work with Ruck Shockey and Associates to understand local, state, and federal compliance requirements for external sales of processed produce. While the currently specified processing equipment can serve the needs of OUSD and PCM, the larger Urschel machines would be necessary to service San Francisco Unified and West Contra Costa Unified School Districts, the next most compatible potential customers
- Interviews demonstrate strong support for and interest in purchasing local produce from the OUSD Central Kitchen if price, quality and service standards can be met.

The overall positive impact inherent in diverting OUSD's purchasing dollars to local family-owned farms cannot be understated. With a produce budget of $1.2 million, OUSD has an obligation to ensure these public funds maximally benefit students, family farms, and the local economy. Processing produce in the OUSD Central Kitchen will generate local jobs and revenue, which will be funneled back into programs like breakfast in the classroom, farm tours, and garden education, which further benefit Oakland's students. Students in Oakland like the menu improvements that have already been implemented[9], and they want more fresh food. The District expects in-house produce processing, along with other meal improvements made possible by the new Central Kitchen, to boost student satisfaction and ultimately increase participation, and hence revenue.

In collaboration with education programs housed at the Central Kitchen and Instructional Farm, produce processing provides unique learning opportunities for students and future food service professionals. Selling processed produce to local food services will not only increase their access to high quality locally grown fruits and vegetables, but will also amplify the impact of the public facilities investment. By internalizing processing, OUSD NS has the opportunity to dramatically

[9] OUSD, survey of student meal satisfaction, key findings: increased meal satisfaction, increased perception of fruits and vegetables, 2013-2017.

increase access to fresh, locally grown produce for students and support the local community and agricultural producers, all while staying in budget. Moreover, processing local produce at the Central Kitchen aligns with OUSD Nutrition Service's mission and sets in motion positive systems changes that will benefit Oakland for years to come.

Appendixes

A-1. Produce processing equipment list – OUSD Central Kitchen

Qty	Description	Model
1	Food Slicer (Automatic)	Bizerba GSP-HD
1	Food Slicer (Automatic)(Future)	BIZERBA GSP-HD
1	60 QT. Floor Mixer	HOBART HL6001STD
1	Food Preparation Machine (Future)	HALLDE RG-400
1	Vertical Cutter/Mixer	HOBART HCM450-61
2	Vegetable Washers	NILMA ATIR 1 (OR I) TILTING
1	Produce Soak	STEELKOR XGRR
1	DRYER	NILMA IDROVER 50
1	Food Processor	ROBOT COUPE R602
1	Food Processor (Future)	ROBOT COUPE R602
5	Trash Receptacle	NIFSEC BY OWNER
2	Food Preparation Machines	HALLDE RG-400
2	Scales	EDLUND WSC-10
8	Mobile Ingredient Bins	RUBBERMAID FG360088WHT
1	60 Qt. Floor Mixer	HOBART HL600-1STD
1	Prep Sink w/Drain Board	Custom ST.STL
1	140 Qt. Planetary Mixer	HOBART HL1400-1STD
1	Refrigerated Prep. Table (Self Contained)	TRAULSEN TU072HT
1	100 Gal Tilt Kettles	TUCS CV-100VV

1	100 Gal Pasta Basket	TUCS
1	150 GAL. Batch Chiller Cook Tank (Remote)	TUCS TEBCCT-150
1	100 Gal. Batch Chiller Cook Tank (Remote)	TUCS TEBCCT-100
90	Transport Cart	SAMMONS 9150-13
1	20 QT Mixer	HOBART HL200-1STD
1	10 Gal. Tilting Skillet	CLEVELAND SET 10

A-2. Food Processor Comparison

A-2-1. Currently Specified Food Processing Equipment

EQUIPMENT	Hallde RG400/ Hobart FP400	Hobart HCM450	Robo Coupe R602
	Currently Specified	Currently Specified	Currently Specified
DESCRIPTION	Floor model for vegetable slicing, grates, shreds, dices, cuts, julienne, crimping slices, and french fries.	Cut, mix, blend and knead a variety of products	120V Countertop vegetable prep (process head of lettuce cut into thirds)
ESTIMATED COST	$14,000.00	$13,500.00	$3,500.00
ESTIMATED PRODUCTION	3,000 lbs/day	35 lbs potatoes/30 sec	400 lbs/day
PRODUCE			
BOK CHOY JULIENNE (CHOW MEIN)			
BEETS-MATCHSTICKS	X		
BROCCOLI CUTS			
BROCCOLI SLAW			X

CABBAGE, GREEN SHREDDED	X		
CABBAGE, NAPA SHREDDED	X		
CABBAGE, RED SHREDDED	X		
CARROTS-DICED			
CARROTS GRATED			X
CARROTS-SLICED			X
CARROT LARGE DICE 1"			
CARROT JULIENNE (CHOW MEIN)			
CARROTS-WOK CUT			X
CARROTS-MATCHSTICK	X		
CELERY DICED			
CELERY JULIENNE CHOW MEIN			
CELERY STEW CUT			
CELERY WOK CUT			X
CUCUMBER DICED			
CUCUMBER SLICED	X		
CUCUMBER MATCHSTICKS	X		
JICAMA MATCHSTICKS	X		
MUSHROOMS-SLICED	X		
PORTABELLA MUSHROOMS-SLICED			
SHITAKE MUSHROOMS-SLICED			
DAIKON MATCHSTICKS	X		

PARSNIP MATCHSTICKS	X		
POTATOES- DICED			
POTATOES-SLICED			
POTATOES-MASHED		X	
POTATOES-FRENCH FRIES			
ROOT FRY BUCKET BLEND (15#)			
POTATO HASH BROWN (15#)			
GREEN ONION DICED			
SWEET POT/YAM BRKFST DICED MIX			
RED ONION-JULIENNE (CHOW MEIN)			
RED ONION-DICED			
RED ONION-SLICED			
YAM FRENCH FRIES			
YAM MATCHSTICKS	X		
YELLOW ONION - DICED			
YELLOW ONION-SLICED			
YELLOW ONION STEW CUT			
PEPPER, RED-DICED			
PEPPER, RED-SLICED			
PEPPER RED LARGE DICE			
PEPPER,YELLOW DICED			

PEPPER,YELLOW SLICED			
PEPPER,GREEN DICED			
PEPPER,GREEN SLICED			
PEPPER,JALAPENO DICED			
RUTABAGAS LARGE DICE			
TOMATO- DICED			
TOMATO- SLICED			
TURNIPS-MATCHSTICKS	X		
ZUCCHINI-DICED			
ZUCCHINI-SLICED	X		
ZUCCHINI-WOK CUT	X		
ZUCCHINI-MATCHSTICKS	X		
ZUCCHINI,YELLOW-DICED			
ZUCCHINI,YELLOW-SLICED	X		
ZUCCHINI,YELLOW-WOK CUT	X		
ZUCCHINI,YELLW-MATCHSTIX	X		
SQUASH BUTTERNUT DICED 1/2"			
SQUASH YELLOW DICED 1/2"			
SQUASH GREEN DICED 1/2"			
CARROT DICED 1/2"			
SQUASH CHAYOTE DICED 1/2"			
TOMATO DICED 1/2"			
CUCUMBER STRIPS 3" LONG	X		

DAIKON MATCHSTICKS	X		X
PICKLED CARROT MATCHSTICK (5#)	X		
PICKLED DAIKON MATCHSTICKS (5#)	X		
SHREDDED CARROTS			X
SHREDDED GREEN CABBAGE -1/16"	X		
SHREDDED NAPA CABBAGE -1/8"	X		
SHREDDED RED CABBAGE -1/8"	X		
SWEET POTATO CHUNKS 1/2"			
SWEET POTATO FRIES 5/16"			

A-2-2. Optional Future Food Processing Equipment

EQUIPMENT	**Robo Coupe CL60**	**Urschel G-A**	**Urschel Sprint 2 w/ optional Discharge Conveyor**
	Option	**Option**	**Option**
DESCRIPTION	**208V Floor Model for vegetable slicing dicing/prep, with auto bulk feeder (process whole head of lettuce)**	**Produces uniform dices, straight french fry strips, and slices from a variety of soft ripe fruits and brittle root vegetables**	**Uniformly dices, strip cuts, granulates, or slices a wide variety of vegetables, fruits, bakery goods, and meats.**
ESTIMATED COST	**$10,000.00**	**$41,000.00**	**$43,000.00**
ESTIMATED PRODUCTION	**2,000 lbs/day**	**8,000 lbs/hr (3/8" dice)**	**9,200 lbs/hr (3/8" dice)**
PRODUCE			

BOK CHOY JULIENNE (CHOW MEIN)			
BEETS-MATCHSTICKS			
BROCCOLI CUTS			
BROCCOLI SLAW	X		
CABBAGE, GREEN SHREDDED			
CABBAGE, NAPA SHREDDED			
CABBAGE, RED SHREDDED			
CARROTS-DICED		X	X
CARROTS GRATED	X		
CARROTS-SLICED	X		
CARROT LARGE DICE 1"		X	X
CARROT JULIENNE (CHOW MEIN)			
CARROTS-WOK CUT	X		
CARROTS-MATCHSTICK			
CELERY DICED		X	X
CELERY JULIENNE CHOW MEIN			
CELERY STEW CUT		X	X
CELERY WOK CUT	X		
CUCUMBER DICED		X	X
CUCUMBER SLICED			
CUCUMBER MATCHSTICKS			
JICAMA MATCHSTICKS			
MUSHROOMS-SLICED		X	X

PORTABELLA MUSHROOMS-SLICED			
SHITAKE MUSHROOMS-SLICED		X	X
DAIKON MATCHSTICKS			
PARSNIP MATCHSTICKS			
POTATOES- DICED		X	X
POTATOES-SLICED		X	X
POTATOES-MASHED	X		
POTATOES-FRENCH FRIES		X	X
ROOT FRY BUCKET BLEND (15#)		X	X
POTATO HASH BROWN (15#)		X	X
GREEN ONION DICED			
SWEET POT/YAM BRKFST DICED MIX		X	X
RED ONION-JULIENNE (CHOW MEIN)			
RED ONION-DICED		X	X
RED ONION-SLICED		X	X
YAM FRENCH FRIES		X	X
YAM MATCHSTICKS			
YELLOW ONION - DICED		X	X
YELLOW ONION-SLICED		X	X
YELLOW ONION STEW CUT		X	X

PEPPER, RED-DICED		X	X
PEPPER, RED-SLICED		X	X
PEPPER RED LARGE DICE		X	X
PEPPER,YELLOW DICED		X	X
PEPPER,YELLOW SLICED		X	X
PEPPER,GREEN DICED		X	X
PEPPER,GREEN SLICED		X	X
PEPPER,JALAPENO DICED		X	X
RUTABAGAS LARGE DICE		X	X
TOMATO- DICED		X	X
TOMATO- SLICED			
TURNIPS-MATCHSTICKS			
ZUCCHINI-DICED		X	X
ZUCCHINI-SLICED			
ZUCCHINI-WOK CUT			
ZUCCHINI-MATCHSTICKS			
ZUCCHINI,YELLOW-DICED		X	X
ZUCCHINI,YELLOW-SLICED			
ZUCCHINI,YELLOW-WOK CUT			
ZUCCHINI,YELLW-MATCHSTIX			
SQUASH BUTTERNUT DICED 1/2"			
SQUASH YELLOW DICED 1/2"			
SQUASH GREEN DICED 1/2"			

CARROT DICED 1/2"			
SQUASH CHAYOTE DICED 1/2"			
TOMATO DICED 1/2"			
CUCUMBER STRIPS 3" LONG			
DAIKON MATCHSTICKS	X		
PICKLED CARROT MATCHSTICK (5#)			
PICKLED DAIKON MATCHSTICKS (5#)			
SHREDDED CARROTS	X		
SHREDDED GREEN CABBAGE -1/16"			
SHREDDED NAPA CABBAGE -1/8"			
SHREDDED RED CABBAGE -1/8"			
SWEET POTATO CHUNKS 1/2"		X	X
SWEET POTATO FRIES 5/16"		X	X

A-3. Analysis of Local Central Kitchen Processed Produce vs. Pre-processed 2015-2016 Purchases

Analysis of Local Central Kitchen Processed Produce with Pre-processed 2015-2016 Purchases				
*Items that are processed by machines currently specified.				
Negative variance indicates costs saved by buying locally				
Positive variance indicates additional price from buying locally				

Current vs. Local Average Clean (7,700 servings)				
Item	**Current Average/lb Clean ($)**	**Local Average/lb Clean (7,700 servings) ($)**	**Variance +/- ($)**	**Variance +/1 (%)**
Jicama*	$3.53	$2.30	-$1.23	34.90%
Cucumbers Diced	$3.70	$1.48	-$2.22	60.02%
Cucumbers Sliced*	$3.70	$1.58	-$2.12	57.37%
Cucumber Strips 3" Long*	$3.70	$1.57	-$2.13	57.67%
Cucumbers Matchsticks*	$3.70	$1.57	-$2.13	57.67%
Red Onion - Diced	$1.69	$2.18	$0.49	-28.76%
Red Onion - Sliced	$1.69	$2.27	$0.58	-34.12%
Yellow Onion - Diced	$1.69	$2.18	$0.49	-28.76%
Yellow Onion - Sliced	$1.69	$2.27	$0.58	-34.12%
Red Pepper - Diced	$3.01	$0.90	-$2.11	69.98%
Red Pepper - Sliced	$3.01	$1.00	-$2.01	66.91%
Yellow Pepper - Diced	$3.01	$0.90	-$2.11	69.98%
Yellow Pepper - Sliced	$3.01	$1.00	-$2.01	66.91%
Green Pepper - Diced	$3.01	$0.90	-$2.11	69.98%
Green Pepper - Sliced	$3.01	$1.00	-$2.01	66.91%
Zucchini - Sliced*	$3.10	$1.04	-$2.06	66.44%
Zucchini - Matchsticks*	$3.10	$1.02	-$2.08	67.16%
Yellow Zucchini - Diced	$3.10	$0.86	-$2.24	72.11%
Yellow Zucchini - Sliced	$3.10	$1.04	-$2.06	66.44%
Yellow Zucchini - Matchsticks	$3.10	$1.02	-$2.08	67.16%
Current vs. Local Average Clean (12,100 servings)				
Item	**Current Average/lb Clean ($)**	**Local Average/lb Clean (12,100 servings) ($)**	**Variance +/- ($)**	**Variance +/1 (%)**

Jicama*	$3.53	$2.28	-$1.25	35.30%
Cucumbers Diced	$3.70	$1.47	-$2.23	60.37%
Cucumbers Sliced*	$3.70	$1.56	-$2.14	57.77%
Cucumber Strips 3" Long*	$3.70	$1.55	-$2.15	58.05%
Cucumbers Matchsticks*	$3.70	$1.55	-$2.15	58.05%
Red Onion - Diced	$1.69	$2.17	$0.48	-28.11%
Red Onion - Sliced	$1.69	$2.25	$0.56	-33.13%
Yellow Onion - Diced	$1.69	$2.17	$0.48	-28.11%
Yellow Onion - Sliced	$1.69	$2.25	$0.56	-33.13%
Red Pepper - Diced	$3.01	$0.89	-$2.12	70.37%
Red Pepper - Sliced	$3.01	$0.98	-$2.03	67.49%
Yellow Pepper - Diced	$3.01	$0.89	-$2.12	70.37%
Yellow Pepper - Sliced	$3.01	$0.98	-$2.03	67.49%
Green Pepper - Diced	$3.01	$0.89	-$2.12	70.37%
Green Pepper - Sliced	$3.01	$0.98	-$2.03	67.49%
Zucchini - Sliced*	$3.10	$1.02	-$2.08	66.94%
Zucchini - Matchsticks*	$3.10	$1.00	-$2.10	67.61%
Yellow Zucchini - Diced	$3.10	$0.86	-$2.24	72.40%
Yellow Zucchini - Sliced	$3.10	$1.02	-$2.08	66.94%
Yellow Zucchini - Matchsticks	$3.10	$1.00	-$2.10	67.61%
Current vs. Local Average Processing Cost (7,700 servings)				
Item	**Current Processing $/lb**	**Local Processing (7,700 servings) $/lb**	**Variance +/- ($)**	**Variance +/1 (%)**
Jicama*	$0.88	$0.30	-$0.58	66.12%
Cucumbers Diced	$0.18	$0.21	$0.03	-16.32%
Cucumbers Sliced*	$0.18	$0.31	$0.13	-70.76%
Cucumber Strips 3" Long*	$0.18	$0.30	$0.12	-64.60%
Cucumbers Matchsticks*	$0.18	$0.30	$0.12	-64.60%
Red Onion - Diced	$0.18	$0.18	$0.00	2.16%
Red Onion - Sliced	$0.18	$0.27	$0.09	-48.16%

Yellow Onion - Diced	$0.18	$0.18	$0.00	2.16%
Yellow Onion - Sliced	$0.18	$0.27	$0.09	-48.16%
Red Pepper - Diced	$1.01	$0.18	-$0.83	81.83%
Red Pepper - Sliced	$1.01	$0.28	-$0.73	72.68%
Yellow Pepper - Diced	$1.01	$0.18	-$0.83	81.83%
Yellow Pepper - Sliced	$1.01	$0.28	-$0.73	72.68%
Green Pepper - Diced	$1.01	$0.18	-$0.83	81.83%
Green Pepper - Sliced	$1.01	$0.28	-$0.73	72.68%
Zucchini - Sliced*	$0.16	$0.32	$0.16	-100.19%
Zucchini - Matchsticks*	$0.16	$0.30	$0.14	-86.33%
Yellow Zucchini - Diced	$0.16	$0.14	-$0.02	9.58%
Yellow Zucchini - Sliced	$0.16	$0.32	$0.16	-100.19%
Yellow Zucchini - Matchsticks	$0.16	$0.30	$0.14	-86.33%
Current vs. Local Average Processing Cost (12,100 servings)				
Item	**Current Processing $/lb**	**Local Processing (12,100 servings) $/lb**	**Variance +/- ($)**	**Variance +/1 (%)**
Jicama*	$0.88	$0.28	-$0.60	67.73%
Cucumbers Diced	$0.18	$0.20	$0.02	-9.00%
Cucumbers Sliced*	$0.18	$0.29	$0.11	-62.59%
Cucumber Strips 3" Long*	$0.18	$0.28	$0.10	-56.82%
Cucumbers Matchsticks*	$0.18	$0.28	$0.10	-56.82%
Red Onion - Diced	$0.18	$0.17	-$0.01	8.30%
Red Onion - Sliced	$0.18	$0.25	$0.07	-38.80%
Yellow Onion - Diced	$0.18	$0.17	-$0.01	8.30%
Yellow Onion - Sliced	$0.18	$0.25	$0.07	-38.80%
Red Pepper - Diced	$1.01	$0.17	-$0.84	82.97%
Red Pepper - Sliced	$1.01	$0.26	-$0.75	74.41%
Yellow Pepper - Diced	$1.01	$0.17	-$0.84	82.97%
Yellow Pepper - Sliced	$1.01	$0.26	-$0.75	74.41%
Green Pepper - Diced	$1.01	$0.17	-$0.84	82.97%

Green Pepper - Sliced	$1.01	$0.26	-$0.75	74.41%
Zucchini - Sliced*	$0.16	$0.30	$0.14	-90.48%
Zucchini - Matchsticks*	$0.16	$0.28	$0.12	-77.50%
Yellow Zucchini - Diced	$0.16	$0.14	-$0.02	15.21%
Yellow Zucchini - Sliced	$0.16	$0.30	$0.14	-90.48%
Yellow Zucchini - Matchsticks	$0.16	$0.28	$0.12	-77.50%

A-4. Oakland Unified School District Nutrition Services Central Kitchen Local Produce Request for Information 2016 (Version 2)

OAKLAND UNIFIED SCHOOL DISTRICT

Community Schools, Thriving Students

900 High Street
Oakland, California 94601

REQUEST FOR INFORMATION

PRODUCE, FRESH FRUITS AND VEGETABLES
Central Kitchen 2017-2018

Dear Grower,

OAKLAND UNIFIED SCHOOL DISTRICT (OUSD) is preparing to open a new central kitchen in West Oakland in the fall of 2017. The new central kitchen will expand OUSD's ability to procure produce directly from local growers. To assist the district in planning for this procurement shift, OUSD is now accepting price quotes for fruits and vegetables for delivery to the central kitchen during the 2017-2018 school year.

If selected by OUSD, growers may be asked to visit schools within the OUSD and present their product(s) to students and staff as an educational activity and interactive method of introducing farm-fresh produce within the cafeteria. All successful grower(s) may be asked to meet with OUSD administration individually or collectively prior to delivery of produce and/or school presentations. All arrangements between OUSD and any successful vendor(s) regarding delivery schedules, ordering, payment and availability/seasonality of produce will be made during the above-mentioned meeting. OUSD reserves the right to select multiple vendors, or none at all.

Please fill out this online form and questionnaire to submit your response to Ben Thomas, Farm to Cafeteria Program Manager for the Community Alliance with Family Farmers.

Please direct all questions and inquiries to Ben Thomas and Aleandra Emmott at the contact information below.

Ben Thomas
Farm to Cafeteria Senior Program Manager
Community Alliance with Family Farmers
Office: 530.756.8518x127 Mobile: 518-265-2022

Alexandra Emmott
Farm to School Supervisor
Nutrition Services Department
Oakland Unified School District
510-434-3334
alexandra.emmott@ousd.org

OUSD PRODUCE REQUEST FOR INFORMATION

OUSD is gathering information about farmers interested in supplying OUSD with produce items during the 2017-2018 school year. OUSD's Farm to School program aims to provide fresh, high-quality produce to our students and to educate them about food and agriculture. OUSD is particularly looking to partner with family-owned farms in the northern California region.

For the purposes of this solicitation "local" is defined as within 250 miles of Oakland, CA. This Farm to School Request for Information (RFI) will solicit information from "local" farmers in

the region interested in selling to OUSD during the 2017-2018 growing season. Interested farmers are invited to fill out and submit the following form using *average* pricing from the 2015-2016 school year.

OUSD will determine which farmers provide the most responsive and cost-effective responses to be considered as Farm to School partner farmers for the 2017-2018 school year. Please note that farmers selling a total amount of product per year below the USDA informal purchasing threshold may be selected based on the information provided in this response, while those selling above the USDA formal purchasing threshold to OUSD will be required to respond to a formal Request for Proposals prior to being awarded a contract.

Selection Process

OUSD aims to work with a variety of family-owned farms in the northern California region. The following are the criteria OUSD is looking for in farmer partners:

- Experience: Proven record of respectful, professional business relationships
- Customer Service: Ability to provide a main "point of contact" who can provide consistent, timely phone and email communication with OUSD staff
- Quality: Ability to grow and provide high-quality produce
- Food Safety: In order to provide food that is safe for OUSD students and staff, farmers are expected to follow good on farm food safety and post-harvest handling practices. This includes safe planting, use of nutrients (compost), pest-control mechanisms, harvesting procedures, cooling, washing, packing, delivery, etc. As part of the process described above, farmers must provide a food safety plan that describes how the farm minimizes on-farm and post-harvest food safety risks.
- Product Specifications and Pack Sizes: All products must be packed and stored under sanitary conditions, kept at proper temperature, and handled in accordance with good commercial practices. Products delivered must match the specifications and standard pack sizes specified for each product, described in individual product specification sheets.

- Traceability: Each case delivered must be labeled with farm name, product, date harvested, and date packed.
- Delivery: Ability to make reliable, timely, and accurate deliveries
- Insurance: Farmer must carry product liability insurance of no less than $1 million. A proof of insurance, such as a Liability Insurance Certificate, must be sent (email, fax or mail) to OUSD before purchasing begins.
- Invoicing/Payment: Farmers must email or fax invoices to OUSD no more than 7 days after delivery. Vendor will receive payment by mail within 30 business days after purchase.
- Competitive pricing

The product quantities described in the application below are estimates of the quantities that OUSD will use during the growing season. OUSD will send farmers exact Purchase Orders (PO's) by email with product need dates and quantities no less than 3 days prior to delivery to OUSD.

Farm Information

Farm Name:
Website:
Primary Contact Name:
Primary Contact Title:
Work Phone:
Cell Phone (if different):
Email:
Farm Address:
Mailing Address (if different):
Type of Organization (LLC or 501(c)3):
Total number of farms represented/associated with organization:
Number of farms represented/associated with organization interested in selling to OUSD:

Product Information:

Product Information: fruit/vegetable production on farm for 2017-2018 growing season:

Does farm fall under any of the following categories? Check all that apply.

☐ Farm is within 250 miles of Oakland, CA

☐ Farm is a family operation (more than 1 family member owns/works on farm)

☐ Farm has a written food safety plan

☐ Farm has a written food safety plan

☐ Certified Organic

☐ Sustainable growing practices (but no certification)

Briefly describe how and where products are rinsed/washed on the farm, if applicable.

Briefly describe how and where products are packed on the farm.

Does farm have product liability insurance?

Does farm use any pesticides or fertilizers? If so, list below - please include natural and synthetic/chemical applications used on the farm. Email extra pages to ben@caff.org.

Local Produce Availability and Pricing

Please fill in the corresponding Farmer Produce Availability Sheet using pricing average pricing from the 2015-2016 school year. Please include item variety, the largest bulk pack size currently offered, estimated average price, the weekly quantity available and the dates in which you produce these items throughout the year.

A-4-1. Oakland Unified School District Nutrition Services Central Kitchen Local Produce Request for Information 2016 (Version 2)

RFI Availability List – OUSD Central Kitchen

Item	Variety, required where highlighted	Bulk Pack Size - insert if not indicated	Estimated Average Price*.	Quantity Available (Weekly)	Dates Available (Please include all growing seasons)
APPLES		138 ct			
APPLES					
APPLES					
BASIL					
BASIL					
BEANS, GREEN					
BEANS, GREEN					
BEETS					
BEETS					
BERRIES					
BERRIES					
BERRIES					
BERRIES					
BOK CHOY					
BROCCOLI					
BRUSSEL SPROUTS					
CABBAGE					
CABBAGE					
CARROTS					
CARROTS					
CAULIFLOWER					
CAULIFLOWER					
CAULIFLOWER					
CELERY					
CHERRY					
CILANTRO					
COLLARD GREENS					
CORN					
CORN					
CUCUMBER					
DAIKON					
DILL					

GARLIC					
GRAPES RED					
GRAPES RED					
JICAMA					
KALE					
KALE		100 ct			
KALE					
KALE					
KALE BABY					
KIWI					
KOHLRABI					
LEMONS					
LETTUCE					
LETTUCE					
LETTUCE					
LIMES					
MANDARINS, SATSUMA		120 ct			
MANGO					
MELON					
MELON					
MELON					
MELON					
MUSTARD GREENS					
ONION GREEN					
ONION RED					
ONION YELLOW					
ORANGES					
PARSLEY					
PEARS		135 to 150 ct			
PEARS					
PEPPER RED					
PEPPERS					
PEPPERS					
PEPPERS					
PEPPERS GREEN					
PERSIMMONS, FUYU		125 ct			
POTATOES					

POTATOES					
POTATOES					
POTATOES					
RADISH					
RADISH					
RAINBOW CHARD					
RUTABEGA					
PEAS, SNAP					
PEAS, SNOW					
SPINACH BABY					
SQUASH					
SQUASH					
SQUASH					
SQUASH					
SQUASH					
STONE FRUIT					
STONE FRUIT					
STONE FRUIT					
STONE FRUIT					
STONE FRUIT					
STRAWBERRY					
SWISS CHARD					
TANGERINES		120 ct			
TOMATO CHERRY					
TOMATOES					
TOMATOES					
TOMATOES					
TURNIPS					

Recipe Name: Black Beans
Servings: 100
Portion Size: 1/2 CUP

Ingredients	Recipe Amount	Weight/ Measure		Weight in Decimals
Beans, Black	7.2 #10 CANS			49.5 lbs
Juice, Lime	1 CUP			0.5 lbs
Salsa	2 CUPS			1.128 lbs
Spice, Cumin	4 TSP			0.025 lbs

total weight: 51.153 lbs
specialty crop weight: 51.128 lbs
specialty crops percentage: 100%

Recipe Name: edamame salad
Servings: 100
Portion Size: 1/2 cup

Ingredients	Recipe Amount	Weight/ Measure		Weight in Decimals
edamame		10 lb		10 lbs
carrots		2 lb	4 oz	2.5 lbs
sugar, brown	1 cup			0.45 lbs
ginger	2 tbsp			0.0625 lbs
spice, red pepper flakes	2.5 tsp			0.0156 lbs
juice, lime	1 cup			0.5 lbs
sauce, soy light	1/2 cup			0.25 lbs
oil, sesame	1/2 cup			0.25 lbs
oil, vegetable	1/2 cup			0.25 lbs
water	1/2 cup			0.25

total weight: 14.5281 lbs
specialty crop weight: 12.5 lbs
specialty crops percentage: 86%

Recipe Name: Garlic Penne
Servings: 100 svg.
Portion Size: 1.25 cups

Ingredients	Recipe Amount	Weight/ Measure		Weight in Decimals
chick peas, green immature	9# 6 oz			9.375 lbs
onions, diced	15 cup			6.45 lbs
carrots, diced	10 cup			1.656 lbs

garlic, minced	1 1/4 cup			0.625 lbs
salt	3 tbsp + 1 tsp			0.125 lbs
basil, ground	2 1/2 tsp			0.0125 lbs
oil, olive	2 1/2 cup			1.25 lbs
juice. Lime	1 1/3 cup			0.666 lbs
pasta, penne	12# 8 oz			12.5 lbs

total weight:	32.6595 lbs
specialty crop weight:	19.3685 lbs
specialty crops percentage:	59%

Recipe Name: fish tostado
Servings: 100 svg
Portion Size: 1 each

Ingredients	Recipe Amount	Weight/ Measure		Weight in Decimals
fish, grenadier	10 lb			10 lbs
oil, olive	3.25 cup			1.625 lbs
salt	8.5 tbsp			0.3187 lbs
pepper, ground	1 tbsp			0.01875 lbs
coleslaw mix, shredded	11 lbs			11 lbs
juice, lime	12 tbsp			0.375 lbs
sour cream	6 lb			6 lbs
sauce, sriracha	6 tbsp			0.2 lbs
cilantro	7.5 cup			0.2678 lbs
tostadio	100 each		50 oz	3.125 lbs
bean, pinto	2.7 - #10 cans			18.225 lbs

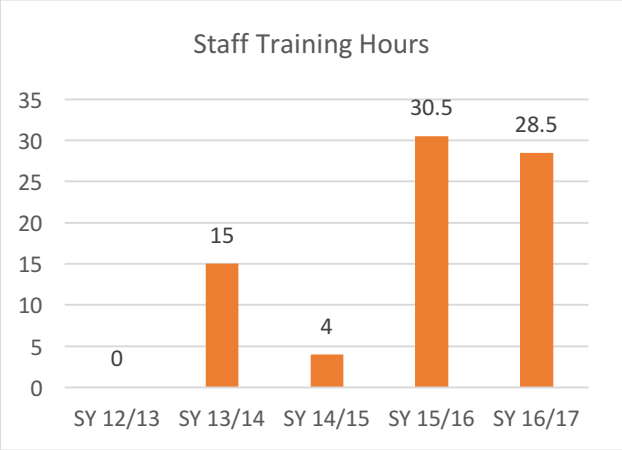
total weight:	51.15525 lbs
specialty crop weight:	31.4928 lbs
specialty crops percentage:	62%

OAKLAND UNIFIED SCHOOL DISTRICT
Community Schools, Thriving Students

OUSD Nutrition Services Staff Professional Development and Retrospective Surveys

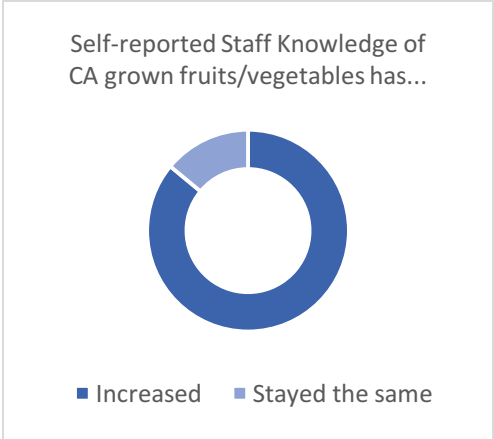
Professional Development

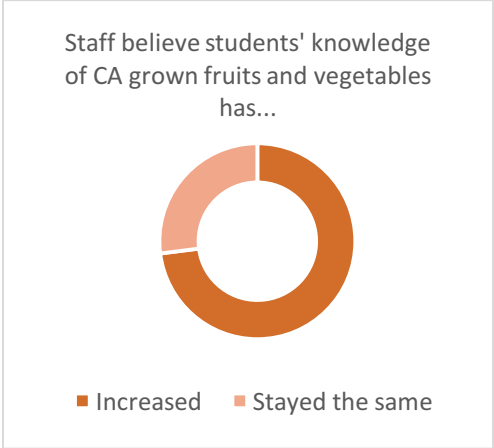
There were no recorded professional development hours in the 2012-13 School Year. A USDA Farm to School Grant in 2013-14 allowed for 15 hours of professional development. The CDFA Specialty Crop Block Grant has supported professional development hours for 2014-2017. During this period, staff training hours increased by 90% to almost double the total hours offered during the 2013-14 school year.

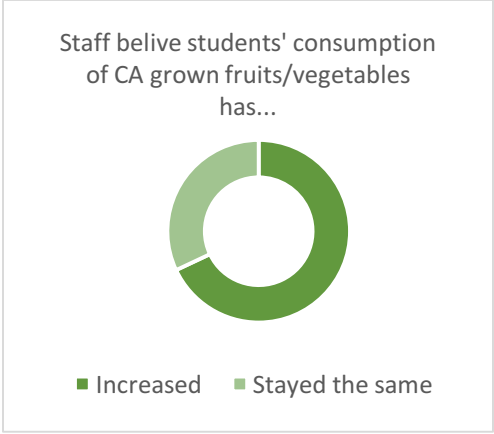


Staff Surveys

Sixty-five kitchen staff members at OUSD completed surveys about knowledge of California Specialty Crops and materials used to promote these crops at school sites. Of those surveyed, 100% of respondents correctly identified at least one local fruit or vegetable used in OUSD recipes, and 71% of respondents correctly identified at least two local fruits or vegetables used in OUSD recipes. Additionally, 100% of respondents stated their school uses at least one promotional item to market California Specialty crops to students. Promotional materials include salad bar banners, Harvest of the Month posters, aprons, student taste tests, etc.







Staff were asked to evaluate changes in their own and their students' knowledge and behavior between 2014 and 2017. 86% reported their knowledge of California fruits and vegetables has increased during this period; 73% reported their students' knowledge of California fruits and vegetables has increased during this period; and 68% reported their students' consumption of California fruits and vegetables has increased during this period.

Summer 2015 Student Taste Test Results:

Oakland Unified School District California Department of Food and Agriculture Specialty Crop Block Grant "California Food for California Kids"

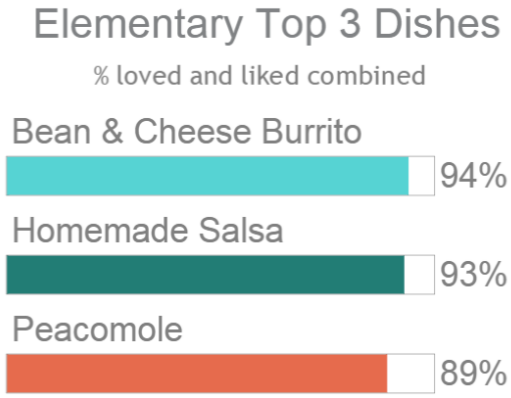
Overview:

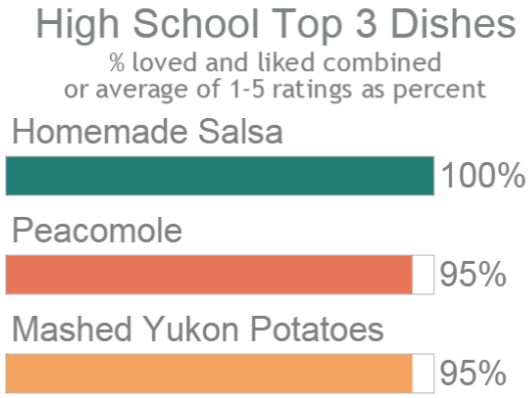
Summer school students tasted and reviewed ten recipes highlighting California Specialty Crops over the course of four weeks in June and July, 2015. Oakland Unified School District (OUSD) Department of Nutrition Services (NS) facilitated the taste tests at East Oakland PRIDE Elementary School (EOP), where an average of 53 students per recipe were surveyed, and Fremont High School, where an average of 21 students per recipe were surveyed. Recipes were prepared from scratch and served fresh same-day at EOP, as the recipe would be served at a school with an on-site cooking kitchen. Food was then held cold overnight and reheated (as needed) day two to serve at Fremont High School, as it would be at a school with a satellite kitchen served by one of OUSD's central kitchens. This two-part approach to recipe testing ensured selected recipes would be able to be served at all 85 OUSD cafeterias.

Elementary students' responses were measured using a simple three-option chart for each recipe: loved it, liked it, or tried it but did not care for the recipe. OUSD worked with students from the HOPE Collaborative's Youth Action Board to conduct peer-to-peer surveys at Fremont High School. High school students were interviewed by their peers and asked to evaluate the recipes on a scale of 1-5 using two metrics: recipe taste and probability of the student "getting in the lunch line" for the dish.

The ten recipes evaluated were: Fiesta Bean Salad, Mashed Yukon Potatoes, Bean & Cheese Burrito, Homemade Salsa, Baked Beans, Pinto Bean Tacos, Peacomole, Vegetable Pizza, Red Beans & Rice, and Garbanzo Bean Pilaf. Results are outlined below.

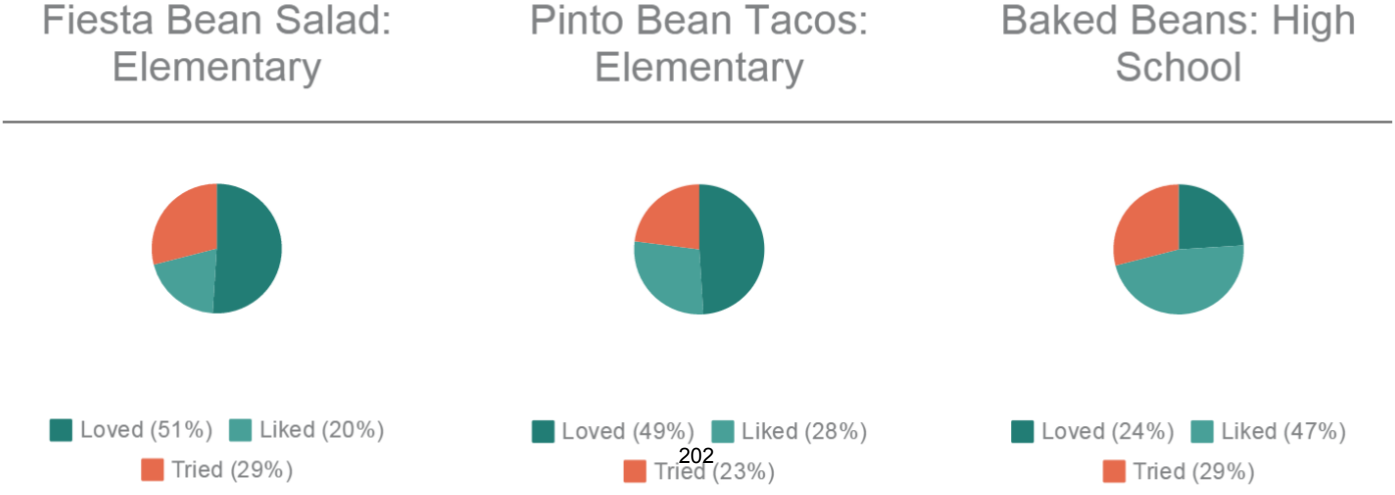
Results:



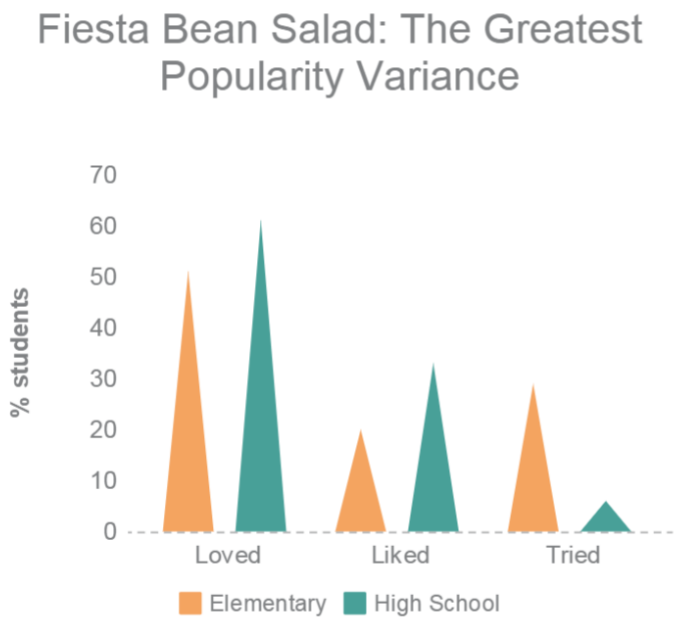


Peacomole — a purée of peas, fresh cilantro, lime, and spices — was popular with both groups, despite the unfamiliar concept and bright green color. One student called it "outstanding!" Also of note, both age groups responded well to the homemade salsa; in fact, every high school student surveyed reported they either "liked it or loved it."

The two least-popular recipes among elementary students surveyed were Fiesta Bean Salad and Pinto Bean Tacos. Among high school students surveyed, Baked Beans was the least popular recipe. Every other recipe was "liked or loved" by at least 90% of students, or ranked between 4 and 5 on the 5 point scale evaluating taste and probability of "getting the lunch line" for the recipe. While these recipes were least-favored when compared to all recipes tested, each received a combination of positive and negative reviews, as illustrated below:



Case Studies:



While 51% of elementary students surveyed reported they "loved" the Fiesta Bean Salad, 29% reported they "tried it and didn't like it." In contrast, among high school students surveyed, only 6% reported they "didn't like it." This 23% difference is the greatest popularity variance between age groups observed.

Fiesta Bean Salad is an example of a recipe received more positively by students after being held overnight and served day-two. Thus, the recipe would be especially appropriate for service in satellite cafeterias served by the OUSD central kitchens.



Seven of the ten recipes were served twice, once freshly prepared same-day and once held and reheated (as needed) day-two. Five out of the seven recipes were better received by students when held/reheated vs. when freshly prepared same-day.

This finding suggests that many recipes tested could succeed at satellite cafeterias. However, the difference could also be attributed to student age as high school students tested held food and elementary students tested freshly prepared food. In subsequent taste-tests, OUSD NS will control for student age when comparing freshly prepared vs. held/reheated recipes.

Final Notes:

Three recipes were tested only once and all ranked in the mid-range for their age group. Vegetarian Pizza and Red Beans & Rice were tested only at EOP: 87% of students surveyed reported they "loved or liked" the pizza and 78% reported they "loved or liked" the Red Beans & Rice.

One additional taste test was conducted during this period at Montera Middle School where students sampled Garbanzo Bean Pilaf. 82% of students surveyed reported they "liked or loved" the dish. This data has been grouped with the high school student survey data for the purposes of this report.

North Coast Opportunities
Lake Farm to School Project
Specialty Crop Certification

In accordance with the requirements of the California Department of Food and Agriculture's Specialty Crop Block Grant Program, North Coast Opportunities must ensure that grant funds are expended solely to enhance the competiveness of specialty crops.

Food Service Directors participating in the project are required to certify that the grant-funded training and infrastructure benefits they receive have been utilized solely to enhance the competitiveness of specialty crops, as detailed below.

Yes	No	
☑	☐	All infrastructure items received through the Specialty Crop Block Grant Program have been used solely to prepare and process eligible specialty crops.
☑	☐	All grant-funded trainings have been focused solely on the preparation and processing of eligible specialty crops.
☑	☐	Grant-funded promotional materials have focused solely on eligible specialty crops.

I hereby certify that the above statements are true and can be verified with supporting documentation upon request.

Jackie Courtney
Food Service Director Signature

Jackie Courtney
Food Service Director Name

Lakeport Unified
School District

4-12-17
Date

NORTH COAST OPPORTUNITIES

COMMUNITY ACTION PARTNERSHIP
Helping People. Changing Lives.

COMMUNITY ACTION
(707) 994-4474
(707) 994-4675 (FAX)

Lake County Farm to School – Quarterly Food Purchase Report

Date Range: October through December, 2016

School District: Konocti Unified School District

1. Total amount spent on all foods:
   a. $134,027.60
2. Total amount spent on local specialty crops (fruits, vegetables, tree nuts, and dried fruits):
   a. $5619.60
3. Name of local vendors you purchased from this Quarter and amount (pounds/boxes)
   a. Seely Farms - $4574.85
   b. NCO Food Hub - $163.25
   c. Adamson Ranch - $981.50
   d.
   e.

Lake County Farm to School Project
In-Kitchen Trainings for Food Service Staff
Training Assessment Summary

During Year 2 of the Lake County Farm to School Project, project staff delivered in-kitchen trainings to 30 food service staff in four school districts. Of the 30 training participants, 29 completed brief assessments of their training experience.

For the first five questions on the survey, participants used a 5-point scale (1=did not learn anything new, and 5=learned several new ideas) to rate the extent to which they learned from each component of the training. As the following table shows, the overall training as well as each of the five training components were all rated highly by participants, with the lowest rating going to the "knife skills" module and the highest rating to the "how to use/expand farm to school" module. All but four of the respondents said they would definitely return for future trainings, and those four thought they would "maybe" return.

Training rating scales

Training component	Kelseyville average response *n=8*	Konocti average response *n=8*	Lakeport average response *n=8*	Upper Lake average response *n=5*	Overall percent 4 and 5 responses	Overall average response *n=29*
1. Overall rating of the training	4.4	3.6	5.0	5.0	79%	4.5
2. Importance of farm to school	4.8	4.1	5.0	4.6	93%	4.6
3. Equipment and how it's used	4.4	3.6	5.0	5.0	86%	4.5
4. Knife skills	4.2	3.3	5.0	5.0	79%	4.3
5. Make a recipe and eat it	4.6	4.5	5.0	4.8	93%	4.7
6. How to use/expand farm to school	4.5	4.6	4.9	4.8	97%	4.7

Participants were asked to respond to several open-ended questions about their experience. Responses to each of these questions are summarized by category in the following tables.

7. Examples of new ideas that will be useful in school kitchens

Category	Selected responses
Kitchen skills	• Chiffonade for cutting kale • Dicing and slicing onions • Proper knife use to prevent hand damage • How to hold knives properly • Basic cutting strategies
Kitchen equipment	• Robot coupe and use of different blades • Tomato slicer • Dicing machine • Long mixer • Hand blender for smoothies
Recipes	• Carrot fries • Making slaw without mayo

8. Most memorable things learned from the training

Category	Selected responses
Collaboration	• Cooking together • Sharing ideas • Trying everyone's recipes
Kitchen skills	• Slicing and cutting strategies • Food storage methods • Proper ways to cut fruit and vegetables
Kitchen equipment	• Learning to use the new equipment • Robot coupe • Tomato slicer • Sealer
Recipes and specific foods	• Sweet potato recipe • Carrot fries • Experiencing foods I never liked before
Other	• The emphasis on local food • When someone got yelled at for cutting the cabbage wrong

9. Comments and suggestions about the training

Category	Selected responses
General	• I had fun, thank you! • Excellent presentation and information. • Always seems there is something new to learn on these trainings. • I liked learning as a group. • I learned a lot, and it was a fun experience.
Trainers and logistics	• Jenny was condescending. • I felt rushed. I would like to have had the time I wanted to ask questions and get explanations and examples.
Kitchen equipment	• I like having new equipment. • Great equipment makes food prep easier. • Need more hands-on use of equipment.
Recipes and specific foods	• I like the idea of cooking from scratch. • I like using more fruits. • We loved learning all the new recipes. • We're sure the kids are going to like the new recipes. • Would have been nice to have all the ingredients we needed.
Other	• Anyone working in a kitchen should already have knife skills. • How to keep costs down. • Need to spend more time cooking.

10. Ideas and suggestions for future trainings

Category	Selected responses
Logistics	• Make the training longer. • Allow time for questions, and don't call out the time.
Recipes and specific foods	• More training on using fresh fruits and vegetables. • Try simple new recipes. • Make salsa.
Other	• Go to a winery. • Make margarita smoothies.

Year 2 Lake Farm to School Project
Feeding Our Future Survey Summary
August 2016

In July 2016, the Lake Farm to School Project hosted the all-day Feeding Our Future event at the Brassfield Estate Winery in Clearlake Oaks. The event was attended by 20 food service directors and food service staff representing the Lake County Office of Education and three Lake County school districts: Lakeport, Konocti, and Upper Lake. Participants received four hours of continuing education units (CEUs) from the California School Nutrition Association in recognition of the educational nature of the event. At the close of the day, participants completed a brief survey to report how much they had learned from the information shared throughout the day. Overall, participants gave the event an impressive rating of 9.85 on a 10-point scale.

The first section of the survey asked participants to use the following five-point scale to report their knowledge about several topics, first reporting how much they knew about the topic *before* the event, and then reporting how much they knew by the end of the day.

- 1 = None
- 2 = Not Much
- 3 = A Little
- 4 = Quite A Bit
- 5 = A Lot

Responses showed that participant knowledge increased overall, and for all of the topics. The following table shows aggregate pretest results, aggregate posttest results, percent change, and the percent of participants that reported a gain in knowledge. For questions 6-8, those participants who had benefited from in-kitchen trainings prior to the event were asked to report their knowledge gain. Note that some questions were not answered by all respondents.

Gains in knowledge (Highest possible rating = 5.0)

Topic	*N*	Pre	Post	Difference	Percent change	Percent reporting knowledge gain
1. Why Farm to School is important	20	4.0	4.8	+0.8	+20%	68%
2. How Harvest of the Month works	20	3.6	4.8	+1.2	+33%	58%
3. How to prepare tasty, economical salads	19	3.1	4.5	+1.4	+45%	83%
4. How to promote salads on the school menu	20	3.2	4.4	+1.2	+38%	74%
5. How to order produce through the MendoLake Food Hub	19	2.0	3.7	+1.7	+85%	83%
6. In-kitchen trainings: knife skills	14	3.7	4.3	+0.6	+16%	62%
7. In-kitchen trainings: use of equipment	14	3.8	4.5	+0.7	+18%	58%
8. In-kitchen trainings: recipes	14	3.8	4.5	+0.7	+18%	62%
OVERALL		**3.19**	**4.42**	**+1.23**	**+39%**	

The survey next asked participants to respond to two open-ended questions: what they found most interesting during the day, and what they would like to learn more about. Responses are provided below for each question.

Category	*What was the most interesting thing you learned from this event?*
F2S Strategies	• Harvest of the Month • Presentation of foods • How the community needs to be involved • Less daunting to use local produce in preschool and after school menus • How difficult it is for cafeterias to purchase and use local produce
Recipes	• Dressings and salad combinations • Salads
Logistics	• About the Food Hub
Value of F2S	• Impact that Harvest of the Month can have • How many lives and students F2S can impact

Category	*What topics would you like to learn more about?*
Logistics and sourcing	• School gardens • Farm to school in general • Locally-grown foods • Food Hub
Promotion	• Taste testing in classrooms • Ways to get kids involved • Signage
Procedures	• More hands-on training for food service staff
Meal planning	• Making the food taste good, given the variation in taste buds • Recipes that kids will eat, including main dishes • Recipes in the binder were great, but we can't use them if they don't include creditable yields • Measurement with regard to food servings • Menu planning (with demonstration) • Presentation of food • Incorporating fresh foods into recipes • Putting flavors together • Recipes that don't require cooking, since we don't have kitchens • Harvest of the Month recipes
Other	• How to educate children through school kitchens • I will use Harvest of the Month at home with my own family

Lake County Farm to School Project
In-Kitchen Trainings for Food Service Staff
2017 Training Assessment Summary

During Year 3 of the Lake County Farm to School Project, staff delivered in-kitchen trainings to food service staff in four school districts. Of the participants, 32 completed brief assessments of their training experience. Overall, participants gave the trainings an impressive rating of 9.6 on a 10-point scale.

The first section of the survey asked participants to use the following five-point scale to report their knowledge about several topics, first reporting how much they knew about the topic *before* the event, and then reporting how much they knew *by the end of the training*.

1 = None 2 = Not Much 3 = A Little 4 = Quite A Bit 5 = A Lot

Responses showed that participant knowledge increased overall, and for each of the topics. For each question, the following table shows the number of people that responded to the question, aggregate pretest results, aggregate posttest results, percent change, and the percent of participants that reported a gain in knowledge.

Gains in knowledge (Highest possible rating = 5.0)

How much did you know before and after the training?	N	Pre	Post	Difference	% change	% reporting knowledge gain
1. Setting up the kitchen workspace for processing fresh produce.	30	3.6	4.5	+0.9	+24.8%	63%
2. Prepping produce that comes straight from the field.	31	3.4	4.5	+1.1	+34.3%	68%
3. Storing fresh produce.	29	3.4	4.2	+0.8	+24.2%	59%
4. Processing fresh produce for freezing.	29	2.8	3.8	+1.0	+37.0%	69%
5. Planning menus using Harvest of the Month produce.	30	2.7	4.2	+1.5	+58.8%	83%
6. Using a Robot Coupe effectively and safely.	31	2.5	4.4	+1.9	+78.9%	87%
7. Using a knife safely, and knowing which knife to use.	31	3.8	4.5	+0.7	+18.6%	32%
8. Which produce can be processed from scratch, using the new equipment.	27	3.2	4.7	+1.5	+44.8%	78%
OVERALL		**3.2**	**4.4**	**+1.2**	**+37.8%**	**59%**

The following table shows the post-test results of the survey by school site.

Percentage providing responses of "4" and "5" on posttest, by question and school district

#	Kelseyville	Konocti	Lakeport	Upper Lake	ALL
	n=7	*n=10*	*n=10*	*n=5*	*n=32*
1	100%	80%	100%	100%	**93%**
2	100%	90%	100%	100%	**97%**
3	83%	78%	100%	100%	**90%**
4	71%	75%	56%	100%	**72%**
5	83%	80%	89%	100%	**87%**
6	71%	100%	78%	100%	**87%**
7	100%	100%	89%	100%	**97%**
8	100%	100%	100%	100%	**100%**
AVG	**89%**	**88%**	**88%**	**100%**	**90%**

Participants were also asked to respond to several open-ended questions about their training experience. Responses to each of these questions are summarized by category in the following tables.

7. Most interesting things learned in the trainings

Category	Selected responses
General	• Being introduced to new foods and new recipes
Kitchen skills	• Using and mixing spices • Using different sauces for vegetables • Roasting vegetables • Heart-shaped cucumbers • Using in-season vegetables • Using herbs • Edible flowers
Kitchen equipment	• Robot Coupe
Recipes	• Chimichurri • Vegetable recipes using spices

9. Topics that participants would like to learn more about

Category	Selected responses
Kitchen skills	• Cooking with fresh herbs • Using spices • Menu planning • Vegetable prepping
Recipes	• Vegetable recipes • Main dish recipes • Pasta dishes
Other	• Hints for growing vegetables at home • Sources for finding locally-grown vegetables

HOTM Calendar for Lake & Mendocino Counties

The harvest of the month selections each month highlight what is ready for harvest here in Lake and Mendocino counties! However, due to fluctuations in the weather, season, etc. selections are subject to change.

January..... Beets

February..... Kale/Leafy Greens or Citrus

March..... Lettuce/Salad Greens

April ..... Radishes

May..... Peas

June..... Strawberries

July..... Cucumbers

August..... Cherry Tomatoes

September ..... Melons or Slicer Tomatoes

October..... Sweet Peppers or Pears

November ..... Apples or Carrots

December ..... Winter Squash

KONOCTI UNIFIED SCHOOL DISTRICT LUNCH MENU



MAY & JUNE 2017



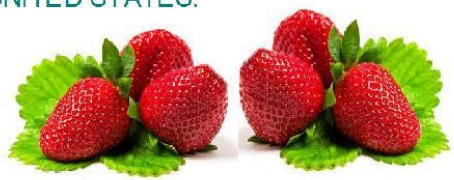
Konocti USD Farm to School

Monday	Tuesday	Wednesday	Thursday	Friday
1 BURRITO CASSEROLE TORTILLA CHIPS SALSA FRESCA FRESH APPLE WEDGES	2 CHICKEN DRUMSTICK WHOLE GRAIN BISCUIT COOKED CORN LOCAL GROWN STRAWBERRIES	3 TERIYAKI BEEF BITES BROWN RICE BROCCOLI SALAD TROPICAL ORANGES	4 LASAGNA WITH MEAT SAUCE SOUR DOUGH BREAD GREEN SALAD FRUIT COCKTAIL	5 CHICKEN BURGER ON A WHOLE GRAIN BUN FRESH MADE POTATO SALAD VANILLA GRAHAM CRACKER ORANGE WEDGES
8 MACARONI AND CHEESE WHOLE GRAIN ROLL GREEN BEANS ORANGE WEDGES	9 ROTINI PASTA WITH BEEF SAUCE SOUR DOUGH BREAD GREEN SALAD FRESH APPLE WEDGES	10 CHICKEN & BEAN BURRITO TORTILLA CHIPS SALSA FRESCA DICED PEACHES	11 COLLABORATION DAY HAMBURGER ON A WHOLE GRAIN BUN CHEESY POTATOES BUG BITES CRACKERS FRESH APPLE WEDGES	12 CHICKEN TOMATO BAKE WHOLE GRAIN BREAD STICK GREEN SALAD ORANGE WEDGES
15 BEAN AND CHEESE CHALUPA TORTILLA CHIPS SALSA FRESCA FRESH APPLE WEDGES	16 ITALIAN CHICKEN BAKE WHOLE GRAIN ROLL GREEN BEANS WHOLE GRAIN CHEEZ-IT ORANGE WEDGES	17 CHEESE PIZZA WHOLE GRAIN BREAD STICK GREEN SALAD SCOOBY DOO CRACKERS FRUIT COCKTAIL	18 TURKEY DOG ON A WHOLE GRAIN BUN COOKED CORN GOLDFISH CRACKERS FRESH APPLE WEDGES	19 STAGECOACH SPAGHETTI SOUR DOUGH BREAD GREEN SALAD DICED PEACHES
22 BEAN AND CHEESE BURRITO TORTILLA CHIPS CUCUMBER COINS ORANGE WEDGES	23 MARINARA CHICKEN WITH ROTINI PASTA SOUR DOUGH BREAD GREEN SALAD DICED PEACHES	24 MEATBALLS & GRAVY MASHED POTATOES WHOLE GRAIN ROLL FRESH APPLE WEDGES	25 SLOPPY JOE ON A WHOLE GRAIN BUN GREEN SALAD SCOOBY DOO CRACKERS LOCAL GROWN STRAWBERRIES	26 CHEESE & OLIVE PIZZA GREEN BEANS ZOO ANIMAL CRACKERS PINEAPPLE
29 MEMORIAL DAY	30 CHEESE ENCHILADAS TORTILLA CHIPS REFRIED BEANS FRESH APPLE WEDGES	31 PIZZA HOT POCKET WHOLE GRAIN BREAD STICK CARROT RAISIN SALAD WHOLE GRAIN CHEEZ-IT ORANGE WEDGES	1 CHEESY NACHOS SALSA FRESCA GREEN SALAD VANILLA GRAHAM CRACKER FRUIT COCKTAIL	2 TURKEY & CHEESE ON WHEAT BREAD LETTUCE & TOMATOES CHOCOLATE ELF GRAHAM FRESH APPLE WEDGES



Harvest of the Month™

THE HARVEST OF MONTH FOR MAY IS STRAWBERRIES. CALIFORINA PRODUCES OVER 80% OF THE STRAWBERRIES GROWN IN THE UNITED STATES.



EVERY LUNCH INCLUDES A WIDE VARIETY OF FRESH VEGETABLES FROM THE VEGGIE BAR AND A CHOICE OF FLAVORED MILK



Menus are subject to change



August
TOMATOES

Harvest of the Month



Tomato Soup

This classic soup goes great with grilled cheese sandwiches!

TOTAL TIME: 40 min PREP: 10 min COOK: 30 min SERVES: 4

INGREDIENTS:

- 1 tbs. Olive Oil
- 1/2 Yellow Onion, peeled, trimmed & diced
- 2 tsp. minced Garlic
- 1/2 tsp. Paprika
- 6 1/2 lb. ripe Tomatoes, washed, cored & diced
- 1 1/2 cups Chicken or Vegetable Stock
- Salt & Pepper to taste
- 2 tbs. chopped Parsley or fresh Basil

In a large soup pot, heat the oil over medium high heat. Sauté the onions and garlic, stirring occasionally, until golden. Add the paprika and sauté for 1-2 minutes. Add the tomatoes and stock and bring to a simmer. Cook for 20 minutes. Purée soup with an immersion blender, or in batches in a standard blender. Taste and season with salt and pepper. Serve, garnishing with chopped parsley.

Recipe Developed by Jenny Huston, Farm to Table Services, www.farmtoservices.com/recipes

SCBG Project 25: Cultivating Community North Valley Event and Partner Lists

Part One (1). Chico State courses/classes for which the project-supported Organic Vegetable Project provided a platform: Sustainable Vegetable Crop Production, Economic Entomology, Soil Fertility and Plant Nutrition, Plant Protection Materials, Living Systems, Horticultural Therapy, Integrated Pest Management, Directed Work in Row Crops, Weed Science, Community Nutrition, Science and Human Values, Concepts in Life Science, Mechanical Engineering Design (for hydroponic mechanisms), and Directed Research in Variety Trials.

Part Two (2). Garden/farmsites supported in the 2014-17 performance period: 1) Pleasant Valley High School Garden (SCBG Project 25: 2014-17 [P25]), 2) Bidwell Junior High School Garden (P25), 3) Rosedale Elementary Garden (P25), 4) Hooker Oak Elementary Garden (SCBG Project 48: 2011-14 [P48]), 5) Parkview Elementary Garden (P48), 6) Citrus Elementary Garden (P25), 7) Chapman Elementary Garden (P25), 8) Sherwood Montessori Elementary Garden (P48), 9) McManus Elementary Garden (P25); 10) Blue Oak Elementary Garden (P25); 11) Paradise Elementary Garden (P48); 12) Concow Elementary Garden (P48); 13) Rose Scott School Garden (P25); 14) Hearthstone School Garden (P25), 15) Marigold Special Ed Garden (P25); 16) Fresh Start Youth Rehabilitation Garden (P25); 17) African American Family & Cultural Center Garden (P48); 18) Lindo Ave. Neighborhood Garden (P48); 19) ARC Garden (P48), 20) Chico Teen Center Garden (P25); 21) Chico Peace & Justice Center Garden (P48); 22) Boys and Girls Club Garden (P25); 23) Chico Grange Garden (P48); 24) Neal Dow Avenue Garden (P25); 25) Skycreek Dharma Center Garden (P48); 26) Fourteenth Street Garden (P48); 27) Humboldt Community Gardens (P48); 28) Dorothy Johnson Youth Center Garden (P48); 29) Oak Way Disability Access Garden (P25); 30) Maker's Garden 2nd Baptist Church (P48); 31) The Jesus Center Farm (P48); and Community Housing Improvement Program (CHIP) urban farmsites, including: 32) Azalea Avenue Apartments Garden (P25), 33) Murphy Commons Garden (P48); 34) Rancho Arroyo Apartments Garden (P25); 35) Kentfield Garden (P48); 36) Avenida Apartments Garden (P25); 37) Hartford Square Garden (P48); 38) Citylight Plaza Garden (P48); 39). Oakmont Senior Center Garden (P25); 40) Jarvis Senior Housing Garden (P48); 41) Prestige Assisted Living Garden (P25), 42) Magalia Gardens (P25).

(Note: While half the above gardens are specified to have first received project resources during Project 48, their listing above indicates continued support by Project 25. Also, while most of the P25 and P48 gardens were initially input and primarily resourced by CCNV's team (SCBG funds), some were instigated and/or partially supported by non-project partners, but were in need of CCNV resources to successfully continue or expand. Because maintaining the longevity of community gardens is always a challenge, CCNV's Team required applicants for new-garden project input materials and labor to submit a plan for ongoing garden maintenance and stewardship. Once committed to a garden project, CCNV sought resource partners and cooperative relationships whenever possible, and assisted garden stewards with outreach for discovering additional, preferably local, sources of support.

Part Three (3). Specialty Crop instructional farming event topics included, but were not limited to: Prepping Beds for Planting; Cool Season Planting; Fall Cover Cropping; Pea Trellis Building; What Healthy Roots Look Like & How to Cultivate Them; Container Gardening; Vegetable & Flower Seed/Start Planting Instruction & Sale; Raised Bed Building; Turning Cover Crops into Vegetable Beds; Improving the Soil for Robust Vegetables; Vegetable Crop Rotation; Planting Melons, Beans & Corn from Seed & Start; Protecting Your Vegetable Plants: Using Bugs to Manage Pests; Growing

Papalo, Buzz Buttons, Tulsi, Cinnamon Basil, Lemon Basil, French Tarragon, Chocolate Mint; Vegetable/Herb/Flower Seed Packaging; Compost Bin Building for a Vegetable Garden; Composting 101; Installing Drip Irrigation for a Vegetable Garden; Seasonal Seed Saving; Seed Ball Making; Identifying/Tasting All Edible Parts of Vegetable Plants; Cut & Grow Salad Greens; Seeding Seasonal Crops; Planting Cover Crops; Garden Box Installation; Berry Stem & Propagation; Pruning Berry Bushes; Transplanting Seasonal Crops; Building Native Bee Hotels; Building Edible Hedgerows; Pruning Fruit Trees; Fruit Tree Grafting; Sowing Wildflower & Flowering Permaculture Seeds; Garlic and Onion Planting Party; Irrigation for Fruit & Nut Orchards; Bees as Pollinators--Series; Washing Veggies & Fruit for Sale; Vegetable, Herb & Flower Heirloom Seed Swap; Perennial Herb Pruning; Direct Seeding vs. Transplanting; Edible “Weeds”; Controlling Weeds Organically; Herb Seed Starting & Planting; Vegetable Companion Planting; Vegetable Variety Trial Testing; Tuber Planting; Fallow to Fertile: How to Refurbish Vegetable Garden; Building Trellis for Berries; Square Foot Garden Planning; Simple, Low-Cost Greenhouse Building; Growing Starts in a Greenhouse: How and When; How to Shade Leafy Vegetables for Longer Growing Season; High Elevation Fruit & Vegetable Gardens; Cold Frame Making for Vegetable Starts; Protecting Your Starts: Gopher Wire & Insulation; Cultivating MicroGreens; Composting for a Vegetable Garden, with Re-cology; Building Potato Growing Bins; Pallet Compost Bin Build; Making Your Garden More Handi-Accessible; Organic Fruit Tree Fertilizing; Mulching; Cultivating Mushrooms; Fruit & Vegetable Drying; Exploring Tomato Varieties; Fundamentals of Commercial Seed Production.

Glean Team events included the following: Mapping Fruit/Nut Tree Locations & Building Relationships for Ongoing Harvest; Apple Harvesting--What To Do With the Good, the Bad & Ugly; Persimmon Harvest: Varieties & Timing; Citrus Harvesting Techniques: When to Pick & What to Leave; Gleaning Walnuts: Cleaning & Aging; Gleaning the Winter Bounty: Pomegranate & Kiwi; Gleaning Cherries: Varieties & Timing; Gleaning Apricots; Harvesting Blackberries for the Best Haul:, Gleaning Peaches & Nectarines; Gleaning Plums & Pears; Gleaning Wild Grapes; Gleaning Summer Squash, Gleaning Tomatoes; Gleaning Cabbage; Harvesting Greens So They Grow Back; Harvesting Lemons & Elderberry Flower; Harvesting Loquats; Proper Harvest of Mulberries; Identifying and Harvesting Kumquats; Harvesting Organic Almonds; Harvesting Multiple Varieties of Apples; Properly Harvesting Melons.

Part Four (4). Cottage Industry Value-Added workshop topics included: Making & Bottling Kimchee & Sauerkraut; Peach Jam & Salsa Making & Bottling; Applesauce Making & Bottling; Sun Dried Tomato Making & Packaging; Making & Bottling Basil Pesto; Juicing and Safely Bottling Pomegranates for Juice, Jam & Jelly; Catering With Seasonal Produce; Beet Kvass-Making & Preserving; Fruit & Nut Bar Making & Packaging for Sale; Drying Herbs & Preparing Teas; Preserving the Stone Fruits of Summer: Peach Jams, Spreads & Sauces; Preserving Stone Fruits of MidSummer: Apricot Jams, Spreads & Sauces; Preserving Midsummer: Plum Jams, Sauces, Spreads; Tomato Salsa Making & Bottling; Making & Bottling Tomato Sauce & Tomato Paste; Making & Bottling Nepalese Gundruck from Vegetables; Making & Bottling Kombucha From Mushrooms; Kale Chip Making & Packaging; Catering Series: Veggie Spring Rolls; Spring Veggie Appetizers; Hearty Seasonal Garden Dishes; Fruit Muffins, Vegetable-Based Cold Salads & Main Dishes; Root Vegetable Roasting; Decorative Chopping & Carving Techniques for Raw Produce; Using Garden Herbs As Sweet/Savory Spices; Making Sauces with Garden Herbs and Vegetables; Sauteing With Garlic, Leeks and Olive Oil; Preserving the Fruit & Vegetable Harvest With Quality Hand Pies; Cooking with Basil & Pesto; Cabbage Roll Cooking; Pumpkin Soup Making.

Partnering organizations for Cottage Industry workshops included: The Grange Kitchen, Bidwell Presbyterian Church Kitchen, Lucian Manor Kitchen, Trinity United Methodist Church Kitchen, ARC Pavilion Kitchen, The Jesus Center Shelter Kitchen; and the Chico State Farm Kitchen.

(Note: no sales arose directly from the items made in the Cottage Industry/Value-Added classes—these were how-to exercises, with products kept for participant quality-testing and use. Revenue from future product processing/preparation/sale would belong to participant vendors/caterers.)

Part Five (5). Culinary Demonstration topics and tastings included the following: Ribboned Asparagus & Spring Mix; Pad Thai with Cabbage and Almonds; Persimmon Date & Walnut Plates; Broccoli & Sauces; Persimmon, Pomegranate & Mandarin Salad; Butternut, Black Bean & Pomegranate Tacos; Brussels Sprouts & Field Mustard; Eggplant, Peppers & Lemongrass; Potato Salad & Herbs; Cucumber Appetizers; Radish Salad; Thai-Spiced Green Veggies; Zucchini Butter; Seasonal Fruit & Nut Snacks; Stir Fry Veggies; Summer Veggie Grilling; Veggie Pizza Toppings; Ratatouille Vegetables; Making Organic Popcorn; Making Spinach Taste Amazing; Making Salad from All the Plant Parts; Spiced Pumpkin; Herbs and Spices for Fall & Winter Dishes; How to Make Squash & Pumpkin Treats; Apple Crunch; Chard Frittatas; Spicing Peas; Chocolate Tomatoes; Loofa & Bidwell Melon; Avocado Kale Salad; Making Seed & Fruit Energy Bars; How to Make Spinach Roll-Ups; Making Cherry Compote; Kohlrabi Tasting; Making Broccoli-Blueberry Salad; Veggie Sushi Making; Making Gazpacho; Veg Stir Fry with Garlic & Tahini; Cooking with Okra; Cooking with Eggplant; Cooking with Squash & Peppers; Cooking with Nuts & Produce; Panzanella Salad with Heirloom Tomatoes; Lettuce Thai Tacos; Zucchini, Lemon & Parmesan.

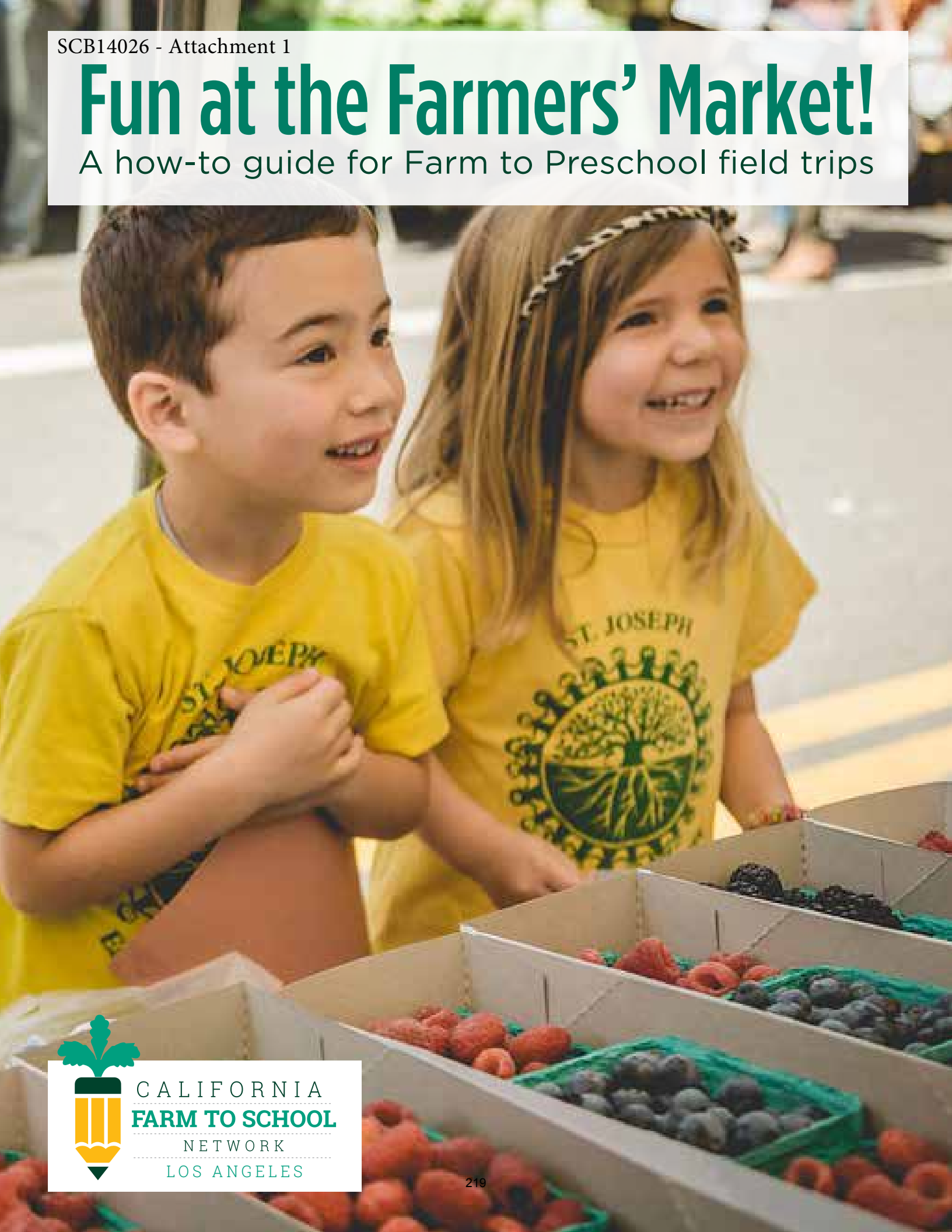
Part Six (6). Project Partners included: 1.) Redwood Organic Seeds; 2.) Tehama County Public Health; 3.) SkyCreek Dharma Center; 4.) Butte County Food for All Food Bank Program; 5.) Butte Community Action Agency; 6.) Four Winds Indian Education; 7.) Yang Family Farms; 8.) Chico Garden Share; 9.) Riparia Farms; 10.) CSU, Chico's Center for Healthy Communities; 11.) CSU, Chico's Hungry Wildcat Student Services; 12.) Butte County Community & Economic Development; 13.) From the Ground Up Farms; 14.) Butte County Public Health Department; 15.) North Valley Food Hub; 16.) CSU, Chico Department of Nutrition & Food Sciences; 17.) Bidwell Presbyterian Healthy Cooking/Eating Program; 18.) Chico Area Recreation District School Garden Programs; 19.) Chico State & Butte College Associated Students Sustainability Programs; 20.) Respectful Revolution Project; 21.) Southside Chico Farmer's Market; 22.) Jarvis Gardens Senior Housing Project; 23.) CalFresh Outreach; 24.) Chico Certified Farmers' Market; 25.) CSU, Chico Center for Regional & Continuing Education; 26.) CSU, Chico "Veggie Bucks" Program; 27.) California Tribal Temporary Assistance for Needy Families Partnership (CTTP); 28.) Chico Grange; 29.) Chico Unified School District Farm-2-School Program; 30.) The CSU Regenerative Agriculture Initiative; 31.) Chico Permaculture Guild; 32.) Chico Natural Foods Co-Op; 33.) Disability Action Agency; 34.) Trinity United Methodist Church; 35.) GRUB CSA Program; 36.) Chico Women's Club; 37.) Salvation Army; 38.) Passages; 39.) Catholic Ladies Relief Society; 40.) Caring Choices of Chico; 41.) Youth for Change; 42.) Hispanic Resource Center; 43.) Valley Oak Tools; 44.) The Wrench: Fix-It; 46.) Triple-J Farms; 47.) Butte County Resource Conservation District; 48.) UC Cooperative Extension; 49.) Community Alliance With Family Farmers (CAFF); 50.) Butte Environmental Council; 51.) Chico News & Review; 52.) Chico Enterprise Record; 53.) KZFR-Radio; 54.) Chico Peace & Justice

Center; 55.) CSU, Chico College of Agriculture; 56.) Butte County Based Coalition: Life Skills; 57.) The Work Training Center; 58.) Butte County Corrections/Juvenile Division.

Note: The project now includes stakeholders in the partner list. Stakeholders attended project coalition meetings. Partners may or may not have attended meetings, but provided other meaningful support to the project. Not-listed above are organizations, agencies, community groups and schools that were primarily beneficiaries of the project (these are listed elsewhere), though they too provided cross-promotion, advertizing among their served populations; and often contributed resources.

Fun at the Farmers' Market!

A how-to guide for Farm to Preschool field trips



CALIFORNIA
FARM TO SCHOOL
NETWORK
LOS ANGELES

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MATH



FOOD MEASURING Use a segment of yarn to wrap around fruits and vegetables to measure how big they are around or how tall or long they are. Stretch out the yarn along a ruler to find out the measurements of each fruit and vegetable.

MAKE A GRAPH of your classroom's favorite fruit or vegetable: Create a graph with 4–6 vegetables to choose from along the bottom axis. Each student will have a sticker or symbol to add to their favorite fruit and build the bar graph!

SORTING ACTIVITIES For younger students try sorting activities: Cut out images of different food items or use fruits, vegetables, and food toys. Sort into categories like grains, dairy, fruit, vegetable, and protein on a bulletin or in baskets.

MORE IDEAS FOR **MATH**



CASHIER STATION Make a cashier station to sort coins and bills into their correct compartments. For older students practice writing simple receipts.

WEIGH STATION Create a weigh station for weighing produce, compare items—which weighs more? What's the heaviest or lightest?

COUNTING OF ITEMS For the youngest ones, try a simple counting of items in a market basket. Create a pretend market basket using toys or paper cutouts and practice counting as the children empty the basket.

Additional math-related worksheets are located in *Appendix B*.

SCIENCE







Build on a child's inborn urge to explore and investigate the world through their senses, make connections between what is familiar and what is new, construct knowledge from experience and to master new skills.

DISCOVERY LAB Allow children to explore and discover fruits, vegetables, seeds, soil, and insects with scientific instruments.

- Place an array of produce and garden materials along with magnifiers, tweezers, scales, rulers, etc., for children to explore with on their own.
- Encourage them to describe what they see, feel, smell, and hear.
- Ask: How are they different? How are they the same?
- Record their observations.

MORE **SCIENCE**







SEEDLINGS Try planting seedlings in cardboard cartons first, that way each child has ownership over their carton and seedlings. Then as they water them and let the seedlings get sun, they will watch them grow and grow. This activity will teach students about water and sun helping plants to grow, as well as patience from watching their seeds sprout and grow. Carton seedlings can also be grown in a sunny spot inside for preschools in colder climates.

Once they are big enough the seedlings can be transplanted into a larger garden bed to grow to full size. Students can work together on the beds as a class. They will continue to learn about plant life, watering, and sunlight, as well as developing teamwork and sharing skills.

ART





PAINTING, SCULPTING, COLLAGE

Painting, sculpting, and creating collages of produce develops creativity and fine motor skills, learning colors and shapes.

- Have children draw the fruit or vegetable that they are exploring. They can use many mediums such as watercolors, tempera paint, crayons, etc.
- Use play dough or clay to create a fruit or vegetable.
- Collage with seeds and leaves from the fruit or vegetable.

Create artwork to reflect what you have planted in the garden or cardboard cartons. Creating artwork of what students have planted helps children to visualize what their seeds will become with the proper care and sunlight. If the students have planted carrots, create artwork of carrots, or use carrots to paint with.

MORE **ART, MUSIC**





BANNERS, SIGNS, LABELS Create banners, signs, or labels to include in the farm stand dramatic play. Then students can use the farm stand they have created for other activities like dramatic play, or using the cash register.

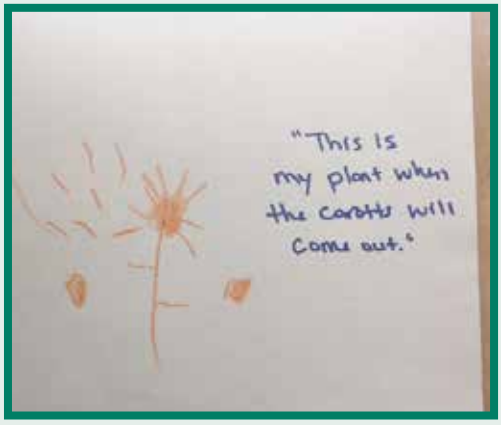
COLLAGE Experiment with fruit-and-veggie themed collage using free flyers and newspaper coupons from grocery stores. This will not only develop artistic and creative ability, but will also develop fine motor skills by using scissors to cut out images, and paint brushes for glue to add to the collage.

SONG:

Take Me Out To The Farmers' Market
(to the tune of **Take Me Out To The Ball Game)**

Take me out to the farmers' market.
Take me out to buy fruits.
Show me some apples and blueberries.
Fill my basket with lots of veggies.
Let's find root, root, roots, we can steam.
Beets and Yams are my fave!
I put one, two, three, in my pot
For dinner on farmers' market day!

WRITING







DICTATION STORIES Ask children to draw the vegetable or fruit that was studied. Next have the child tell the adult about their picture and ask for permission from the child if it is okay to write on their art work. If it's okay, write down their description of the picture. Some preschoolers may want to write their own story.

"V" IS FOR VEGETABLES
Create a writing sample for students to practice writing letters. Then the children can accompany their writing with illustrations of their favorite vegetables.

SENSORY, DRAMATIC PLAY





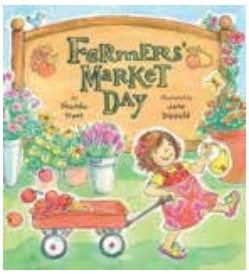


SENSORY Another alternative to garden beds, if you are located in a cooler climate, is soil sensory bins. Fill bins with soil and various produce items. Then provide gloves, scoops, shovels, and rakes for the children to explore the bin and its contents. Talk about how of each fruit and vegetable interacts with your senses. How did it feel?—Was it smooth? Prickly? Fuzzy? Leafy? How did it smell?—Earthy? Sweet? How many items are in each bin? Can you count them?

DRAMATIC PLAY Create a farmers' market set in your classroom repurposing boxes, tables, and grocery toy items as a market stand. Children can help to design banners and labels for the market stand. Then the market stand can have different roles for the students to try playing. Roles could be the farmer, the customer, or the restocker. The farmer and customer could practice an exchange of questions and sale that would occur at the real farmers' market they visit later. The restocker will sort and stock items into the correct places as they are used.

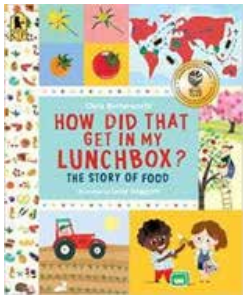
RECOMMENDED READING

3–5-year-olds



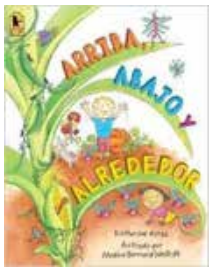
Farmers' Market Day
by Shanda Trent
Trent's story follows a young girl as she goes to the farmers' market and talks about each action she does, from preparing beforehand, to making purchases at the market, and then going home with her fresh purchases.

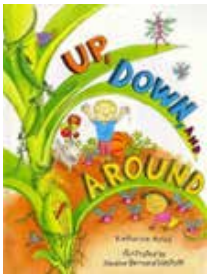
"This book got the children excited about going to the farmers' market. They came up with their own story about what was going to happen during the field trip, from the beginning to the end. They also showed interest in counting money at the market."



How Did That Get In My Lunchbox?
by Chris Butterworth
This story is an excellent way to give students an introduction into the food system. It shows how many steps there are before foods reach their plate to eat.

"The children were very interested in learning where food comes from. They personally related to some of the characters from the book. At the end of the book they had so many questions about other types of food."





Arriba, Abajo, y Alrededor
by Katherine Ayres
This story, available in English and Spanish, shows how plants and all things in nature grow and move in all different directions. Some plants grow high to the sky, while other vegetables grow beneath the soil where we can't see them. This book is also available in both English and Spanish for bilingual classrooms.

"The children had been wondering about how some vegetables grow. This book helped them understand that not all vegetables grow in one direction. They became curious about carrots and how they grow down, so we decided to plant carrot seeds in a viewer planter so they could see the carrots grow down."

MORE RECOMMENDED READING

Younger Students (18 months–3 years)



Market Day and Growing Vegetable Soup/
A sembrar sopa de verduras
by Lois Ehlert

"We read both books and talked about some of the vegetables that we saw in the books. We even had a basket full of fresh vegetables for the children to smell and hold after reading the book."

"When we went to the farmers' market on our field trip we bought some of the vegetables and fruits that were in the books we read during circle time, and even got to taste some fresh produce. We also had some vegetables left and decided to make our very own vegetable soup with the remaining vegetables that we had left from our trip. The children each had their own plastic butter knives and practiced cutting vegetables and adding them to our soup. Once all of our vegetables were added we let them cook in the crock pot. When the vegetables were ready, we tasted it and the children all gave a thumbs up because they liked the soup."

Additional book recommendations are listed in *Appendix A.*

TIPS, TRICKS, AND MORE







TIPS AND TRICKS

- Organize student and chaperone/teacher groups before arriving at the market. Color coding groups by T-shirt, or having all students and chaperones wear the same color t-shirt or a special school t-shirt is helpful when navigating a busy market and sticking together.
- Plan for many parent chaperones. Markets get busy, and having extra chaperones helps to keep students organized in seas of people.
- Make sure students are well fed and have used the bathroom to avoid meltdowns.

TRANSPORTATION

- For larger groups and younger students, school busses or vans work best.
- For smaller groups and older students consider taking public transportation if available. Provides an added experience and lesson for students about sustainability and navigation.

GETTING TO KNOW YOUR FARMER

- Ask your farmer to point out his or her farm on map. Talk about where their farm is in relation to the market. How long would it take to get there?
- Ask your farmer questions about their farm: how long have they been farming? Is it their family's farm? How old is the farm? What do they grow? What is their favorite item they grow there? How big is their farm? What kind of equipment do they use?

SPENDING MONEY

- Many markets provide market dollars for educational groups. Check with your local farmers' market manager to learn more about market dollars.
- If your local market doesn't have funding for market dollars, offer to subsidize a certain amount of dollars per student so each student has vouchers to purchase items directly from farmers without having to handle cash.

ACTIVITIES

- Try a color scavenger hunt or matching game
- Example: Have different colored stickers and have the students stick a sticker to a worksheet every time they see a different fruit or vegetable of that color
- See an example of during-farmers'-market worksheets in *Appendix B.*

PURCHASES AND REFLECTING



USING MARKET PURCHASES

- 18 mo–3 yrs: Making fruit kabobs. Stabbing the skewer through the fruit and using plastic cutlery to cut fruits for kabobs develops fine motor skills and also develops decision-making skills when deciding which fruits to use and which fruits taste yummy together.
- 3.5–4.5yrs: Following a recipe. Start by finding all the ingredients at the market, measuring the correct amount of each ingredient, then adding to the blender for a smoothie.
- *"After our trip to the farmers' market, we talked about the colors of our fruits and vegetables and the way that we think that they taste. Once we were done talking about them we made some fresh fruit and veggie smoothies the next day. Caterpillars also tasted the smoothies and really liked them."*
- Older age group: designing their own recipe, tasted things together and decided what tasted good together.

REFLECTING ON THE MARKET

- All age groups: Much more open to trying new fruits and veggies at the market and immediately afterward than they normally are in the classroom. Change of environment has a big impact on openness to trying.
- Older age groups: Loved when the farmer asked them lots of questions, was very engaging.
- Younger age groups: Lost interest or were shy with the farmers after their free sample. Samples after talking with the farmers may be more effective.

BEST PRACTICES







- **Designate a home base** at the market before hand and mark it on a map. If anyone is lost, needs to check in, or has an emergency, that will be the place to meet. It is also a good place to gather everyone at the end of the field trip before heading back to the school bus or to the bus stop.
- **Have an excellent ratio of parents to students** to keep all children supervised and safe at a busy market.
- **Alert the market manager** that your group is coming in advance. This will allow them to make special accommodations for your groups if necessary, or arrange for educational activities.
- **Have everyone wear the same brightly colored shirt** to simplify locating each other in large crowds.
- **Time the field trip for the late morning**. This allows the students to come to the classroom first to have a snack, use the bathroom, and get ready for the field trip. By the end of the market the children will be ready to have lunch.
  - If there is large grassy area or a seating area near the market aim to have a packed lunch picnic right after the market to replenish blood sugar levels for happy students on the way home.
  - Once the children arrive back at the classroom they will already have had lunch and will be ready for a much needed nap or rest time.

LESSONS LEARNED



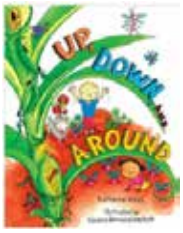






- **Map the closest bathrooms,** know where they are at all times as little ones need to go at a moment's notice.
- **Be prepared with very structured organization:** divide children into groups with designated chaperones before arriving at the market. Give each group a map and a timetable to talk with each farmer, make purchases, visit the education table, and finally to meet back up with everyone at the end of the market.

Appendix A: BOOKS



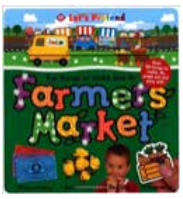
Up, Down, and Around (Arriba, Abajo y Alrededor)
From seeds dropping into soil to corn bursting from its stalks, from children chasing butterflies to ants burrowing underground, everything in this vibrant picture book pulses with life—in all directions!



A sembrar sopa de verduras / Growing Vegetable Soup
Bilingual board book (Spanish and English Edition)
"Dad says we are going to grow vegetable soup." bold picture book about vegetable gardening for the very young. The necessary tools are pictured and labeled, as are the seeds (green bean, pea, corn, zucchini squash, and carrot). Then the real gardening happens . . . planting, weeding, harvesting, washing, chopping, and cooking! In the end? "It was the best soup ever."



At the Farmers Market, En El Mercado, Spanish and English
A Spanish and English book to teach kids about fruits and vegetables on shopping trips to the Farmers' Market and the Grocery Store.



Fun Things to Make and Do Farmers Market (Let's Pretend)
Interactive book which folds out to create a farmers' market
Characters and accessories to press out and play with to bring the market to life.



A Visit to the Farmers' Market/Una Visita al Mercado de los Granjeros
Young or old, country folk or city folk, everybody loves going to the Farmers' Market! This easy-to-read bilingual picture book about shopping at the Farmers' Market stresses the importance of eating a variety of colorful, fresh fruits and vegetables.



Tractor Mac Farmers' Market
Pete and Paul the pigs love food, especially snacks and sweets. But Tractor Mac knows there is a better way to eat, and that it can even be fun, too: buying food from the farmers' market! So Tractor Mac and friends visit the local farmers' market, pick out a variety of fresh fruits and vegetables, and cook up a big, healthy feast.

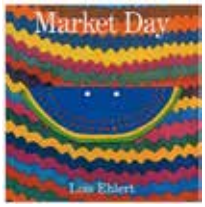
MORE **BOOKS**



Farmers Market/Dia de mercado
Colorful vegetables, delicious fruits, and lots of friends. The farmers' market is always fun!



How Did That Get in My Lunchbox?: The Story of Food
One of the best parts of a young child's day is opening a lunch-box and diving in. But how did that delicious food get there? From planting wheat to mixing dough, climbing trees to machine-squeezing fruit, picking cocoa pods to stirring a vat of melted bliss, here is a clear, engaging look at the steps involved in producing some common foods



Market Day: A Story Told with Folk Art
Everyone's going to the town square. But this is no ordinary market—it's a feast of folk art from around the world. Whether you're looking for fruits, vegetables, or just an afternoon of fun, this is a shopping trip you don't want to miss!



We're Going to the Farmers' Market
In this story, readers get to visit local farmers, fill baskets with fresh fruits and vegetables, and then head home to cook a feast, all with goodies from the farmers' market!



Max Goes to the Farmers' Market
Max and his mom go to the farmers' market. There are vegetables, fruit, and flowers everywhere! What will Max and his mom buy?



At the Farmers' Market with Kids: Recipes and Projects for Little Hands
At the Farmers' Market with Kids profiles the fruits and vegetables available at most farmers' markets, explaining how to tell which ones are ripe and how to store them. With age-specific tips that cater to children of all ages, plus 65 nutritious and kid-pleasing recipes to put your farmers' market spoils to use.



Farmers' Market Day
It's Farmers' Market Day! Follow an enthusiastic (and slightly clumsy) little girl as she searches for the perfect treat. She'll discover forests of broccoli trees and rainbows of flowers, taste freshly baked breads and pies, cuddle a kitten, and make a bit of a mess! But will she find her prize? Bursting with energy and humor, Farmers' Market Day captures a colorful feast for the senses!



Ana Cultiva Manzanas / Apple Farmer Annie: A Bilingual Edition in Spanish and English
A delicious treat about America's favorite fruit is now available in a Spanish bilingual format. Ana grows and sells apples, and she makes cider and applesauce and muffins. A glossary helps kids learn the names of Ana's delicious ingredients in both languages. With tie-ins to math and science curricula and units on autumn, this book will be especially welcomed by teachers.

Appendix B: CLASSROOM WORKSHEETS & FARMERS' MARKET ACTIVITY SHEETS

Veggie Garden 2

Our Charming Chart

Find the Fruit or Vegetable

My Favorite Thing at the Farmers' Market was...

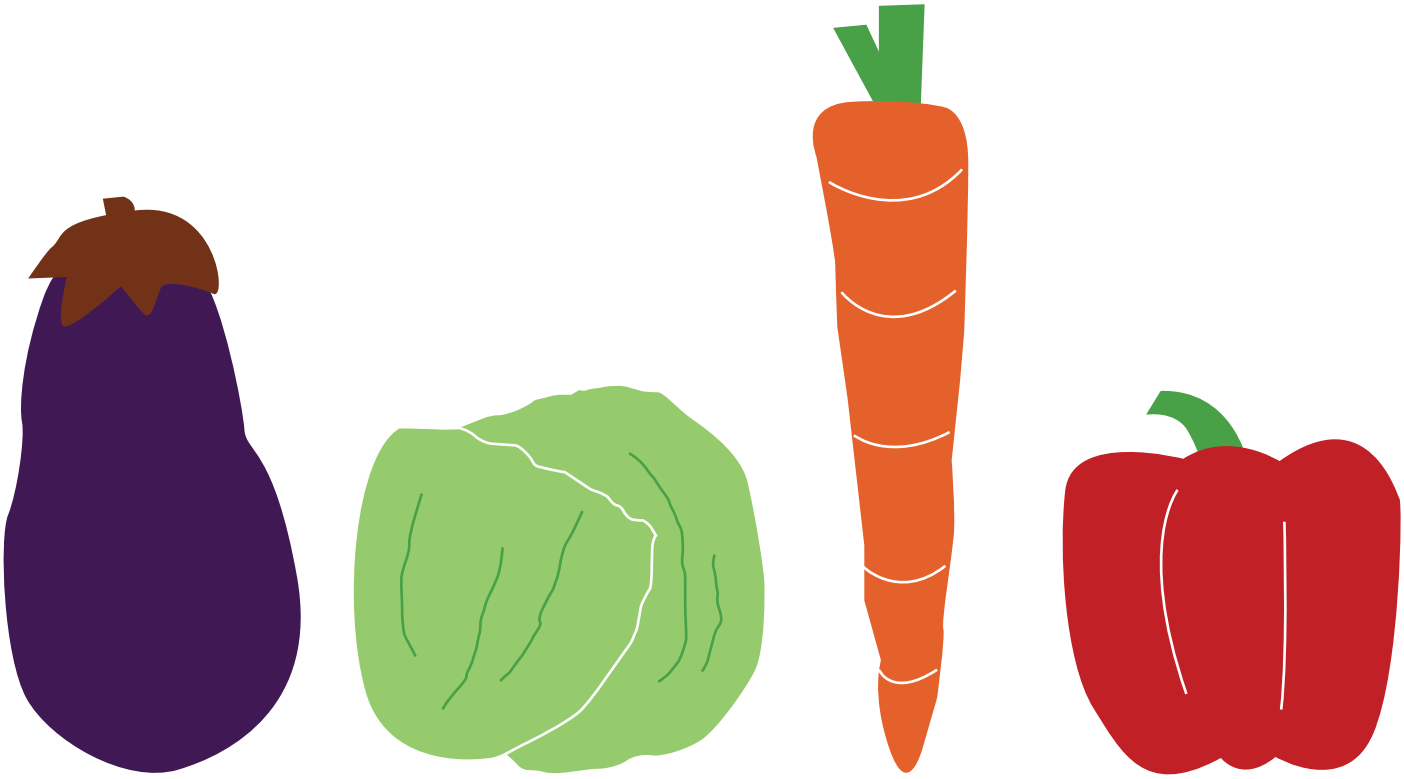
California Food Literacy Center Farmers' Market Scavenger Hunt

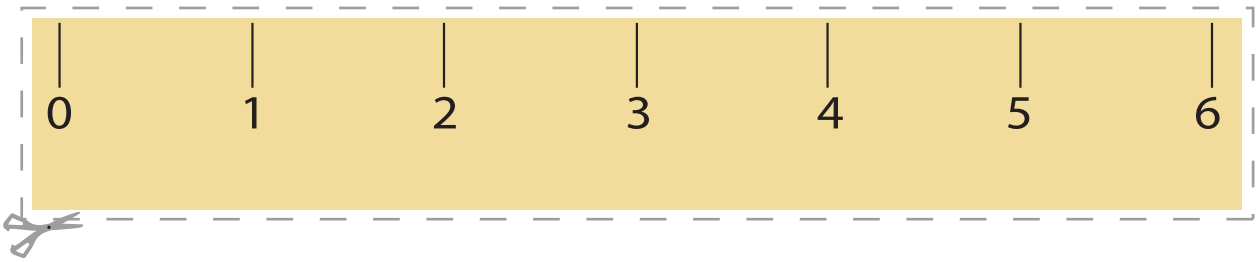
Santa Monica Farmers' Market Scavenger Hunt

Veggie Garden 2

Cut out the ruler. Measure each vegetable. Write the number of inches in the box under each vegetable.

Circle the shortest vegetable red.
Circle the longest vegetable green.





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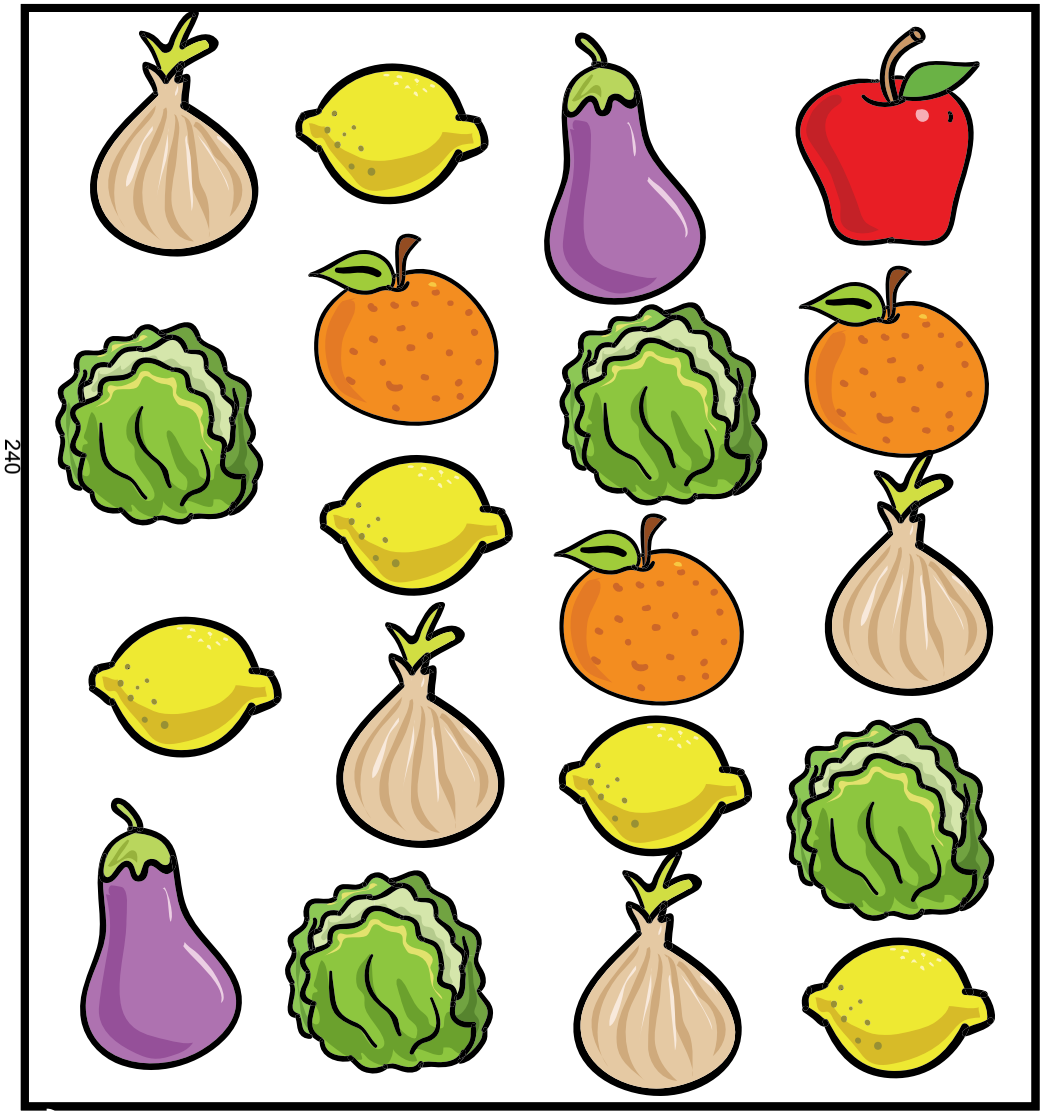
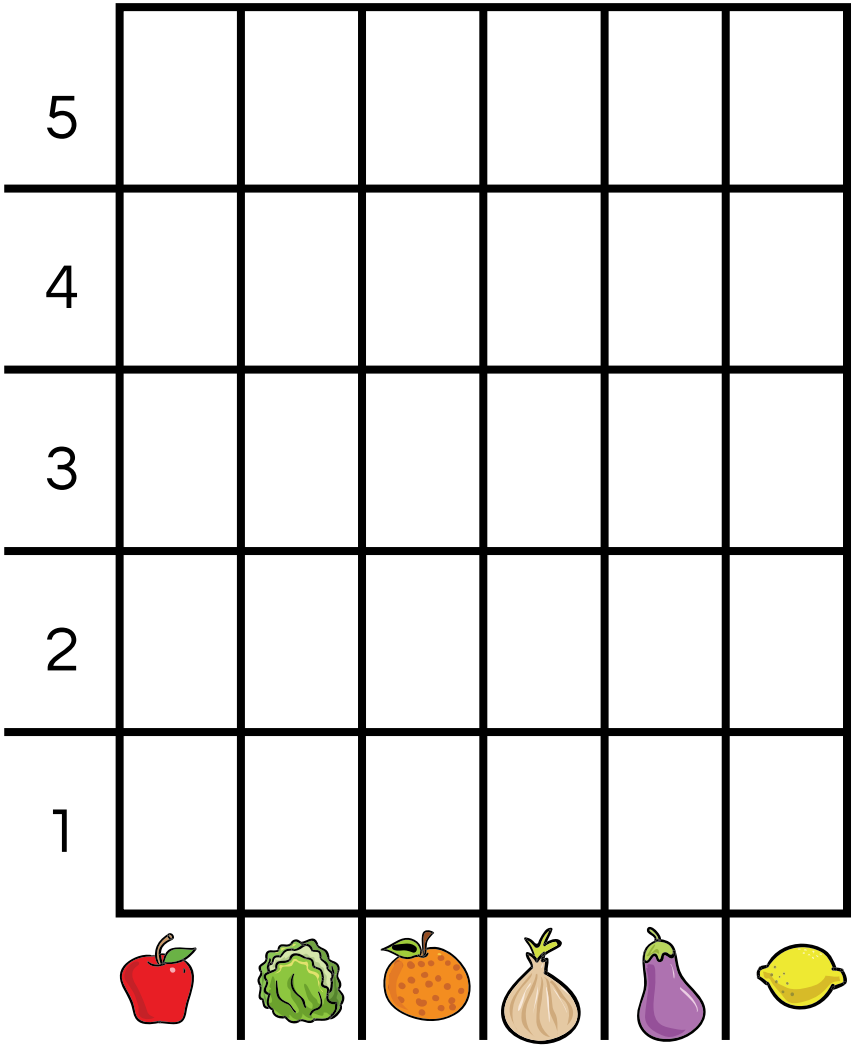
Our Charming Chart

What a wonderful garden! These living things are growing quickly! Let's use a graph to show how many of each thing we have. Count the vegetables and color in the chart next to the correct picture.





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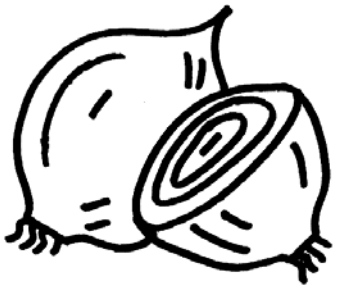
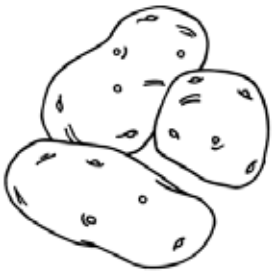
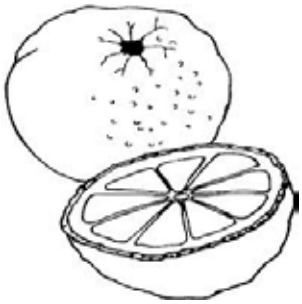
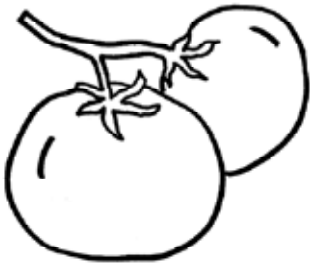
Can you find the fruit or vegetable at the farmers' market?

ONION 	POTATOES 	LETTUCE 
_____	ORANGE 	AVOCADO 
STRAWBERRY 	_____	CARROTS 
TOMATOES 	PEAS or BEANS 	CHARD or KALE 



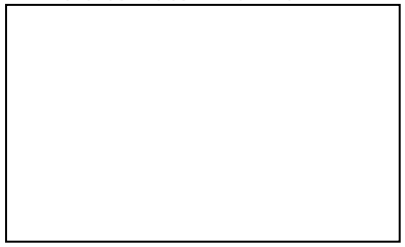
My favorite thing at the Farmers Market was…

Name_____

K

Farmers Market Scavenger Hunt

1. Find a tomato. Draw it.



2. Find some grapes. Write the color.

_____

3. Count the number of fruits or vegetables you see on a farmer's scale. Write the number: _____

4. Ask a farmer what his/her name is. Ask how to spell it. Write the name:

_____

5. Find a farmer giving sample tastes of a fruit or vegetable. Taste it. Write 1 word to describe the flavor:

_____

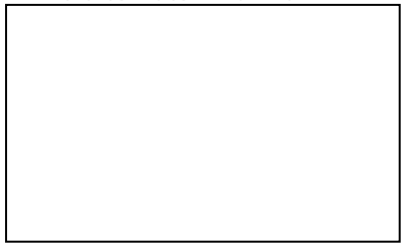
6. Talk to someone buying food from a farmer. Ask what he/she will cook with that food. Ask them to write it:

_____

7. Of all the foods you saw at the market today, which was your favorite? Write it here: _____

Farmers Market Scavenger Hunt

1. Find a tomato. Draw it.



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CaliforniaFoodLiteracy.org

Farmers' Market
1901 Main St Ste F
Santa Monica, CA. 90405
Tel: 310 458-8712
Fax: 310 399-9996

Santa Monica Farmers' Market Scavenger Hunt!

1. Name two varieties of melons:

2. Find 2 fruits or vegetables that are bigger than your fist:

3. Find 3 green vegetables:

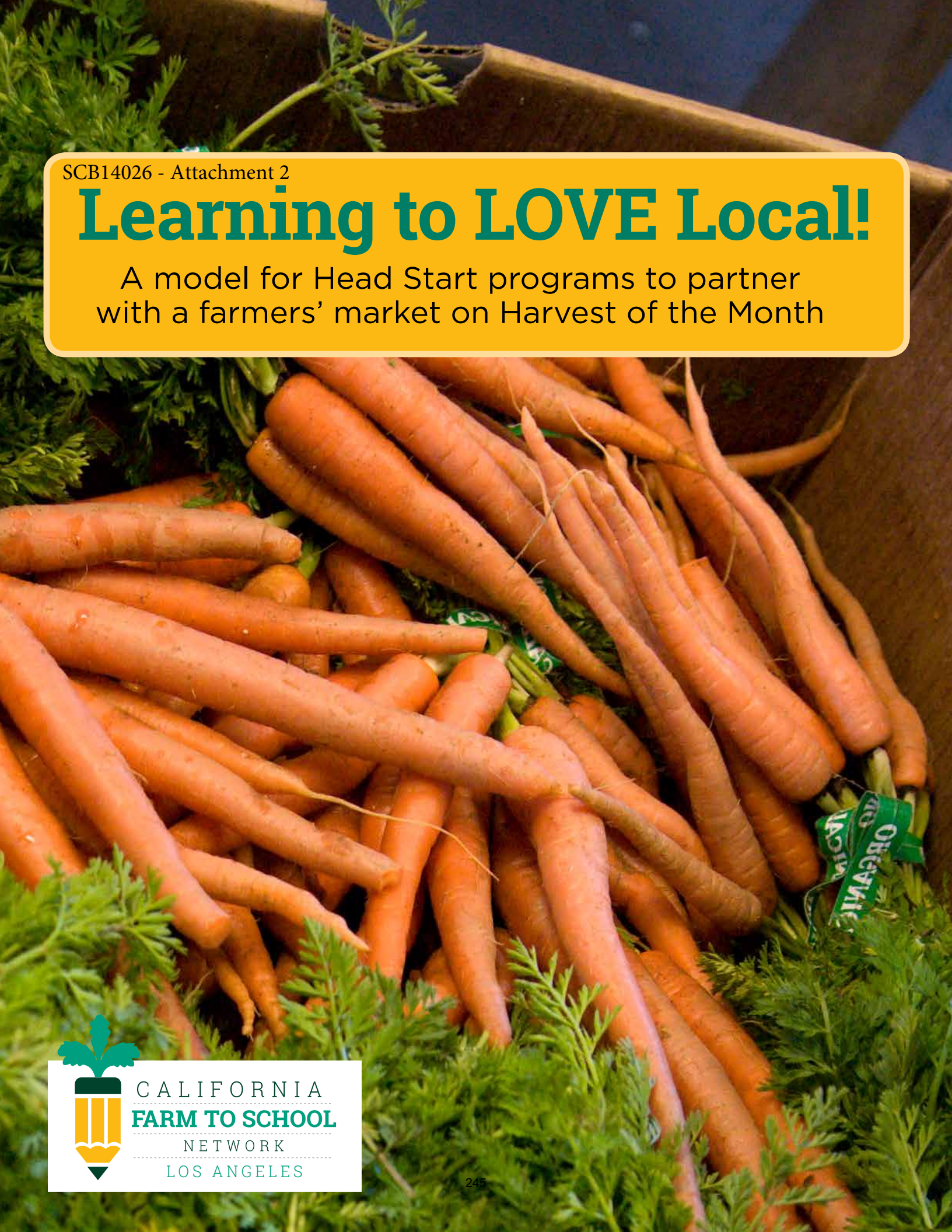
4. How many different colors of potatoes can you find?

5. Name a vegetable you had never seen or heard of:

6. What is your favorite fruit at the Farmers' Market?

7. Name 2 different varieties of squash:

8. Name 3 different colors of tomatoes:



SCB14026 - Attachment 2

Learning to LOVE Local!

A model for Head Start programs to partner with a farmers' market on Harvest of the Month

CALIFORNIA
FARM TO SCHOOL
NETWORK
LOS ANGELES

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INTRODUCTION

The ultimate objective of Harvest of the Month is to create a unique way for preschool students to interact with their local food system. Many classrooms can take a field trip to a farm or farmers' market, but Harvest of the Month seeks to bring the farmer and his or her produce into the classroom as well. In most preschools, cooking and food exploration are core elements of learning for communication, math skills, and nutrition. It is important to implement food based activities into HeadStart classrooms as well, to provide access to the valuable skills learned from cooking and tasting foods in the classroom.

To achieve this goal, the Harvest of the Month pilot was arranged by the Urban and Environmental Policy Institute and Farm to Preschool movement, with help from Sustainable Economic Enterprise of Los Angeles to coordinate with local farmers and Pacific Asian Consortium of Employment to partner with local HeadStart preschool classrooms. The pilot organized a monthly taste test of a single fruit or vegetable provided by a local, small-scale, organic farmer. Each month curricula were provided to teachers to preface and accompany the taste test, and provide more insight into the fruit or vegetable, where it came from, and how it got to the plate in the classroom. Through group interviews with staff members of all participating organizations, as well as surveys distributed to teachers in each classroom the pilot was evaluated using a mixed methods approach to understand the feasibility of implementing a monthly taste test in preschools across the country, outside of the funded pilot scenario.

The intention of this report is to inform ECE providers of the best practices for designing their own Harvest of the Month curricula. However, the main audience of this report is HeadStart child care providers as our pilot occurred in the HeadStart setting, and the best practices would be most replicable in a similar environment.





BACKGROUND

The Harvest of the Month program is designed to promote healthy eating in the classroom by introducing new fruits and vegetables to students through interactive curriculum and taste tests. Each month revolves around a different fruit or vegetable, with the goal being to choose in season options and source the produce from local, organic farmers. Before the taste test, lesson plans about the month's fruit or vegetable is built into the curriculum to teach students about the diversity of fruits and vegetables they can eat, especially in the bountiful state of California. The curriculum also focuses on the many stages of the particular fruit or vegetable from seed and planting to preparation and eating. Then a taste test is organized by partnering with local farmers to supply organic fruits and vegetables for students to try. By providing the opportunity to eat unique and delicious fruits and vegetables the goal promote excitement about eating healthy and living a healthy lifestyle in and outside of the classroom.

The initial Harvest of the Month pilot was run in HeadStart Preschool classrooms in Southern California as a collaborative effort with the Urban and Environmental Policy Institute (UEPI), Farm to Preschool, Sustainable Economic Enterprise of Los Angeles (SEELA), and Pacific Asian Consortium of Employment (PACE). UEPI is an applied research and advocacy center with the mission of advancing community-driven programs and policies to build healthy, thriving communities and achieve social, economic, and environmental justice. Farm to Preschool is an extension of the Farm to School movement, which started at UEPI, as a model to increase the role of locally grown fruits and vegetables in the classroom and childcare settings for children age 3–5. The goal of farm to preschool is to pique the natural curiosity of young children by introducing new fruits and vegetables and encouraging healthy eating habits at a young age. By partnering with farmers to increase access to nutritious foods in the classroom, farm to preschool also supports local small scale



farms and educates children about local food systems. Farm to preschool curriculum and programs vary by preschool, but many include gardening, taste tests, and farm field trips.

For the purpose of sourcing the produce for Harvest of the Month taste tests, UEPI partnered with SEE-LA, a non-profit organization based in Los Angeles with the mission of building sustainable food systems to support local businesses, small scale farmers, and low-to-moderate income residents. SEE-LA brings pieces of a sustainable food system together through their six farmers' markets located around the city. Their farmers' markets are dedicated to increasing access to healthy, affordable foods by working with CalFresh EBT, WIC, and Market Match. They also support their mission by promoting educational and cultural programming to enrich healthy lifestyles. One of their longest running programs is the "Bring the Farmer to Your School" program which teaches students about fruits and vegetables as well as local agriculture through interactive presentations given by local farmers.

Lastly, UEPI partnered with preschool classrooms supported by PACE, a community development non-profit in Los Angeles County, focusing mostly on API and multi-ethnic communities in the South Bay, Central LA, and San Gabriel Valley. PACE began to address employment and job training needs in API communities, but has now expanded into business development, financial education, affordable housing development, sustainability efforts, and early childhood education (ECE). Through their ECE initiatives, PACE operates 14 Head Start State Preschool and child-care centers for children age 3–5, as well as Early Start home based programs to work with parents and children under age three. PACE's ECE programs promotes a holistic approach to education, health, and wellness by supporting and empowering the whole family to champion their child's future success in school.



METHODOLOGY

The key goal of Farm to Preschool Harvest of the Month is to explore the feasibility of a partnership between a farmers' market organization and preschools to access local farmers and introduce local foods to a preschool classroom setting. To evaluate the Harvest of the Month pilot we have divided indicators of feasibility into three categories: 1) cost, 2) logistics and facilities, and 3) ECE site factors. Indicators of cost assess whether Harvest of the Month will be achievable in an ECE setting, outside of a grant funded pilot scenario. Logistic indicators assess whether or not Harvest of the Month is achievable given the systems in place and resources available in ECE settings. Lastly, indicators of classroom preparedness evaluate how much additional preparation needs to occur by ECE professionals to be able to conduct a Harvest of the Month curriculum and taste test each month.

To evaluate financial feasibility, we examined the cost of all stages from farm to classroom. Specifically, we assessed the cost of buying bulk amounts of produce from local farmers, the cost of delivery from the farmer to the kitchen and from the kitchen to the classroom, teacher training, and accompanying materials like books and kitchen tools. Indicators of logistic feasibility fell into two natural groups: indicators directly involving the farmer, and indicators involving preparation for the classroom. In terms of logistics involving the farmer, our assessment focused on the availability of amount and type of produce items during a given month or season, the ease or difficulty of delivery from the farmer to the ultimate destination in the classroom, and the invoicing procedure. Indicators of logistical feasibility on the child care setting side included the availability of kitchen facilities and storage to prepare each harvest item for the taste test, skills and buy-in of the kitchen staff to accomplish such preparation, and lastly the preschool policies regarding safety of outside food and food themed activities in the classroom. Finally, to





assess classroom preparedness the key indicators were the training required for teachers as well as their availability to participate in additional training, the preparedness for food tastings in the classroom, as well as preparedness of the central kitchen to take on the additional task of preparing the monthly taste test.

Once indicators of feasibility were established, qualitative and quantitative data was collected through semi-structured interviews, focus groups, and short written surveys. An individual semi-structured interview was conducted with Rosa Romero, Farm to Preschool Program Director at Urban and Environmental Policy Institute (UEPI) in Los Angeles, CA. The interview focused on the goal, intention, and development of the Harvest of the Month pilot. Next a group Interview with Romero, as well as Julia Rauter, the Nutrition coordinator for Pacific Asian Consortium for Employment (PACE) ECE program, and Alyssa Seibert, the Program Coordinator for *Bring the Farmer to Your School* at Sustainable Economic Enterprises Los Angeles (SEELA). The group interview focused on reflection of the key challenges and barriers to success the pilot has faced thus far, as well as quantitative analysis of the distribution of harvest items, number of classrooms participating, and amount of items purchased and the costs incurred in total and the estimated costs per classroom. Following the group interview was a focus group conducted at the PACE central kitchen in Los Angeles, CA. The focus group included eight employees of the PACE central kitchen including the kitchen manager, three cooks, and four delivery drivers. The focus group concentrated on the delivery of produce to the kitchen by the farmer, the process of preparation and distribution for each classroom, and finally the delivery and drop off to each classroom. Finally, short written surveys were distributed to teachers of classrooms participating in the Harvest of the Month taste test. The surveys were distributed by the PACE nutrition coordinator, Julia Rauter, with the March and April produce deliveries to each classroom. The surveys were voluntary, and only 12 classrooms participated.

Mo/Yr	Farm	Harvest	Quantity	Delivery Cost	Cost of Produce	Total Cost*	Cost per lb
5/16	J. Davis Farm	Avocado	" 40 lb (1 case)	$30.00	$35.00	$65.00	$1.63
9/16	Cottonwood Urban Farm	Tomato	27 lbs	$25.00	$88.29	$113.29	$4.19
9/16	South Central Farmers' Cooperative	Tomato	160 lbs	$0.00	$261.00	$261.00	$1.63
10/16	Cottonwood Urban Farm	Sweet Potato	50 lbs	$25.00	$163.50	$188.50	$3.77
11/16	Cottonwood Urban Farm	Squash	120 lbs	$25.00	$392.40	$417.40	$3.48
12/16	J. Davis Farm	Persimmon	"80 lbs (2 cases)	$30.00	$70.00	$100.00	$1.25
1/17	Weiser Family Farm	Carrot	120 bunches (10 cases)	$0.00	$150.00	$150.00	$1.25
2/17	Harvest Santa Barbara	Kiwi	" 525 kiwi (5 cases)	$0.00	$170.00	$170.00	$1.30
3/ 17	J. Davis Farm	Tangerine	" 160 lbs (4 cases)	$30.00	$140.00	$170.00	$1.06
4/ 17	Rick's Seasonal Produce	Avocado	" 100 lbs (4 cases)	$0.00	$240.00	$240.00	$2.40
5/ 17	Harvest Santa Barbara	Cucumber	90 lbs	$0.00	$170.00	170.00	$1.89
					Sept through May =	$1,980.19	
					Total for entire pilot =	$2,045.19	
					Cost per site =	$34.09	

FINDINGS

Cost

In order to evaluate cost, the costs were broken down by the following categories: Produce cost, delivery cost, training cost, and material cost. In summation, the overall cost of produce and delivery for the entirety of the school year totaled $1,980.19, equivalent to $34.09 per classroom for 58 classrooms. Please reference figure 1 below to see monthly costs for each individual produce item. Of all produce items, persimmons were the least costly, and squash was the most costly.

In addition to monthly cost for monthly produce and delivery costs, there are additional costs for materials and training. Training occurs one to two times annually, costing $500 per site for each training session. One training session covers all classrooms at a given ECE site. In addition to training, there are materials such as curriculum books, recipe cards, and simple kitchen utensils, which again cost approximately $500 per site each year. Materials only need to be purchased for each site, because classrooms can share the materials.

Logistics and Facilities

When working directly with farmers to supply produce for the taste test each month one of the key logistic challenges was crop variety and availability. There were times when the harvest item as planned in the curriculum was simply not available from any of the farmers that had an existing relationship with SEE-LA. In this case the curriculum needed to be changed to an item that the partner farmers had the ability to supply. There were also instances when one farmer was contracted to supply the produce items and were unable to fulfill their order so another farmer needed to be contacted at the last minute to fulfill the month's taste test. Further, there were times, such as in the month of September with tomatoes, when one farmer didn't have the quantity of produce needed for



the taste test, and produce from another farmer needed to be purchased to supplement. These experiences informed the buying coordinator's decision to work with specific farms, such as Cottonwood, because they are flexible and reliable to fulfill their order each month, despite being slightly more expensive. Flexibility and reliability are key traits to look for in a partner farmer. Additionally, it is important to find a farmer that is patient and willing to work with the buying coordinator to figure out the correct amount of produce to purchase. The Harvest of the Month taste tests are typically organized by number of units, while farmers tend to sell by weight. Finding a farmer that is willing to help convert the count of items per pound is important to buying efficiently and effectively.

Once the produce purchase has been secured and the farmer fulfills the order, comes the step of delivery and invoicing. Farmers do not deliver to each individual site. They deliver the bulk amount of produce to a central kitchen which then prepares and distributes produce to each classroom. This is the case for two reasons: to simplify delivery for the farmer, and because HeadStart preschools have strict regulations on outside food and must approve all food items through a central kitchen before they can be enjoyed in the classroom. Following this procedure for delivery and distribution has gone smoothly for both the farmer and central kitchen staff. After delivery, in the first few months of Harvest of the Month there was some confusion between the farmer and the central kitchen about the invoicing procedure. Farmers are meant to either send or deliver the invoice to the nutrition coordinator at the central kitchen who will then send payment to the farm through the organization's bookkeeper. However many farmers left their invoice with the incorrect person making it difficult for the invoice to make it to the correct administrator and to receive payment. Additionally, on a few occasions farmers forgot to even send an invoice due to the low value of the produce they were selling.

The initial hiccups with invoicing frustrated the kitchen staff, because they were concerned the farmer would be angry with them if he or she didn't receive payment, because the invoice didn't get to the correct person. The kitchen staff also would prefer not to work with





squash in the future the size range of different types of squash made them difficult to distribute evenly to each classroom. Distribution was a learning process, because at first neither the farmer nor the central kitchen were dividing the produce for each classroom so the PACE nutrition coordinator needed to assist in the organization and distribution of produce items into the boxes for each classroom's taste test. Additionally, the squash were difficult for the kitchen staff to prepare because they did not have time to prepare all of the squash in addition to their daily work load, so items that can be eaten raw are preferred. Raw items only need to be washed and divided up by classroom making the process much simpler. Despite some critiques, buy-in of central kitchen was generally high. When asked on a scale of 1-10 to rate their experience and willingness to continue the program all staff members answered either 9 or 10.

ECE Site Factors

At the participating ECE sites, indicators of feasibility involved teacher training, teacher buy-in, and classroom preparedness. Teacher training occurred on professional development days, when students were not in the classroom. The timing for training was unfavorable from the teachers' perspective because they were already overwhelmed with new information and policy on the day, making it more difficult to be enthusiastic and retain information about Harvest of the Month training. To address the retention of training, a secondary refresher training course was held later in the year to keep teachers up to date. There was also variation in how comfortable and eager each teacher was to participate in harvest of the month training. Some teachers wanted to do in-class cooking demonstrations with the taste test, while others did not want to conduct the taste test at all. Overall, to make the taste test simpler for the teacher all produce items should be ready to eat without cooking.



Further, there was some miscommunication and lack of communication between site directors, teachers, and the central kitchen about when the taste test would occur each month. This became a problem because the central kitchen would deliver taste test items when the teacher had not included the taste test in the curriculum that day, and produce would go unused.

Overall, communication among the various players in Harvest of the Month was limited and unorganized. Both teachers and site directors are overworked and underpaid, leading to lower levels of motivation to implement new food activities. Also, because of this type of workplace environment the turnover rate for teachers is quite high, making it difficult to maintain continuity each month and year. However, among the teachers that were excited for the Harvest of the Month taste test, their reviews were positive. When asked to rate their experience from 1 to 10 the average response was 9.3, with a range from 7 to 10. The teachers were pleased with the response from most children. Many children tried tangerines or kiwis for the first time, and like them very much. The kiwis especially were an opportunity for children to learn about new tastes, textures, and smells, as well as use new vocabulary they learned about these senses. Teachers who participated in the survey also incorporated at least one curriculum item to the taste test, and often added additional Harvest of the Month themes during their mealtimes and artistic activities. Some of the key barriers they faced was having students allergic to the month's fruit, or reluctant to taste because they had never seen the fruit or vegetable at home. Teachers also requested to have enough fruit so each child had their own to try.



RECOMMENDATIONS

Working with the Farmer

When working with local farmers it is best to establish a relationship with flexible and reliable farmers to ensure every order is fulfilled in full and on time. It is worth spending slightly more per pound of produce if the farmer has the capacity to fulfill your orders without last minute changes or shortcomings. It is also to work with a farmer that is flexible to make changes to the order should you need to increase or decrease the order to suit the number of classrooms participating. Additionally it is valuable to find a farmer that is patient and willing to take time with you over the phone to plan the correct weight of produce to buy for the number of units you need. It is worthwhile to spend slightly more per pound of produce if the farmer can provide reliable service to suit your comprehensive needs. It is important to consider the quality of service the farmer can provide just as heavily as raw cost is considered. There is also potential for partnership with a local food hub. Using a local food hub will draw from a consortium of local farmers, but has a larger overall capacity and is therefore more reliable for bulk orders. Additionally, by working with a food hub the variety of produce from a multitude of farmers can be aggregated in one central location to simplify purchasing.



When Purchasing Produce

In addition to finding a reliable farmer to work with, it is important to choose in season fruits and vegetables each month. By choosing in-season fruits and vegetables farmers are more likely to be able to supply a large amount of the given fruit or vegetable. Further, the produce is likely to be of higher quality, at peak ripeness, and less expensive. When considering quantity, aim to supply at least one unit per child for smaller individual items like kiwi or pear, and enough of larger items like melon or cauliflower for each child to have one full serving. Beyond supplying enough produce for each child to have one serving, buying additional produce to send home with students can be helpful to students and families to try new fruits and vegetables.

One reason children were not willing to try a given item was because they were not exposed to it at home. By sharing fruits and vegetables at home, students may become more likely to experiment with other new fruits and vegetables during Harvest of the Month.



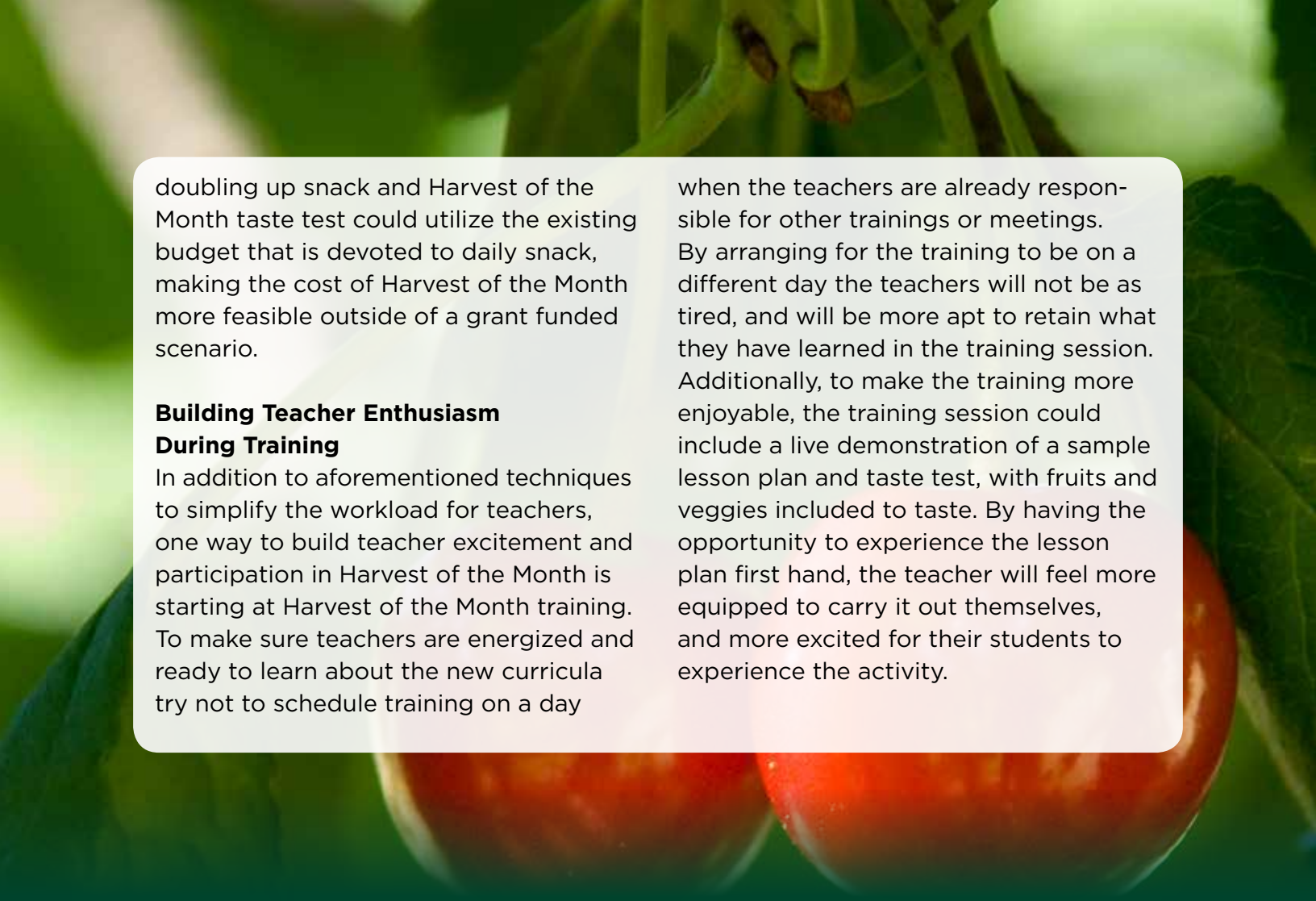
Lastly, choose items that are ready to eat raw, and do not need to be cooked. Many classrooms are limited in their capacity to cook and prepare foods, so it helpful for teachers to simplify the preparation for the taste test as much as possible. However, be wary of stone-fruits, like peaches, plums, and avocado. Although they are ready to eat and easy to prepare, it is difficult to predict the time of peak ripeness and line up the peak ripeness perfectly to the day of the taste test.

Planning Harvest of the Month Curricula and Deliveries

To clarify the intention of the delivery when dropped off it is helpful to arrange for Harvest of the Month deliveries to be in a unique, recognizable container that is the same each month. By designating a special delivery container, the teacher receiving the delivery will be aware of what the delivery should be used for instead of setting it aside for snack or a meal. In addition to the recognizable delivery container, it will simplify the communication between the teacher and site director if each delivery comes with all the additional materials needed to conduct the taste test and Harvest of the Month lesson plan. Additional items may be tools like a peeler, knife, or toothpicks, or curricula materials like books, recipe cards, or other school supplies. This way the teacher does not need to scramble or contact the site director to find all of the necessary elements to fulfill to taste test. Afterward, there should be a record of if the taste test occurred, and how successful it was. If teachers continually do not hold the taste test, the Harvest of the Month deliveries should discontinue, as if they were on a reward system for continued participation. This creates a great incentive for teachers to be prepared and include the Harvest of the Month lesson plan each month.

Repurpose Harvest of the Month Taste Test as Snack Item

Another way to simplify the work required by the teacher is to repurpose the Harvest of the Month taste test as the snack item for that day. By serving the taste test as a snack it reduces the teacher's workload by repurposing the taste test as a pre-existing element of each day in a preschool classroom. However, for this to be a viable option in HeadStart preschools, the taste test must include at least two food groups, meaning the Harvest of the Month item will need to have other ingredients to accompany it. Additionally, there are strict food safety rules for snack time items to ensure no foods are a choking hazard or that any students are allergic to the snack item. Repurposing the Harvest of the Month taste test as a snack item may restrict what can be tasted in the classroom based on the limitations of safety protocol as well as the two food group policy. However,



doubling up snack and Harvest of the Month taste test could utilize the existing budget that is devoted to daily snack, making the cost of Harvest of the Month more feasible outside of a grant funded scenario.

Building Teacher Enthusiasm During Training

In addition to aforementioned techniques to simplify the workload for teachers, one way to build teacher excitement and participation in Harvest of the Month is starting at Harvest of the Month training. To make sure teachers are energized and ready to learn about the new curricula try not to schedule training on a day when the teachers are already responsible for other trainings or meetings. By arranging for the training to be on a different day the teachers will not be as tired, and will be more apt to retain what they have learned in the training session. Additionally, to make the training more enjoyable, the training session could include a live demonstration of a sample lesson plan and taste test, with fruits and veggies included to taste. By having the opportunity to experience the lesson plan first hand, the teacher will feel more equipped to carry it out themselves, and more excited for their students to experience the activity.

CONCLUSION

In summation, Harvest of the Month is a unique way to introduce new delicious fruits and vegetables to children in a preschool classroom setting. Children are more likely to choose fruits and vegetables, if they are eating them at home, but if that's not possible introducing them at school where they will spend many of their days is the next best option. Harvest of the Month not only piques the curiosity for fruits and vegetables in preschool students, but it also support local small-scale farmers by buying local, in-season, and organic. By linking preschoolers with local farmers it builds their awareness of their local food system and the mutual benefits of supporting local farmers. Students get delicious juicy fruits and vegetables, while supporting a local business of the small-scale farmer. Implementing Harvest of the Month in preschools across the country doesn't come without hurdles to overcome. Teachers are overworked and underpaid, HeadStart preschools have a lot of red-tape surrounding food in the classroom, and working with farmers can sometimes be predictable. However, exposing children to healthy, fresh foods in the classroom is beneficial to their learning, not only about nutrition, but also for math skills, communication, and sharing. By finding which practices work best for each individual classroom, Harvest of the Month can be an invaluable experience for both students and preschool teachers to learn more about healthy fresh foods and their local food system.



CALIFORNIA FARM TO SCHOOL NETWORK
FARM TO PRESCHOOL

Urban & Environmental Policy Institute
UEPI OCCIDENTAL COLLEGE

SEE LA
Sustainable Economic Enterprises of Los Angeles

pace
Pacific Asian Consortium in Employment

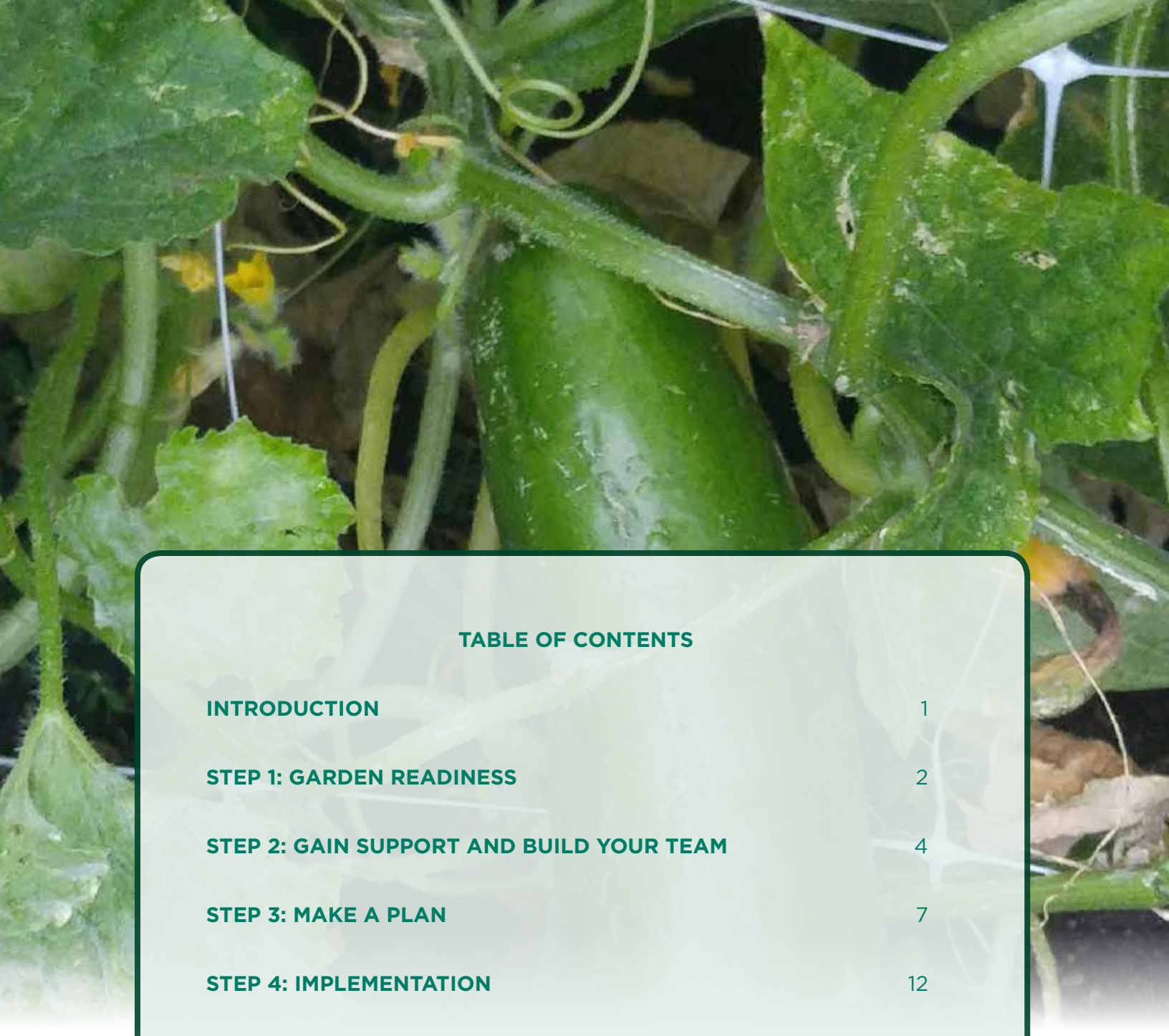
SCB14026 - Attachment 3

Garden to Cafeteria

Steps to Success



CALIFORNIA
FARM TO SCHOOL
NETWORK
LOS ANGELES



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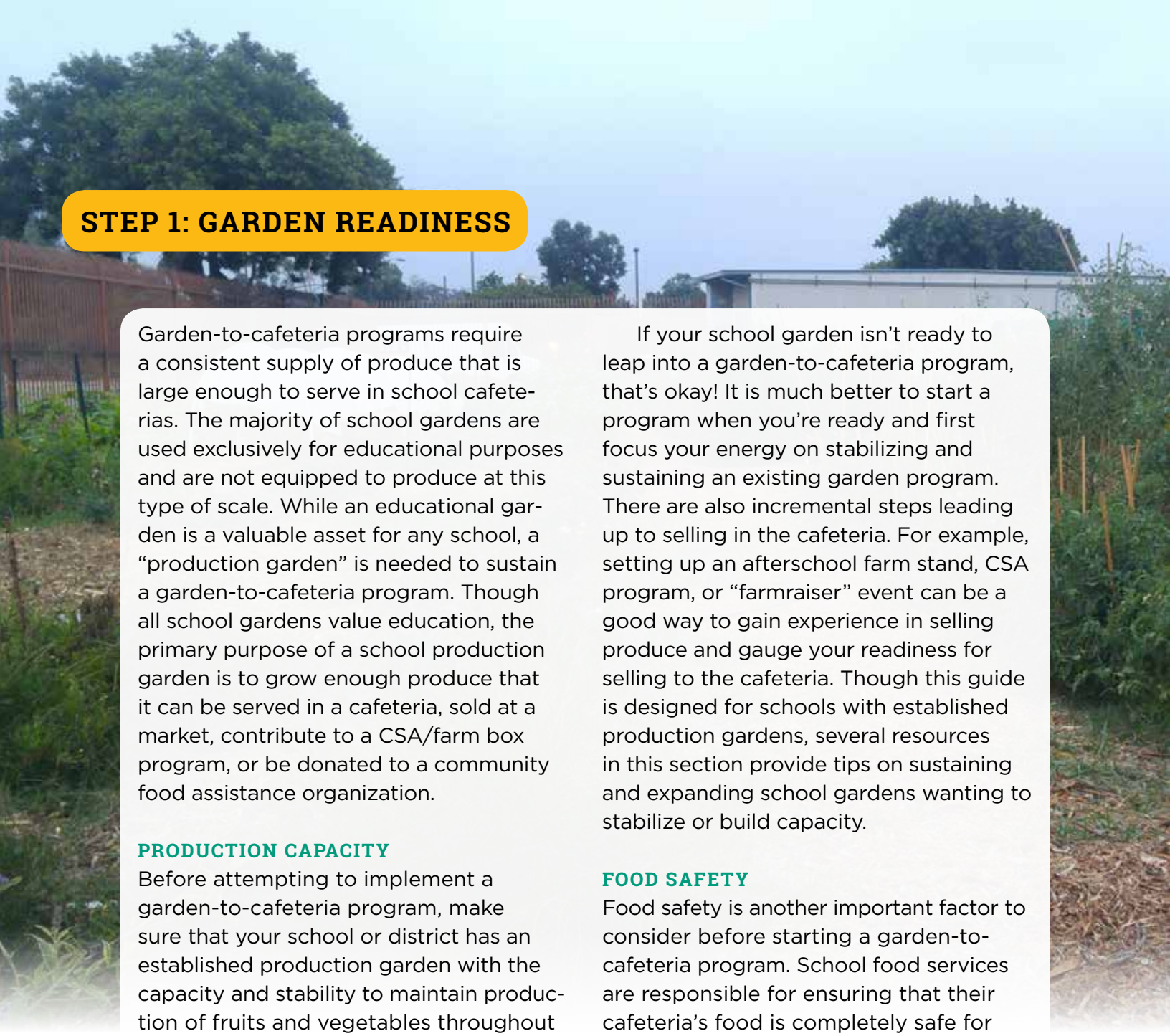
INTRODUCTION

In recent years, as the popularity of school gardens and Farm to School programs has been on the rise, an increased interest has emerged in connecting garden produce directly to school cafeterias though garden-to-cafeteria programs. These holistic programs merge the education, school garden, and procurement components of Farm to School. Students who participate in garden-to-cafeteria programs are more likely to eat the types of fruits and vegetables grown in the garden, even if the items have to be substituted. Garden-to-cafeteria programs also provide students with valuable food systems lessons, having the opportunity to engage in the process of producing food from seed to plate.

Though garden-to-cafeteria programs have many benefits, they are often challenging to implement and sustain. This guide is designed to address these challenges and provide step-by-step guidance for new programs. It is the product of a partnership between the Urban & Environmental Policy Institute at Occidental College (UEPI) who leads the Los Angeles Farm to School Network, and Pasadena Unified School District (PUSD) who launched a successful garden-to-cafeteria program over the 2016–2017 school year. Celebrating the lessons learned from PUSD's success, this guide documents the staff roles, collaborative efforts, and processes that enabled PUSD to develop and establish a robust garden-to-cafeteria program, and presents these findings in a format designed to help aspiring programs get off the ground, and into the lunch line.



STEP 1: GARDEN READINESS

Garden-to-cafeteria programs require a consistent supply of produce that is large enough to serve in school cafeterias. The majority of school gardens are used exclusively for educational purposes and are not equipped to produce at this type of scale. While an educational garden is a valuable asset for any school, a "production garden" is needed to sustain a garden-to-cafeteria program. Though all school gardens value education, the primary purpose of a school production garden is to grow enough produce that it can be served in a cafeteria, sold at a market, contribute to a CSA/farm box program, or be donated to a community food assistance organization.

PRODUCTION CAPACITY

Before attempting to implement a garden-to-cafeteria program, make sure that your school or district has an established production garden with the capacity and stability to maintain production of fruits and vegetables throughout the year. Slow Foods recommends that prior to developing a garden-to-cafeteria program, a district should ideally have multiple production gardens, ½ acre to 2 acres in size, running for at least a year.[1] In addition, it is vital to have consistent staff or volunteers committed to caring for the garden, as well a clear plan for maintenance during the summer when students and staff are gone.

If your school garden isn't ready to leap into a garden-to-cafeteria program, that's okay! It is much better to start a program when you're ready and first focus your energy on stabilizing and sustaining an existing garden program. There are also incremental steps leading up to selling in the cafeteria. For example, setting up an afterschool farm stand, CSA program, or "farmraiser" event can be a good way to gain experience in selling produce and gauge your readiness for selling to the cafeteria. Though this guide is designed for schools with established production gardens, several resources in this section provide tips on sustaining and expanding school gardens wanting to stabilize or build capacity.

FOOD SAFETY

Food safety is another important factor to consider before starting a garden-to-cafeteria program. School food services are responsible for ensuring that their cafeteria's food is completely safe for students to consume, and they are required to meet very stringent food safety standards. Therefore, having an approved food safety protocol in place in a garden before starting a program is highly recommended. This way, issues that might derail the program in the future might be avoided altogether.

Maintaining food safety practices in a school garden can also be simple and provide a valuable educational opportunity for students.

[1] http://gardens.slowfoodusa.org/garden-to-cafeteria

LESSONS FROM PASADENA UNIFIED

Before piloting their garden-to-cafeteria program, PUSD already had a strong and well-established Farm to School program that integrated the three Farm to School components of local sourcing, classroom education, and school gardens. In addition to having a garden instructor on staff and gardens at nearly every school, seven schools had designated "production gardens." While most of the District's gardens are used only for educational purposes, the production gardens are run by older students and can produce enough fruits and vegetables to collectively support a garden-to-cafeteria program.

A full year before the launch of their garden-to-cafeteria program, PUSD worked with the Department of Public Health to develop a manual for garden production that would guide district-wide implementation of the garden-to-cafeteria model and ensure that all of the produce served in the cafeteria would meet food safety standards. Once the production garden sites were determined to be compliant with the safety standards outlined in the manual, they were ready to start producing for the cafeteria and avoided the need to worry about issues with food safety compliance down the line. PUSD staff emphasized that having established production gardens and food safety standards in place before the start of the pilot was essential. This eased the relationship with the Food Service Department by guaranteeing safe produce and a (relatively) consistent supply. PUSD's approved food safety protocol manual is listed in the resources section below.

GARDEN READINESS RESOURCES:

- "Funding A School Garden Program," from KidsGardening.org
- "Sustaining School Gardens: Funding Garden Coordinators," from Whitney Cohen, *Life Lab*
- "Funding a Garden Coordinator," from Collective School Garden Network
- "Green Fundraising Ideas for Schools," from Kokua Hawai'i Foundation
- "Making the Connections: Using School Garden Produce in School Food Service," from *Norwalk Grows* and National Farm To School Network
- "Schoolyard to Market," Center for Urban Education about Sustainable Agriculture (CUESA)

FOOD SAFETY RESOURCES:

- "Procedure for Serving School Garden Produce," Ventura Unified School District
- "Development of Garden to Cafeteria Protocols in Denver Public Schools" from 2014 Farm to Cafeteria Conference (Slow Food Denver)
- "Food Safety Tips for School Gardens," USDA
- "Farm to School Safety Protocol Manual," Pasadena Unified School District



STEP 2: GAIN SUPPORT AND BUILD YOUR TEAM

No garden-to-cafeteria program can be accomplished in isolation. At minimum, these programs require coordination between a school's garden program and food service department. In most cases, successful programs engage multiple school departments as well as the school board and other stakeholders such as students, parent groups, and/or outside nonprofits. Strong relationships and cooperation among these participating entities is key to developing robust and sustainable programs. Partners from a range of school departments and other positions can advocate for the program and effectively advance policy changes, facilitate funding opportunities, or secure staffing needs to support and maintain the program. As a general rule, the more buy-in and support a program has, the higher its likelihood of success.

KEY ROLES AND RESPONSIBILITIES

Though garden-to-cafeteria programs can vary widely and incorporate leadership from a variety of school departments or outside groups, there are a few roles and responsibilities that are key to the successful implementation of any program. This section lays out each of these positions and corresponding responsibilities. The most important aspect of each of these roles is a person's willingness to be a committed and engaged team player. Representatives from all departments must understand the perspectives of others on the team and do their best to work collaboratively to accommodate other department's restrictions and program needs.

Program Coordinator

Engaging partners, coordinating information, and facilitating conversations to move a garden-to-cafeteria program forward can be a lot of work. Therefore, it is important to acknowledge this coordination as a key role in the project. Ideally, a paid staff person within one of the school's departments takes on this role because it is easiest to get the job done and maintain momentum when it is a part of someone's paid position. However, it can be performed by a parent, other volunteer, or partnering nonprofit organization. This "program coordinator"



needs to understand all of the moving pieces within a garden-to-cafeteria program, be able to translate information across school departments, and take the lead in troubleshooting when barriers or challenges arise during the course of implementation.

School Garden Representative

A representative from the school garden must be actively involved throughout a garden-to-cafeteria program's development and implementation. In a best-case scenario, this is a paid garden instructor or garden manager, though a dedicated master gardener or other volunteer could potentially do the job. This position must have the authority to determine what is planted in the school garden, and also be able to oversee garden maintenance (including food safety protocol) and harvesting activities.

Food Service Representative

Food service administrators decide what goes on the menu and are also in charge of all food purchasing. Therefore, a garden-to-cafeteria program cannot function without participation from a school's food service department. The food service representative on the team must have enough decision-making power to incorporate garden produce into the menu, coordinate purchasing, train staff on any new processing or preparation tasks, and develop a plan for supplying backup items if the garden produce does not come through as planned or is insufficient to serve the entire student body.

LESSONS FROM PASADENA UNIFIED

PUSD has been a long-time proponent of Farm to School. A few years before the launch of PUSD's garden-to-cafeteria program, the school board passed a non-binding resolution to source 2% of cafeteria produce from the school gardens in the district. Though this commitment was not enforceable, it demonstrated district-wide support and justification for a garden-to-cafeteria program.

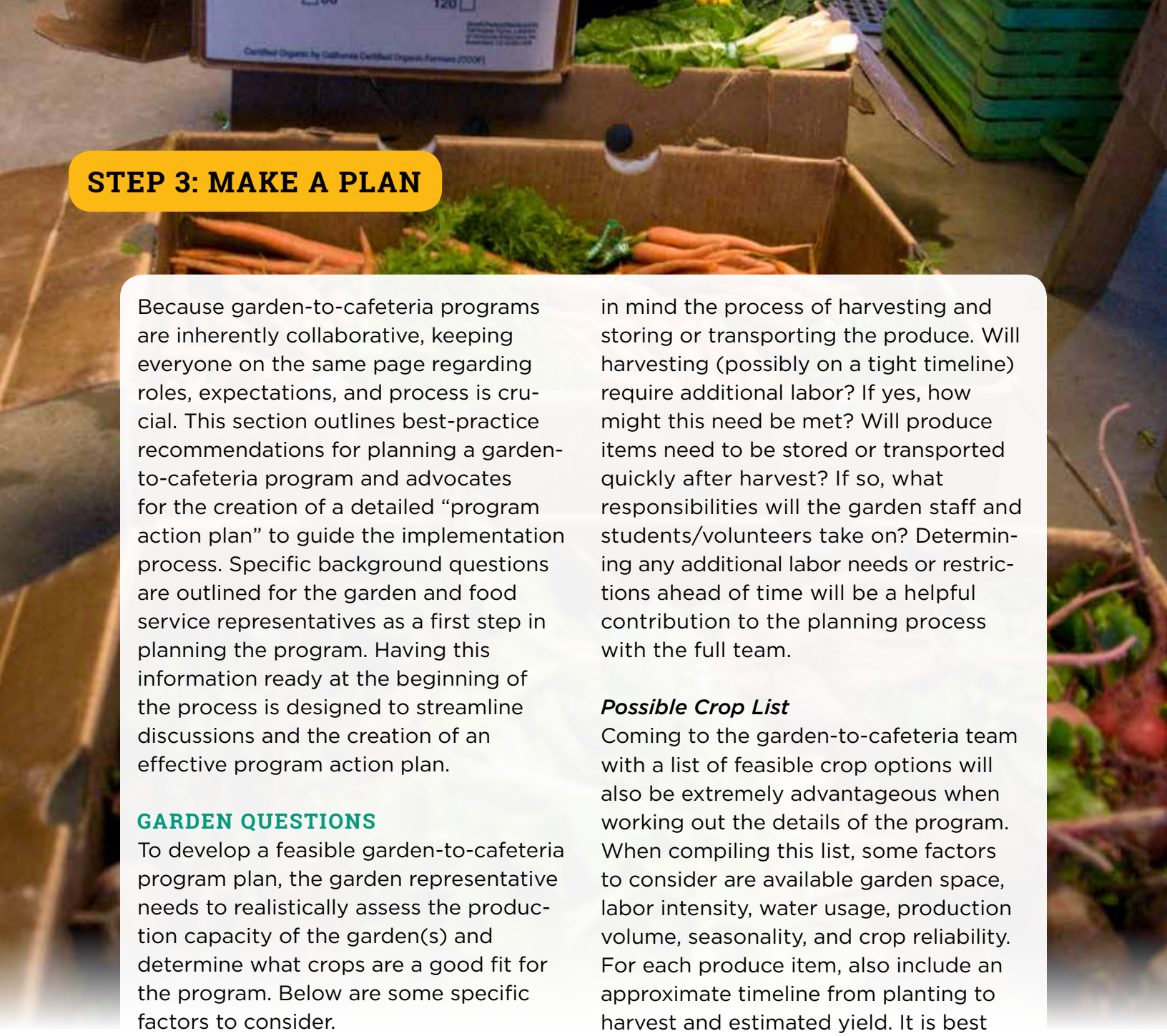
PUSD's garden-to-cafeteria program is a highly collaborative initiative between their Health Services, School Garden, Facilities, and Food and Nutrition Services departments. The District is fortunate to have Health Programs staff who fundraise for their Farm to School programs and also oversee and coordinate program implementation. Not only are their Health Programs staff passionate about Farm to School, but they are also able to dedicate time to taking on the garden-to-cafeteria "program coordinator" role, acting as the glue that pulls the rest of the program together.

In addition to the Health Programs Department, PUSD has a paid garden teacher representing the garden program, an employee in the Facilities Department who helps to build the gardens and ensure water access, etc., and a Food and Nutrition Services Director who is willing to incorporate garden produce into the menu. The Health Programs staff maintain ongoing communication between these "core team" department partners and also convene other community members and stakeholders at bi-monthly Farm to School meetings. These regular events provide an opportunity share progress and discuss next steps for the program.

All of PUSD's core team members agreed that the successful development and implementation of their garden-to-cafeteria program hinges upon having active staff involvement and ongoing collaboration across different departments.

RESOURCES:

- USDA Farm to School Planning Toolkit
- "Building Healthy Communities: A School Leader's Guide to Collaboration and Community Engagement," from California School Boards Association and Cities Counties Schools Partnership
- Vermont Farm to School Network Strategy
- "Stakeholder's Interest in and Challenges to Implementing Farm-to-School Programs," from Courtney A. Pinard, Teresa M. Smith, Leah R. Carpenter, Mary Chapman, Mary Balluff, Amy L. Yaroch



STEP 3: MAKE A PLAN

Because garden-to-cafeteria programs are inherently collaborative, keeping everyone on the same page regarding roles, expectations, and process is crucial. This section outlines best-practice recommendations for planning a garden-to-cafeteria program and advocates for the creation of a detailed "program action plan" to guide the implementation process. Specific background questions are outlined for the garden and food service representatives as a first step in planning the program. Having this information ready at the beginning of the process is designed to streamline discussions and the creation of an effective program action plan.

GARDEN QUESTIONS

To develop a feasible garden-to-cafeteria program plan, the garden representative needs to realistically assess the production capacity of the garden(s) and determine what crops are a good fit for the program. Below are some specific factors to consider.

Available Garden Labor

Who is primarily responsible for maintaining the school gardens? Does extra work generally fall on the garden instructor or do students and/or volunteers help as well? Will the existing staff, students, and volunteers be able to fulfill the labor needs of a garden-to-cafeteria program? If so, will they need any additional training? The garden representative should consider these questions and also keep in mind the process of harvesting and storing or transporting the produce. Will harvesting (possibly on a tight timeline) require additional labor? If yes, how might this need be met? Will produce items need to be stored or transported quickly after harvest? If so, what responsibilities will the garden staff and students/volunteers take on? Determining any additional labor needs or restrictions ahead of time will be a helpful contribution to the planning process with the full team.

Possible Crop List

Coming to the garden-to-cafeteria team with a list of feasible crop options will also be extremely advantageous when working out the details of the program. When compiling this list, some factors to consider are available garden space, labor intensity, water usage, production volume, seasonality, and crop reliability. For each produce item, also include an approximate timeline from planting to harvest and estimated yield. It is best to be conservative when making yield estimates, as many factors can impact production volume.

QUESTIONS FOR FOOD SERVICE

Before finalizing the garden-to-cafeteria plan as a team, the food service representative also needs to compile some key information about the capacity of the food service department to incorporate garden produce into school kitchens and cafeterias. Again, it is recommended



that the food service representative write up an outline of these needs and restrictions before discussing possibilities with the full garden-to-cafeteria team. Having this information ready to go and in an accessible format will streamline the conversation with other members of the team when selecting produce items for the menu and planning out the program. Some specific topics for food service to consider are laid out below.

Facilities & Equipment

Available kitchen facilities and equipment can determine which produce items are feasible (or not possible) to include in the program. Is there a kitchen where produce can be washed and prepared? How much storage space is available for fresh produce? Are there any other restrictions?

Staff Capacity

Staff skills, time, and training needs must also be factored in. Do food service staff currently have the ability to handle and prepare fresh (usually whole) fruits and vegetables? If not, is training a feasible option? How much time can be dedicated to produce preparation? Would some produce items be easier to handle than others?

Purchasing

The food service representative will have to determine the best strategy for purchasing produce from the garden program. School districts participating in the National School Lunch Program (NSLP) are required to put out a competitive bid for all food vendors. In this process, prospective vendors submit a proposal to sell specific food items to the school district. For the most part, the district is required to accept the most cost-effective bid. A school garden could never hope to compete in this process. Luckily, beginning in 2015, the USDA (who regulates the NSLP) made a special allowance for purchases under $3,500. Through a new classification called a "micro-purchase," these very small purchases (from vendors such as school garden) are exempt from the competitive bid process. As long as garden purchases do not exceed $3,500, the micro-purchase designation is a viable option for garden-to-cafeteria programs. Other aspects of purchasing that the food service representative should look into include cost (i.e. what is the average price per unit currently paid for comparable produce items), if there are any standard pack or delivery requirements for specific products, and any invoicing procedures that might need to be adjusted.

PROGRAM ACTION PLAN

Once the garden and food service representatives have explored the issues and questions above, the team is ready to create a garden-to-cafeteria program action plan! This is the point at which the team works together to decide on



key program details, including the crops, timeline, cafeteria menu, logistics, communication strategies, and expectations. Specifically, this detailed program outline should address the following topics and questions.

Crop Selection

Based on the research and information gathered by the garden and food service representatives, what crops will be the best fit for the program? Are there any produce items that would be easy to work with from both the garden and food service perspectives? Starting out with the most simple solution is usually the best method. Save the more challenging projects or garden experiments for once the program is better established.

Menu Planning & Troubleshooting

The garden-to-cafeteria menu determines how and when the selected produce items will be served in the cafeteria. Given the size of your student body and structure of school meals, how might your kitchen incorporate garden produce into its menu planning? Garden items typically yield a small amount of a single product for a short period of time, but there are still many possibilities. Garden produce can be offered in a salad bar with minimal preparation or incorporated into a school lunch recipe. Depending on the program, it can be offered once a week, every month, or once a year. What interval would be best for your program? Garden items can also be incorporated into a special meal or event that provides an additional opportunity to highlight the fact that an item was grown and harvested right in the school garden.

It is also important to consider the timeline for menu planning in relation to maturation time required for the crops. How far in advance are the menus decided? And when should crops be planted if they need to be ready at a certain time? Leaving as much flexibility around the garden items as possible is highly recommended as things do not always grow as planned.

There is also the question of what to do when unanticipated problems arise. What if a produce item does not come in as expected? It is always important to have a backup plan in place that provides direction to team members on actions they can take to remedy the situation. Produce from a garden is inconsistent and often involves surprises. Even if it shows up on time, it may not be at the volume anticipated. Therefore it is always important to have a supplemental source on hand, especially if the item is required for a recipe. If a supplemental or backup item does need to be used, it should not diminish the program's impact on students. Leaders of several existing programs have noted that students tend consume the "school garden" items at a higher rate than other fruits and vegetables, even if they are served a substitute or "backup" items.



Logistics

Logistics are a major component of garden-to-cafeteria programs. Once produce is harvested, where will it be stored? Who will transport it to a school kitchen? Is there one central kitchen or several smaller kitchens? Does it need to be delivered within a certain time window? Figuring out these important logistical issues ahead of time is essential to a program functioning smoothly.

Communication

Starting a new garden-to-cafeteria program is likely to be an unfamiliar experience for everyone involved, from the school departments all the way up to the board members and community volunteers. This makes ongoing communication between these groups all the more important. Once the program is up and running, what are the expectations around communication for the various team members? How often will the group check in about the program's status and next steps? If something goes wrong, who needs to be contacted about the issue? And finally, what is the strategy for sharing information about the program more broadly, both within the school and the wider community?

Define Success

Each garden-to-cafeteria program is unique so success can look very different from program to program. Though the school gardens typically receive payment for their produce, these funds are minimal and rarely cover the costs of production, let alone the full cost of running a school garden program. If the goal of a garden-to-cafeteria program is not economic sustainability, then what makes a program successful? Is it student involvement? The amount and consistency of produce that reaches the cafeteria? Staff engagement? To keep a program going in the long term, evaluating its success is critical. A clear measurement of success enables the program team to communicate the program's achievements the wider community. It also gives team members a straightforward understanding their own performance, i.e. what is going well and what aspects of the program could be improved.

LESSONS FROM PASADENA UNIFIED

PUSD's team decided to coordinate their seven production gardens to grow and harvest one item per month that would be purchased collectively by PUSD's Food Service Department as a "micro-purchase." In the 2016–2017 school year, the PUSD Food Service purchased a produce item from the production gardens each month as a part of the District's "CA Thursdays" program (in which all food served on a given Thursday is produced in CA). The items were either offered in the salad bars or incorporated into recipes. At PUSD, success was measured primarily by the holistic completion of all parts of garden-to-cafeteria: educating students through courses and field trips, bringing produce from the school garden to the cafeteria with food safety practices, and finally having students taste the food that they or their classmates grew.

RESOURCES:

- "Yield Expectations for Mixed Stand, Small-Scale Agriculture," from Rutgers New Jersey Agricultural Experiment Station
- "Grower 101: Calculations," from Thomas Boyle, UMass Plant, Soil & Insect Sciences
- "Grow Your Own Vegetables Value Calculator," from University of California Agriculture and Natural Resources
- "Southern California Vegetable Planting Chart," from *Plant Good Seed*
- "California Agricultural Water Use," from Heather Cooley and the Pacific Institute
- "How Much Water Does My Food Garden Need?," from University of California Agriculture and Natural Resources



STEP 4: IMPLEMENTATION

Once the program action plan is in place, the garden-to-cafeteria program is ready to begin. At this point, team members work on their respective tasks. The garden staff work with students to plant, tend, and harvest the selected crops. The food service staff prepare to handle the garden produce and advertize the program to students. And the coordinator continues to facilitate conversations and build awareness about the program.
The most rewarding part of a garden-to-cafeteria program is when all of the hard work pays off and the first garden item is served in the cafeteria and enjoyed by students.

TROUBLESHOOTING

In a garden-to-cafeteria program, it is best to expect the unexpected as garden production rarely goes exactly as planned. Maintaining flexibility around timing and product availability is the best way to deal with this uncertainty. Food services should always have a backup plan just in case a specific garden item fails to come through and also make sure staff are prepared to accommodate a relatively large volume all at once if the crop is abundant.

COMMUNICATION & PROGRESS MONITORING

Even if the program is running smoothly, regular communication and check-in meetings are still needed. This gives the group an opportunity to monitor progress, problem solve collaboratively, plan for next steps, and share work with other members of the school community. Also, make sure to track and document any measures of success established in your program action plan.

LESSONS FROM PASADENA UNIFIED

After launching their program in the 2016–2017 school year, PUSD's primary takeaways and lessons learned had to do with the importance of preparation, communication, and flexibility. Staff also agreed that the most important factor in a successful garden-to-cafeteria program is buy-in from and communication between all departments involved. Key staff communicated regularly throughout the pilot and also convened bi-monthly Farm to School meetings with the larger community. PUSD also reported that flexibility and the ability to troubleshoot was essential to their success.

Produce items were not always available on precise dates. Additionally, some crops thrived beyond expectations while others did poorly. In all cases, Food Service had to improvise and adjust, and sometimes use backup sources. One month, this improvisation resulted in a "pumpkin-peach crisp" due to the unexpected availability of 400lbs of pumpkins. Though the cafeteria staff had to change plans on short notice, it was the students' favorite garden-to-cafeteria dish all year!

RESOURCES:

- "Garden to Cafeteria Protocol," Denver Public Schools
- "California Fresh Produce Seasons," from california-grown.com
- "Micro-Purchases for Local Products," from *School Nutrition Resource Guide,* Tennessee Department of Education Website
- "Good Agriculture Practices & Good Handling Practices," from USDA Agricultural Marketing Service Website



STEP 5: CELEBRATE SUCCESS!

Now that you have put in the work and established a strong program, it's time to celebrate and share your success! Promoting your program's achievements can be done in a variety of ways. This "celebration" can take the form of an actual community or school event, or it can be done through social media, conferences, or publications etc... Whatever the means, make sure to highlight your accomplishments so that others can be inspired and learn from your work.

LESSONS FROM PASADENA UNIFIED

PUSD is the recipient of multiple Farm to School awards and honors. Their garden safety protocol manual is available on their website and staff regularly attend local events and conference to discuss and promote their work.

RESOURCES:

- "Building & Growing A Healthy School Environment," Pasadena Unified Farm to School Website
- "Evaluation for Transformation: A Cross-Sectoral Evaluation Framework for Farm to School," from the National Farm To School Network
- "Garden to Cafeteria: A Step-by-Step Guide," by Kaitlin Koch and Colleen Matt of the Michigan State University Center for Regional Food Systems

Technical Report: Modeling Nitrate Leaching Risk from Specialty Crop Fields During On-Farm Managed Floodwater Recharge in the Kings Groundwater Basin and the Potential for its Management

In partial completion of:

USDA Project No: PIN #26174

Project Title: Nitrate Leaching Risk from Specialty Crop Fields During On-Farm Managed Floodwater Recharge in the Kings Groundwater Basin

Recipient: Sustainable Conservation

Grant Agreement No: SCB14028

Groundwater Recharge Project, 2016

Sustainable Conservation, San Francisco, CA

By

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July 31, 2017

This project was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

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Executive Summary

This project has focused on better understanding the potential impact of On-Farm Flood Capture and Recharge (OFFCR) on groundwater quality pertaining to salts and nitrate and on assessing potential management opportunities. To achieve these goals, we used a combination of field and modeling studies. For the field study, soil cores were taken to a depth of 30 feet in replicate across fields with three different specialty crops identified as important to the San Joaquin Valley (tomatoes, almonds, vineyards) and with potential suitability for OFFCR. A prime goal of the field study was to provide data for parameterizing two models developed to assess nitrate, salt and water transport through the vadose zone, prior to percolating into the groundwater aquifer. However, the field study also resulted in key findings that show its value as a stand-alone study:

- Nitrate concentrations are highest in the upper vadose zone and affected by texture. Those effects are not evident in the deeper vadose zone.
- Vadose zone nitrate concentrations are affected by the crop grown. These results suggest an opportunity for lower legacy mass transport for grapes and higher legacy mass transport for both tomatoes and almonds.
- Variability in individual farmers' past and present fertilizer and water management practices contributes to different legacy salt and nitrate loads in the vadose zone.

Data from the field study and other related and concurrent OFFCR field efforts were used during model development. The overall modeling approach was designed to model nitrate and salt transport for lands under OFFCR operation for different crop types, vadose zone characteristics and groundwater characteristics. The defined goals of this design and modeling approach were to: 1) model nitrate and salt movement through the vadose zone and into groundwater; 2) test the model against scenarios that consider different recharge rates, cultural practices, soil types, and depths to groundwater, assessing the timing and magnitude of loading through the vadose zone and the effects on underlying groundwater; and 3) recommend management practices to mitigate potential groundwater impacts. To achieve these goals, two models were integrated to simulate nitrate and salt transport through the vadose zone to groundwater under different scenarios: a 1D Hydrus model and an analytical groundwater model (AGM).

Several significant methodological advances have occurred from this study as related to the integrated models. First, significant effort and resources were put into the development of the Hydrus model. For the Hydrus model, an important outcome of this effort was the documentation of a method to define typical inputs (e.g., nitrogen, irrigation, recharge) and then to put numbers to those inputs. These inputs were used to develop a Hydrus model that reasonably models nitrate and salt transport through the vadose zone, based upon a comparison to our field data and to results from other OFFCR studies. Second, an AGM was developed that allows testing of various OFFCR scenarios for different representative groundwater basins. This AGM, integrated with Hydrus, provides an important tool to widely assess OFFCR across the Central Valley and across areas interested in implementing OFFCR. This work provides an analytical tool to test OFFCR, anticipate potential outcomes to groundwater, and enable the planning and testing of mitigation measures.

For this project, a number of scenarios were identified to test the potential impacts of OFFCR to groundwater and the sensitivity of those impacts to changes in crops, cultural practices, groundwater pumping, etc. Early results from the models suggest a number of groundwater

quality effects. Simulated groundwater quality effects are most noticeable near the OFFCR area at the first encountered groundwater depths. The magnitude of the groundwater quality effects decreases spatially with distance from the OFFCR area and with depth within the groundwater and temporally until they are effectively negligible. Increased quantities of recharge water applied during OFFCR events may not greatly affect groundwater quality. Rather, early results suggest the magnitude of legacy constituents flushed from the vadose zone as well as the magnitude of salts and nitrogen contributed by ongoing fertilization cultural practices are major determinants. Improved agronomic water and nutrient management practices in the future reduce longterm nitrogen loading effects. Over time, longterm legacy loading effects diminish as the vadose zone is flushed with additional clean recharge water. Further work is needed to further test fertilizer and crop management and groundwater sensitivity to these practices, and to assess the opportunities and constraints of regionally expanding OFFCR. Work is ongoing in part funded through leveraging funds from the National Institute of Food and Agriculture, Bachand & Associates, and Tetra Tech. Completion of these runs will provide important information and insight into OFFCR and groundwater quality management.

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Technical Project Report

This Specialty Crop Block Grant project assessed the potential impact of On-Farm Flood Capture and Recharge (OFFCR) on groundwater quality related to the flushing of salt and nitrates from agricultural lands. Technical work conducted included development of the experimental design, collection of field and existing data sources for model calibration and validation, and development of an integrated model to assess nitrate, salt and water transport through the vadose zone and into the groundwater aquifer. This report provides a summary of these technical efforts, findings, and recommendations for next steps to further validate and apply the models to other potential locations in California's Central Valley where groundwater replenishment is a high priority.

I. Experimental Design

An experimental design was laid out for the project, integrating field data collection and modeling. The overall approach is detailed below.

Modeling Approach

The overall modeling approach was to be able to model transport of nitrate and salts for lands that would be used for OFFCR for different crop types, vadose zone characteristics and groundwater characteristics. The defined goals of this design and modeling approach were to: 1) model nitrate and salt movement through the vadose zone and into groundwater; 2) test the model against scenarios that consider different recharge rates, cultural practices, soil types, and depths to groundwater, assessing the timing and magnitude of loading through the vadose zone and the effects on underlying groundwater at various depths, distances, and times; and 3) recommend management practices to mitigate potential groundwater impacts.

To achieve these goals, two models were developed to simulate nitrate and salt transport through the vadose zone to groundwater under different scenarios: a 1D Hydrus model and an analytical groundwater model (AGM) (Figure 1). Using that modeling structure, an approach was designed to test groundwater quality effects from OFFCR considering the effects of crops grown, recharge intensity used, the recharge area size, nitrogen management practices, soil stratigraphy, depth to groundwater, groundwater pumping (simulated through groundwater velocity), and ambient groundwater concentrations. For the 1D Hydrus model that describes the vadose zone, inputs were used to characterize farm practices (e.g., nitrogen fertilization, irrigation); OFFCR methods (e.g., recharge area size, recharge intensity, frequency, period), and soil textures in the root zone and in the deeper vadose zone. Nitrogen and hydrologic inputs were defined by crop type based upon UC Davis, UC Cooperative Extension and other published sources.

Outputs from the vadose zone model were then input into the AGM. As each model was separate, different Hydrus runs could be fed into different groundwater model runs. Together, these models were used to describe nitrogen, salts and hydrologic transport from specific crops through the vadose zone and into groundwater for the different modeled scenarios developed to understand OFFCR effects and to be able to develop management and land use recommendations.

Define Modeling Scenarios

Table 1 presents the modeling scenarios identified for testing under this project. Scenarios were first identified early in the project to assess the different factors that affect vadose and groundwater. The main factors for testing in the scenarios were the effects of crop fertilizer and irrigation management, the effects from vadose zone texture, and the effects from different recharge strategies. The scenarios presented here represent the most recent iteration. The integrated model design plan focused on testing how different independent variables affect constituent and flow transport through the vadose zone: e.g., vadose zone core texture, irrigation levels, recharge intensity, size of recharge area, depth to groundwater, crops and their nutrient management, ambient groundwater quality, groundwater pumping characteristics (as defined by groundwater velocity). These different scenarios are tested against a "Reference" scenario, defined in the table as Grapes under specific management and in certain environments. The table defines representative conditions as have been identified by the team and are covered in more detail in a project technical memorandum which will be finalized as individual publications[1].

Modeling Sites

The modeling area has been generally defined as the Tulare Lake Hydrologic Region. Much effort on recharge has been ongoing throughout the region including the first field tests[2], implementation and testing of the first full-scale system[3] and considerations for regional scale-up[4]. Modeling sites defined as representative to groundwater and vadose zone conditions are shown in Table 2.

Current Status and Achievements

The purpose of the experimental design was to provide a framework and structure for the research and to coordinate collaborative efforts. With collaboration amongst several organizations involved across the spectrum of research, consulting and planning, this task was critical in working towards that end. Moreover, this project tackles a complex problem by: 1) developing a better understanding of the vadose zone and its implications on water and constituent transport; and 2) leveraging different modeling tools to understand how to best implement OFFCR.

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[1] Bachand, P.A.M., S.M. Bachand, H. Waterhouse, J. Rath, M. Ung, V. Kretsinger, B. Dalgish, W. Horwath, H. Dahlke, C. Creamer, J. Choperena and S. Roy. 2017. Technical Memorandum: Modeling Nitrate Leaching Risk from Specialty Crop Fields During On-Farm Managed Floodwater Recharge in the Kings Groundwater Basin and the Potential for its Management. Technical Memorandum is currently under preparation as funded through this and other grant projects and chapters will be submitted as individual peer reviewed manuscripts. Submission planned for 2017.

[2] Bachand PAM, Trabant S, Vose S, Mussetter B. 2013. McMullin On-Farm Flood Capture and Recharge Project: Hydraulic and Hydrologic Analyses (H & H). Final report, TO# 01, prepared for Kings River Conservation District for submittal to California DWR.

[3] KRCD. 2012. McMullin On-Farm Flood Capture and Recharge Project, Summary Project. FloodSafe California Project, California Department of Water Resources awarded to Kings River Conservation District: BMS No:2010FPCP0014. Awarded July 2012.
http://www.water.ca.gov/floodmgmt/fpo/sgb/fpcp/docs/Summary_McMullin.pdf

[4] Bachand, PAM, S.B. Roy, N.R. Stern, J.Choperena, D. Cameron and W.R. Horwath. 2016. On-Farm Flood Flow Capture – Addressing Flood Risks And Groundwater Overdraft In The Kings Basin With Potential Applications Throughout The Central Valley. Calif Agr. 70(4): 200-207.

The process of developing the experimental design helped focus the efforts and expertise of the different team members to develop a relevant and functioning modeling approach in the context of today's water and specialty crop environment.

Table 1. Scenario Testing Design Plan

Table 1 presents the scenarios planned to be simulated using the Hydrus and AGM models. The blue font represents the reference recharge scenario (Reference) against which all effects are tested under the different scenarios.

Independent Variables [1]				Scenario and Its Definition								
					1	2	3	4	5	6	7	8
Name	Value		Units	Control [1]	Effects of BMP for Nutrient Mgmt Plan on different crops	Effects of Soil Texture	Depths of Vadose Zone	Effects of different crops on GW (included in Scenaro 1)	Effects of different recharge scale on GW	Effects of Recharge Strategy	GW velocity	Ambient GW
Crop and Nutrient												
Spec Crop 1	Tomatoes	BP Farm (414)	lbs-N/Ac		x							
Spec Crop 2	Almonds	BP Farm (428)	lbs-N/Ac		x							
Spec Crop 3	Grapes	BP Farm (74)	lbs-N/Ac	x	x	x	x		x	x	x	x
Spec Crop 1	Tomatoes	Low Input(276)	lbs-N/Ac		x							
Spec Crop 2	Almonds	Low Input(204)	lbs-N/Ac		x							
Spec Crop 3	Grapes(22)	Low Input	lbs-N/Ac		x							
Irrigation												
BAU [4]	1.1 X BP		in/y									
BP Farm [4]	1.05 X ETc		in/y	x	x	x	x		x	x	x	x
Recharge [2]												
Rotating	15: 0.58; 150: 0.48; 500: 0.41		in/d							x		
Dedicated	15: 2.3; 150: 1.92; 500: 1.65		in/d	x	x	x	x		x	x	x	x
Size (cfs)												
Field	15		acres						x			
Farm	150		acres	x	x	x	x		x	x	x	x
Farm Complex	500		acres						x			
Texture												
Sandier	Core 1			x	x	x	x		x	x	x	x
Clayier	Core 2					x						
Depth to GW												
low	100		ft				x					
Middle	150		ft	x	x	x	x		x	x	x	x
High	200		ft				x					
Velocity												
Low	H: 0.2, V: 0.002		ft/d	x	x	NA	NA		x	x	x	x
High	H: 0.8; V:0.008		ft/d								x	
GW Water Quality [3]												
Upper Quartile	NO3-N: 10; TDS: 700		mg/L									x
median	NO3-N: 5; TDS: 400		mg/L	x	x	NA	x		x	x	x	x
Lower Quartile	NO3-N: 2.5; TDS: 250		mg/L									x
Total Scenarios												
All	17			1	6	2	3		3	2		
Minus Control	12			1	5	1	2		2	1		
Modeling Tools												
Hydrus	13			x	x	x	x		x	x	x	x
GW	13			x	x	x	x		x	x	x	x

Notes

1 Control shaded blue in Independent Variables

2 Rotating is simulated using 1/4 of infiltration rate under dedicated recharge (2.4 in/d). Dependent upon system capacity

3 BAU is used for 25-y runup to achieve equilibrium conditions in vadose zone

4 Irrigation under Best Practices is estimated at 1.05 X ETc (Crop ET). BAU is estimated at 10% higher than BP

Table 2. Groundwater and vadose zone conditions selected for modeling sites representative of the Tulare Hydrologic Region and the Kings Basin

Vadose Zone Thickness							
	Location						**Source**
Depth to Groundwater (ft below GSE [4])	**Fresno, SR99 & SR180**	**Raisin City**	**NE Helm at SR145**			
Spring 2015	90	160	260			CASGEM, 2017
Spring 2017	90	160	200			CASGEM, 2017
Average	90	160	230			
Modeled	*100*	*150*	*200*			
Groundwater Zones and Model Sample Depths						
Available Data (ft below water table)	**Value**					
Domestic Well Depth within Saturated Aquifer	75					CVSalts [1]
Saturated Production Zone	324					CVSalts [1]
Selected Model Sampling Depths (ft below water table)						
Upper Zone	*10*					
	40					
	70					
Lower Zone	*130*					
	190					
Water Quality Ranges	**Lower Q**	**Median**	**Upper Q**	**Mean**	**Reg. 2, 3**	
TDS (mg/L)						
Upper Zone	295	408	662	544		CVSalts [1]
Lower Zone	211	295	495	395		CVSalts [1]
Regulatory Standard					500	CCR Title 22. Div. 4, R-21-03, May 2006[2]
Selected Model Ambient Levels	*250*	*400*	*700*			
NO3-N (mg-N/L)						
Upper Zone	3.6	5.9	9	7.2		CVSalts [1]
Lower Zone	2.3	4.6	8.8	6.6		CVSalts [1]
Regulatory Standard					10	Fed & CA MSCls, July 2014 update [3]
Selected Model Ambient Levels	*2.5*	*5*	*10*			
Groundwater Velocity (ft/d)	Low	High				
Observed Range and Ambient Modeling Levels						
Horizontal	0.16	0.81				
Vertical	0.002	0.009				

Notes

1 CVSalts High Resolution Geodatabases
2 EPA National Secondary Drinking Water Regulation
3 EPA and CA drinking water standard
4 GSE = Groundsurface Elevation

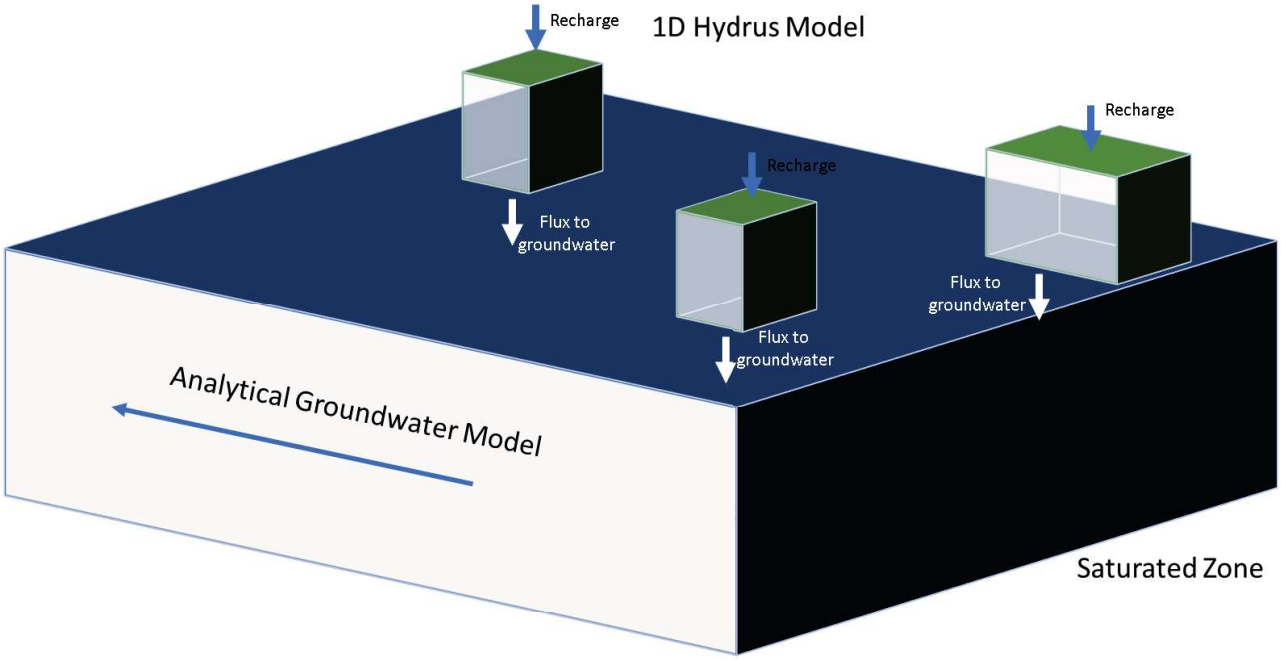


Figure 1. Modeling Framework

This project uses a 1D Hydrus model as an input to an analytical groundwater model (AGM). The 1D Hydrus model is used to test OFFCR efforts for different crops, soil stratigraphy, and cultural practices (e.g. irrigation, fertilization). Outputs from the Hydrus model enable the groundwater model to predict groundwater chemistry responses to OFFCR inputs temporally and spatially. These results will enable testing of different land uses and management practices as a way to best protect groundwater quality under OFFCR.



Figure 2. Study Area.

The site for modeling is the Tulare Lake Hydrologic Region. Groundwater and vadose zone conditions were based upon conditions typical for this region. Field data were collected from within the Study Area.

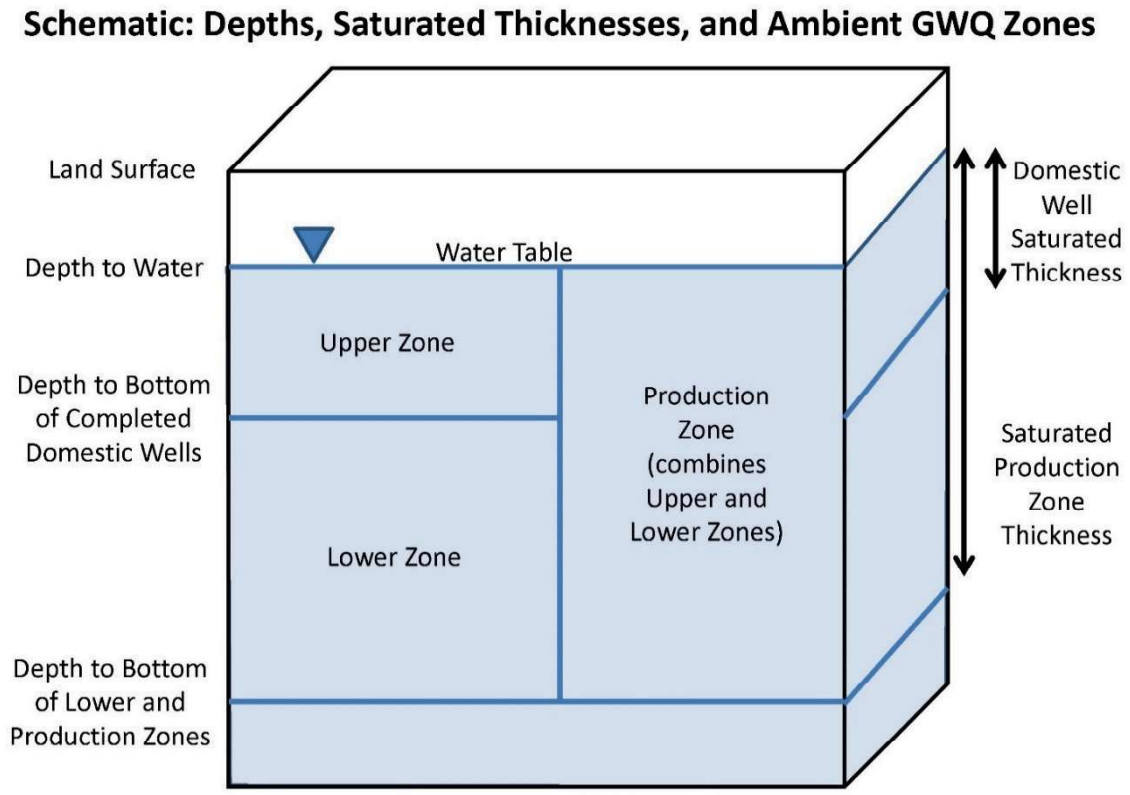


Figure 3. Groundwater schematic

This schematic describes upper and lower zones in the groundwater system typical for the Study Area and defines the production zone from which groundwater is pumped. The production zone is the main zone of interest when considering the quality of groundwater.

II. Data Collection for Model Calibration/Validation

This task was primarily focused on model calibration. A variety of data sources were targeted under this project to be used for model calibration, and these are discussed below. Additionally, this effort expanded into other areas. Particularly, this project was able to leverage other data sources for model validation and also to provide a stand-alone analysis of the vadose zone as related to crop types. These additional efforts are also discussed below.

Targeted data sources

1. **Hydrogeologic, Hydrologic and Soil Series Data.** A variety of soil sources were assessed; e.g. United States Geological Survey Central Valley Hydrologic Model (CVHM), Natural Resource Conservation Service (NRCS) soil survey data, UC Davis Soil Agricultural Groundwater Banking Index (SAGBI) data, and Caltrans borelogs. These data provided an overview of the hydrogeologic conditions and soils for the area. Specific to this project, GeoProbe data were collected and ultimately provided the most reliable and defensible source of data for use in the Hydrus Model and the AGM.
2. **Groundwater and Surface Water Nitrate and Salinity Data.** Groundwater chemistry and hydrogeologic characterization were provided through leveraging ongoing area efforts related to CV-SALTS compliance and compliance with the Central Valley Regional Board Irrigated Lands Regulatory Program, particularly as related to groundwater protection and management.
3. **Vadose Zone Soil Moisture, Chemistry and Infiltration Rates.** These data were generated through field work utilizing GeoProbe coring at identified sites selected as representative of the Tulare Lake Hydrologic Region. This is described in greater detail below. Other data sources were utilized for parameterizing the Hydrus model. These are also described below.
4. **Root Zone Chemistry Data** were primarily from GeoProbe data and other sources as described below.
5. **Industry and Collaborator Cultural Practices:** Fertilizer and irrigation data were developed based upon interviews with participating growers, input from UC Cooperative Extension specialists, CDFA fertility and irrigation guidelines, USDA National Agricultural Statistics Service (NASS) data and a review of the published literature as related to growing tomatoes, almonds and grapes. More detail and information on those sources can be found at Bachand et al (2017).[1]

GeoProbe Vadose Zone Field Study

The original concept for this project was to leverage different data sources to provide modeling information for the Hydrus model. These other sources are described above but after much review were found inadequate for developing a working vadose zone model. Thus, the project team focused on collecting vadose zone data to depths of 30 feet on fields planted with the different crops of interest and considered to represent a steady state condition with regard to transport and accumulation of salts and nitrate in the upper vadose zone under specific farming conditions (e.g. crops, cultural practices)..

Summary of Data Collection

The study area includes six farms in the Kings River Basin west of Fresno, CA. Replicate cores (N=3) were collected to depths of 30 ft under almond, tomatoes and wine grapes for two different NCRS hydrologic soil classes, Class A and Class C/D (Table 3). Class A soils are defined as soils with low runoff potential, with saturated hydraulic conductivity greater than 5.67 inches/hour (NRCS Part 630 Hydrology National Engineering Handbook), Class C soils are defined as having moderately high runoff potential and saturated hydraulic conductivity 0.14 inches/hour to 1.42 inches/hour and Class D soils have high runoff potential with saturated conductivity less than 0.14 inches/hour. Class C and Class D soils on farmland were considered in this study as many of these soils are deep tilled to remove restrictive soil horizons and to increase infiltration rates especially in orchard and vineyard systems (O'Geen et al. 2015). Cores were analyzed in the lab for NO3 , texture, moisture and electrical conductivity. For the first three feet, subsamples were taken every foot. Below that depth, samples were taken based on morphological changes within the core where distinct layers were identified. Where a lighter textured soil overlay a heavier texture layer, a sample was taken in the middle of the sandy layer, at the top of the heavier texture layer, and in the middle of the heavier texture layer to capture any NO3 that may have accumulated at the top of the heavier texture layer . Samples were analyzed statistically to assess differences on chemistry as related to texture, crops and individual farm.

Summary of Key Data Findings

Core data provided interesting data on the chemistry as related to farm practices and soil classes:

1. **Nitrate concentrations are highest in the upper vadose zone and are affected by texture. Those effects are not evident in the deeper vadose zone.**
   Nitrate pore water concentrations decreased with depth for all crop types. For lower permeability soils, nitrate concentrations were higher near the surface than for higher permeability soils, suggesting possible mechanisms such as evapoconcentration and /or slower downward movement. These distributions resulted in statistically significant differences in NO3 (ug N/g soil) between soil hydrologic classes A (5.26 ug N/g soil) and C/D (7.18 ug N/g soil) in the top 4 meters, with group C/D soils having higher NO3 levels compared to group A soils. However, this relationship disappeared below the top 4 meters with no statistical difference between soil hydrologic classes. These differences in the upper 4 meters suggest texture may affect nitrate evapoconcentration and transport (Table 4).

2. **Vadose zone nitrate concentrations are affected by the crop grown. These results suggest an opportunity for lower legacy mass transport for grapes and higher legacy mass transport for both tomatoes and almonds.**
3. Throughout the entire sampled profile, soil NO3 concentrations were significantly higher in almonds (7.07 ug N/g soil) and tomatoes (7.59 ug N/g soil) compared to grapes (4.17 ug N/g soil). This outcome held the same pattern above four meters. Below four meters soil NO3 concentrations statistically differed across all 3 cropping systems in the

following decreasing order: tomatoes (5.94 ug N/g soil)>almonds (4.82 ug N/g soil)>grapes (2.63 ug N/g soil) (
Figure 6). Similar findings were found for total NO3 load. Grapes NO3-N load (495.37 kg N/ha) was statistically lower in grape cropping systems compared to almonds (829.08 kg N/ha) and tomatoes (816.69 kg N/ha), with no statistical difference between almond and tomato cropping systems. The same relationship of total NO3 loading between cropping system was found when examining the top four meters and below four meters. The top four meters represents 61%, 62% and 55% of the total NO3 load for grapes, almonds, and tomatoes respectively. These findings suggest the type of crop grown will affect the potential mass transport of legacy vadose zone N under OFFCR.

4. **Farmers' varied management practices confound vadose zone chemistry effects of crops.**
   Vadose zone chemistry differed under different farmer management. Within almond cropping systems, Alm-A-2 had significantly higher pore water NO3 throughout the nine-meter profile compared to Alm-A-1, Alm-CD-1, and Alm-CD-2, with Alm-CD-2 having the lowest concentrations (Figure 7A). Across the nine-meter profile TDS did not statistically differ across farms. However, when examining the data within almond cropping systems, TDS did vary by farmer with Alm-CD-2 having statistically lower TDS compared to Alm-A-2 (Figure 7B). Some of these differences showed up in the other crops though definitive comparison of different crops for different farmers was not possible as all crops were not grown by all farmers. However, the data suggests that farmers' unique production objectives and past and current management choices confound the vadose zone chemistry of similar crops.

Table 3. Experimental design

A total of 36 cores were selected to a depth of 30 feet. Twelve field sites were sampled. Specific field sites were distinguished by crop type (i.e.. almonds, tomatoes, wine grapes), two soil hydrologic classes (i.e., A, C/D) and two location replicates (i.e., location 1, location 2). Three replicate cores (N=3) were sampled at each site.

Site Code	Crops	Soil Hydrologic Class	Location Replicate
Alm-A-1	Almonds	A	1
Alm-A-2	Almonds	A	2
Alm-CD-1	Almonds	C/D	1
Alm-CD-2	Almonds	C/D	2
Tom-A-1	Tomatoes	A	1
Tom-A-2	Tomatoes	A	2
Tom-CD-1	Tomatoes	C/D	1
Tom-CD-2	Tomatoes	C/D	2
WGr-A-1	Wine Grapes	A	1
WGr-A-2	Wine Grapes	A	2
WGr-CD-1	Wine Grapes	C/D	1
WGr-CD-2	Wine Grapes	C/D	2

Table 4. Pearson correlation coefficients of percent sand, percent silt, percent clay, and moisture vs pore water nitrate in the upper 4 meters.

In the upper four meters of the vadose zone, soil texture affected nitrate pore water concentrations and moisture. Moisture, total dissolved solids and texture (i.e. % sand, silt, and clay) were able to explain 39% of the variation in pore water NO3 concentrations (adjusted R^2= 0.39). Percent sand and silt and moisture had the strongest correlation with pore water nitrate. Asterisk indicates significant correlation ($p<0.05$).

	Pore Water Nitrate (mg/L)	TDS (mg/L)	Moisture (g/g)
% Sand	0.57*	0.09*	0.47*
% Silt	0.35*	0.19*	0.82*
% Clay	0.09*	0.06	-0.05

Figure 4. Core sample collection.

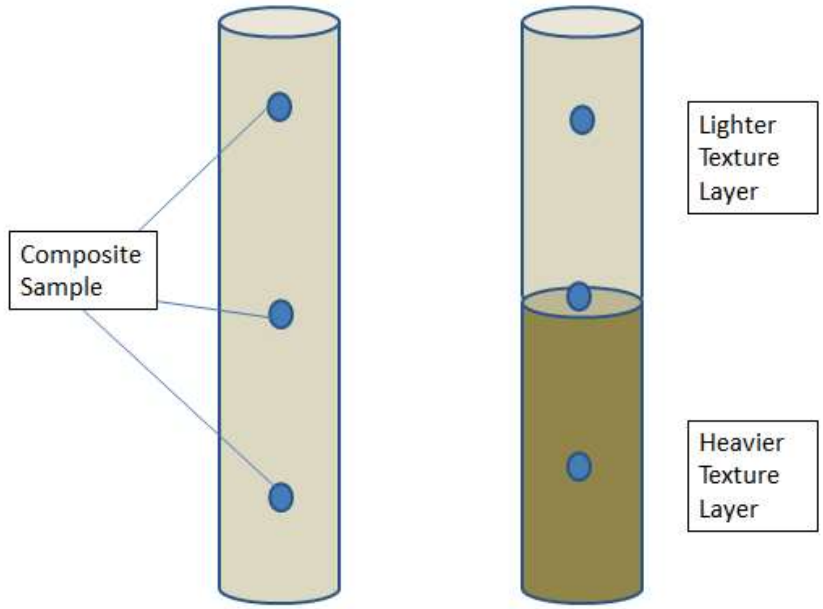


Figure 5. Pore water nitrate profiles.

Nitrate concentrations decrease with depth for all crop types. For lower permeability soils, nitrate concentrations are higher near the surface than for higher permeability soils, suggesting possible mechanism suchas evapoconcentration and /or slower downward movement.

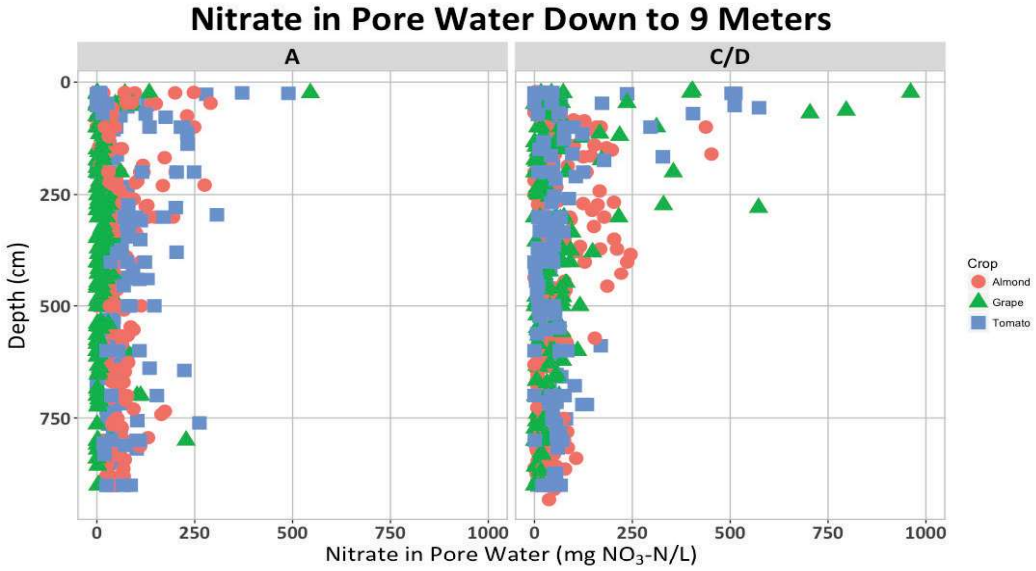


Figure 6. Mean soil NO3 (ug N/g soil) concentrations at varying depths; the entire 9 m profile, the top four meters, and below four meters.

Throughout the entire sampled profile, soil NO3 concentrations were significantly higher in almonds (7.07 ug N/g soil) and tomatoes (7.59 ug N/g soil) compared to grapes (4.17 ug N/g soil). This outcome held the same pattern above four meters. Below four meters, soil NO3 concentrations statistically differed across all three cropping systems in the following decreasing order: tomatoes (5.94 ug N/g soil)>almonds (4.82 ug N/g soil)>grapes (2.63 ug N/g soil).

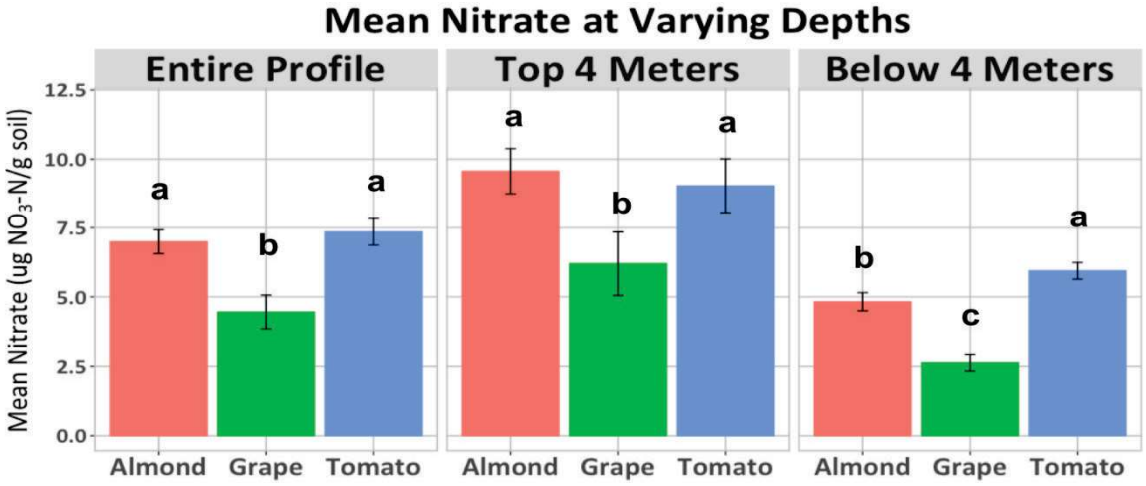
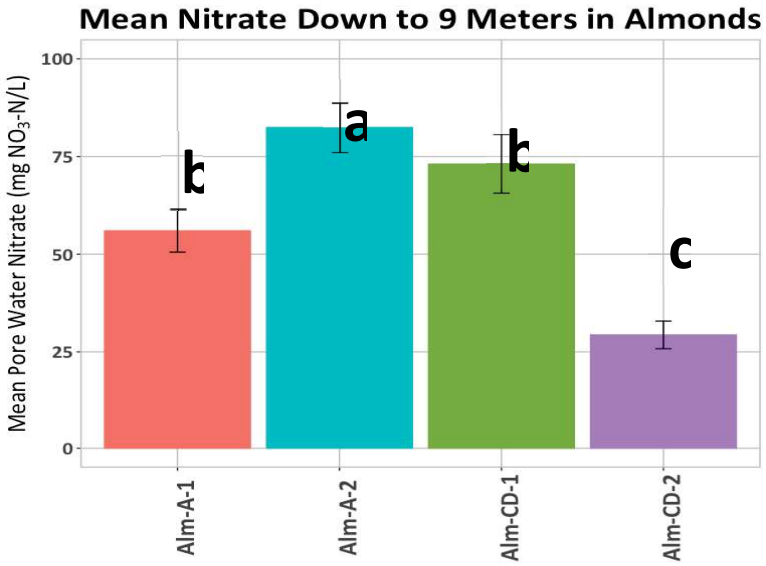
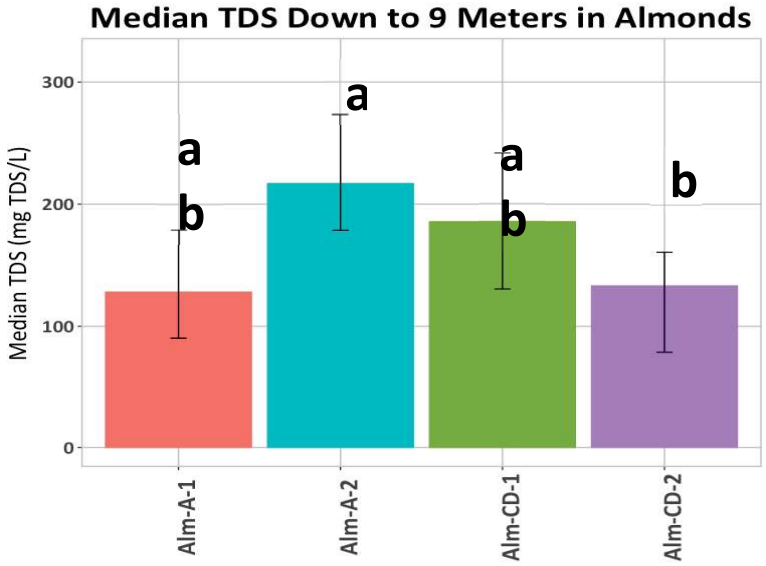


Figure 7. Farm Effects on Vadose Zone Chemistry

Vadose zone chemistry differed under different farmer management. Within almond cropping systems, Alm-A-2 had significantly higher pore water NO3 throughout the nine-meter profile, compared to Alm-A-1, Alm-CD-1, and Alm-CD-2, with Alm-CD-2 having the lowest concentrations. Across the nine-meter profile, TDS did not statistically differ across farms. However, when examining the data within almond cropping systems, TDS did vary by farmer with Alm-CD-2 having statistically lower TDS compared to Alm-A-2.



A. Nitrate.



B. TDS:

Use of data for modeling parameterization

Data from this study were used to parameterize the Hydrus model and to develop the Hydrus model inputs in several ways:

Nitrogen inputs: Nitrogen inputs from the different participating farmers were compared to other sources (e.g., UCD and CDFA guidelines; UC CE recommendations) in order to check the practices of the participating farmers against the industry (not outliers) and for estimating changes in N inputs over the last 25 years.

Texture and Lithology. Soil lithology was mapped for all the sampled cores as were NO3 concentrations in pore water. Comparing against all the lithological and NO3 profiles, four representative core classes were identified. For two of the 4 classes, a representative core was used for building the Hydrus 1D model. One core reflects finer soils and the other core reflects coarser soils. The effects of soil texture and lithology will be explored in the Hydrus model runs.

Nitrogen mass profiles. Nitrogen mass profiles were developed for each core and those profiles have been shown by crops and soil type (Figure 5). Those profiles were used to validate the Hydrus models. Those profiles were considered to be in steady state condition and reflect the variance in steady state conditions across a given crop (and soil type). For the Hydrus models, those profiles constrained the model. Models that produced N profiles inconsistent with general N trends were considered inadequate and efforts were made to correct.

Other Data Sources – Chowchilla Study

This study was designed to rely upon field soil cores and other data representative of steady state and did not include funding to assess changes in soil NO3 concentrations under OFFCR since availability of water for recharge could not be assumed during the project period. However, in 2016 when federal water was available, Sustainable Conservation provided additional funding to set up an OFFCR field trial on organic almonds[5] and purchase water for recharge. Soil cores collected at control (no recharge) and recharge treatment replicates in the orchard provided data used to help calibrate this project's modeling of NO3 flushing under OFFCR operations.

Next Steps

The results from this field study warrants further analyses of the data. That analysis is ongoing with the development of a peer reviewed publication under additional funding sources (e.g., Almond Board of California Grant, National Institute of Food and Agriculture, Tetra Tech, Bachand & Associates). These analyses are further exploring farm management and texture effects on soil N profiles and the potential impact on legacy transport of N under OFFCR.

Findings from this field study provide a stand-alone data set that can inform opportunities and constraints of OFFCR outside of its use in model development. Thus, these results will also be

[5] S. Bachand, S. Carlton and P.A.M. Bachand. 2017. On-Farm Flood Capture and Recharge (OFFCR) at an Organic Almond Orchard, Recharge Rates and Soil Profile Responses. Groundwater Recharge Project, 2016. Report to Sustainable Conservation, Sustainable Conservation, San Francisco, CA. In prep for publication.

used in informing interested parties and stakeholders (e.g. Water Boards, Groundwater Sustainability Agencies , farm groups) on the OFFCR practices.

III. Developing and Running Modeling Framework

Under this task, the integrated model earlier discussed under Task 2 (Figure 1) was developed and run. This section describes the key technical efforts and results associated with this task and identifies next steps.

Model Development

The Hydrus and Analytical Groundwater Model (AGM) were developed for this project. This section summarizes this process. More details will be available in a technical memorandum[1] serving as the draft for in-progress peer review publications.

Hydrus Model

Hydrus requires a defined vadose zone, the development of input files, and parameterization of the model. For the Hydrus model, two representative cores were selected from the field study that were found to be representative of lithological core classes for this study.

Fertilization and Irrigation Inputs

Fertilization and irrigation inputs were defined based upon a review of the literature. For fertilization, sources included input from participating farmers, University of California Cooperative Extension (UCCE) and the California Department of Food and Agriculture (CDFA). Irrigation inputs for each crop were defined by their ETc demand. California Irrigation Management Information System (CIMIS) at the Stratford Station (Station 15) were referenced to represent area evaporation needs. Crop specific ET rates (ETc) were developed using published crop coefficients (ABC 2017, Hanson et al 2006; Williams et al 2003, Snyder et al 2000), . Irrigation rates under the various practices were based upon an analysis of Application Efficiency (AE) for different regions and irrigation methods. AE measures irrigation system performance efficiency with regard to delivering a target irrigation depth for beneficial uses (Burt et al, 1997; Sandoval-Solis et al, 2013). Other beneficial uses aside from irrigation can be for salinity leaching, field preparation, microclimate control, weed germination or cover crop ET (Sandoval-Solis et al 2013, Canessa et al 2012). AE was used as a surrogate for Irrigation Efficiency (IE). IE represents a seasonal assessment tallying all beneficial uses, AE is event-based and assumes all water destined for a beneficial use will be used for those uses (Burt et al, 1997). If the targeted requirement is equal to the sum of all beneficial uses, AE provides a conservative estimate of IE if the beneficial uses are distributed uniformly across a field, acknowledging that unavoidable, nonbeneficial uses lower efficiency as does non-ideal scheduling (Burt et al 1997). The concept of AE was applied to assess the efficiency of water applied to a field meeting irrigation needs under two irrigation management scenarios: BAU, Business-as-usual; BP, Best Practices. Based upon that analyses, typical BP was estimated as 5% greater than ETc, and typical BAU was estimated as 10% greater than BP.

OFFCR Recharge Capacity, Rates, Frequency and Period

For this study, recharge rates of 15, 150 and 500 CFS are based on current ongoing efforts in the Kings Basin. These current efforts are effectively tangible models for implementation of this technology throughout the study area and the Central Valley in general. Terranova Ranch has conducted recharge in both 2012 (Bachand et al, 2011, 2014) and more recently in 2017 (LA

Times) at a recharge rate of about 15 CFS diversion rate from the James Bypass, limited by conveyance capacity and typical in capacity to other recent farm OFFCR efforts (TID 2017). The McMullin On-Farm Flood Capture and Recharge (OFFCR) Project funded through a California Department of Water Resources (DWR) Flood Corridor Grant, was begun in 2012 with the completion of the Hydrologic and Hydraulic Analyses (H&H) in January 2014, and CEQA in 2016 (Tetratech 2016a, b) and with design, permitting and agreements in process, and with construction planned to begin in 2018 (Monreal et al 2017). This project is currently being designed for a 150 CFS diversion capacity (Monreal et al 2017; KRCD 2012). The project is also planned for future expansion to a 500 CFS capacity (Bachand et al 2016) and current project design efforts are taking that expansion into consideration (Monreal et al 2017). This SCBG project modeled these OFFCR scale efforts, identifying appropriate acreage and predicted infiltration rates based upon previously published findings and relationships.[6]

All these recharge efforts are based upon infiltration rates measured under the NRCS CIG study used to test the hydrologic and logistical feasibility of OFFCR (Bachand et al, 2011, 2014). For the modeling purpose of this study, those measured infiltration rates are considered generally representative of much of the study area soils and changes in the recharge rates are primarily achieved through increasing acreage at an approximate ratio of 10 acres needed to capture and recharge 1 CFS (Bachand et al, 2011, 2014).

Groundwater Model

A 3-dimensional hydrologic and water quality analytical groundwater model (HW_qAGM-3DNS – Hydrologic Water quality Analytical Groundwater Model – 3D, Non-Steady State) was developed to simulate water quality effects on groundwater from vadose zone fluxes. More information is available on model development from Ung et al, 2017. Key points are summarized below.

HW_qAGM-3DNS is a 3-dimensional non-steady state analytical model based upon the fundamental equations describing saturated flow (Freeze and Cherry, 1979). Mass transport is modeled using advective-dispersion equations. The model was linked to Hydrus-1D such that hydrologic and water quality fluxes from Hydrus-1D would be inputs into HW_qAGM-3D. In this application, this model assumed conservative water quality transport. Neither NO3 or TDS were assumed to transform or degrade during groundwater transport.

A recharge area for a 10-mile x 10-mile watershed was defined for this study (Figure 9). Depending upon the recharge capacity, the soils and whether the lands were dedicated or rotational, the area varied. Under dedicated recharge on soils typical for the study area (Bachand

[6] Bachand, P.A.M., S. Roy, J. Choperena, D. Cameron and W.R. Horwath. 2014. Implications of Using On-Farm Flood Flow Capture To Recharge Groundwater and Mitigate Flood Risks Along the Kings River, CA. Environmental Science and Technology48(23), 13601-13609.

Bachand, P.A.M., W.R. Horwath, S. Roy, J. Choperena, and D. Cameron. 2011. Final Report: Implications of Using On-Farm Flood Flow Capture To Recharge Groundwater and Mitigate Flood Risks Along the Kings River, CA. For Grant Agreement No. 68-9104-0-128 between Bachand & Associates and the United States Department of Agriculture Natural Resources Conservation Service. September 30, 2012. http://aquaticcommons.org/11287/

et al 2011, 2014), approximately 150 acres are needed to divert 15 cfs, 1500 acres are needed to diver 150 cfs and 5000 acres are needed to divert 500 cfs.

Three monitoring locations were selected downstream of the recharge area. The recharge area used depended upon the capacity of the system being used. For each monitoring location, depths were selected to monitor groundwater quality representing a gradient through the production zone (Figure 3). CVSalts data were used to define general ambient groundwater quality conditions in the upper and lower groundwater zones. Ambient velocities and groundwater quality values are defined to represent the modeled area based on CVHM numerical flow model results in the Kings Subbasin region. Three ambient groundwater quality levels were selected based upon statistically analyzing the groundwater quality data in the upper and lower zones: 1) TDS = 250 mg/L and NO3-N = 2.5 mg/L; 2) TDS = 400 mg/L and NO3-N = 5 mg/L; and 3) TDS = 700 mg/L and NO3-N = 10 mg/L. These values represent the range of water quality distributions across the upper and lower zones, represent a more log-normal distribution, and are relevant to the regulatory limits for both NO3-N (10 mg/L, EPA 2006) and for TDS (500 mg/L secondary MCL,EPA 2014). Groundwater velocities were bracketed using high and low values representative of simulated velocities in the study area. These rates represent the range of observed horizontal and vertical velocities.

Model Outputs and Validation

Model outputs for both the Hydrus and groundwater models were identified by the project team as detailed in Figures 10 and 11. These outputs were a combination of graphical outputs and summary performance metrics. These outputs were used to 1) describe and quantify spatial and temporal hydrologic and water quality changes in the vadose zone and in groundwater and 2) to quantify temporal changes in flux from the vadose zone to groundwater under the different scenarios being tested, and Table 1. These outputs have also been used to compare model outputs to collected field data to assess model performance particularly in the model parameterization process and for the validation of the Hydrus model.

A variety of data were used to assess performance of the Hydrus model. Findings from the Chowchilla study have shown the expected amount of flushing that would be expected under low and high OFFCR rates.**Error! Bookmark not defined.** Those data were used to determine if Hydrus was modeling legacy flushing under OFFR. Nitrogen profiles from the soil core study (Data Collection for Model Calibration/Validation section) have provided a N profile range found in this study as typical for the different crops.

Nitrogen core profiles were qualitatively used to validate the Hydrus model (Figure 8), its inputs and parameters. This model validation has been, by necessity somewhat qualitative. The Hydrus model defines a model domain or universe which reflects human biases and assumptions. It is not possible to define the exact Hydrus model for this process given the limitations of the Hydrus model and the datasets available. Instead, significant effort and resources were invested to define a Hydrus model that will provide a reasonable representation of constituent and hydrologic transport through the vadose zone with respect to –

- the timing and magnitude of legacy flushing during the early periods of OFFCR,
- the mass of N and salts that will remain in the vadose zone over time,
- the effects to groundwater from different crops, land uses and practices,

- the effects to groundwater from the connectivity of surface water with groundwater under OFFCR, and
- other drivers of transport.

Ultimately, the Hydrus model will provide a reasonable tool for predicting the effects of OFFCR on the transport salt and nitrates through the vadose zone to groundwater, and for determining the potential impacts from changing agricultural and OFFCR management practices.

Use of the Analytical Groundwater Model for these purposes was not assessed.

Run Model for Scenario Testing and Characterization

Model runs have been ongoing with scenario testing to continue under funding from other projects. Some early data from the model runs are shown here. Figure 8 shows the cumulative NO3 profile in the 200-ft vadose zone under BAU conditions after a 25-year period. These modeled results show NO3 distribution in the vadose zone after historic farming operations. These model results are considered reasonable as they are in the range of NO3 profile concentrations measured in field soil core data collected from this study using the Geoprobe.

The Hydrus model was used to model the effects to groundwater under low and high volume recharge conditions similar to recharge conducted for field studies at Terranova Ranch and Chowchilla.[4, **Error! Bookmark not defined.**] The groundwater model was set up to observe locations at different distances and depths from the recharge location (Figure 9), enabling a spatial / temporal analyses of OFFCR effects on groundwater quality.

Figures 10 and 11 are examples of early groundwater runs. These runs model groundwater 2, 11 and 20 meter (6.5, 36 and 66 feet) below the groundwater/vadose zone interface at distances 2000, 6000 and 10,000 m (approximately 1, 4 and 6 miles) downstream of the recharge area. Groundwater responses are shown for low and high volume OFFCE (i.e., 2- and 10- feet annual recharge).[7] Under both these scenarios, water quality effects are most noticeable near the OFFCR area at the groundwater/vadose zone interface (shallow groundwater depths). The magnitude of the effects decrease with distance from the OFFCR area, with depth in groundwater and over time. In this example, ambient groundwater nitrate concentration is defined in these scenarios as 5 mg-N/L. Concentrations at the top of the groundwater near the OFFCR location initially increase by 40% and stay elevated over 30 years. For deeper groundwater locations (i.e. 11, 20 m; 36, 66 ft), and for locations further downstream (i.e. 6000, 10,000 m; approximately 4 and 6 miles), these effects are less and generally negligible. Groundwater quality effects are similar under both low and higher volume OFFCR scenarios. In this example, concentrations near the higher OFFCR location increase slightly more than under lower OFFCR levels but for the most part are very similar. These results suggest that the amount of recharge water is not the main driver for groundwater impacts, but the flushing of legacy

[7] Note early runs were used in model development, parameterization and validation. Current modeling efforts are looking at recharge efforts of 15, 150 and 500 CFS with infiltration rates of about 2 – 3 in/day (Bachand et al 2011, 2014). The rates of 2-ft and 10-ft are generally consistent with the recharge that would occur annually under dedicated recharge and rotating recharge.

constituents from the vadose zone as well as ongoing fertilization cultural practices may be the key drivers.

Next Steps

Further model runs are planned for next steps. The current project has provided a reasonable integrated vadose zone / groundwater model for use with various specialty crops studied here (tomatoes, almonds, grapes). The further runs will test the effects of the scenarios and management on groundwater quality and transport of nitrate and TDS to groundwater. Important findings will result from these runs including the following:

1. An estimate of N and salts remaining in the vadose zone under long-term OFFCR
2. The relative importance of ongoing fertilizer management with legacy constituents flushed from the vadose zone by OFFCR
3. The impact of increased surface water and groundwater connectivity that results from OFFCR on groundwater quality
4. Reasonable estimates of timing regarding the time for constituents to be flushed from the vadose zone and the time for that initial pulse to dissipate spatially.
5. The impact on groundwater quantity and quality across the production zone.
6. An understanding of potential pumping effects on groundwater quality, both temporally and spatially.

Table 5.Modeling Outputs

Model outputs identified for both the Hydrus and groundwater models are provided in the table. These outputs are a combination of graphical outputs and summary performance metrics. These outputs are used 1) to describe and quantify spatial and temporal hydrologic and water quality changes in the vadose zone and in groundwater and 2) to quantify temporal changes in flux from the vadose zone to groundwater under the different scenarios being tested. These outputs have been also used to compare model outputs to collected field data to validate the Hydrus model, particularlyduring the parameterization process and .

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			Unit	Graphs	Files/ Spreadsheets
Groundwater					
	Temporal Graphs and spreadsheets by time				
		NO3-N & TDS levels by detph (t)	NO3-N mg/L; TDS mg/L	Selected locations/ runs/depths	Selected locations/ runs/depths
		Avg NO3-N & TDS in production zone(t)	NO3-N mg/L; TDS mg/L	All	All
	Summary performance metrics				
		Time of run	y or days	NA	All
		Total time above 10 mg/L at each depth	y or days	NA	All
		NO3-N and TDS average during time to steady state at each depth	NO3-N mg/L; TDS mg/L	NA	All
		Time to steady state	y or days	NA	All
Vadose Zone					
	Descriptive				
		NO3-N & TDS profile with depth in vadose zone	mg/kg	Selected years	Selected years
so		water flow and NO3-N & TDS mass fluxes		Selected years	Selected years
	Temporal Graphs and spreadsheets by time				
		water flux	volume per year		All
		vadose zone NO3 and TDS mass over time	NO3-N, TDS (kg)		All
		N & TDSapplied(t)	NO3-N, TDS (kg)		All
		N & TDS exported to groundwater(t)	NO3-N, TDS (kg)		All
		N & TDS exported past root zone (t)	NO3-N, TDS (kg)		
		% NO3-N & TDS exported to groundwater(t)	%		All
		% NO3-N& TDS exported past rootzone (t)	%		
	Summary performance metrics				
		Initial Vadose zone mass post BAU	NO3-N, TDS		
		Final vadose zone mass post BMPs/recharge run	NO3-N, TDS		
		Time to steady state	y or days		All
		Time of run	y or days		All
		Cumulative N applied by steady state	NO3-N kg		All
		Cumulative N exported by steady state	NO3-N kg		All

Figure 8. Modeled Cumulative N Profile for different crops

Hydrus model outputs were developed for the different specialty crops. Soil profiles were developed over a 25-year run under BAU fertilization and irrigation practices. Nitrogen profiles are shown for a 200-foot unsaturated (vadose) zone showing cumulative N mass by depth. The profiles show increasing N with depth over the 25-year period and compares those profiles with the first 30-feet of data from collected soil cores.

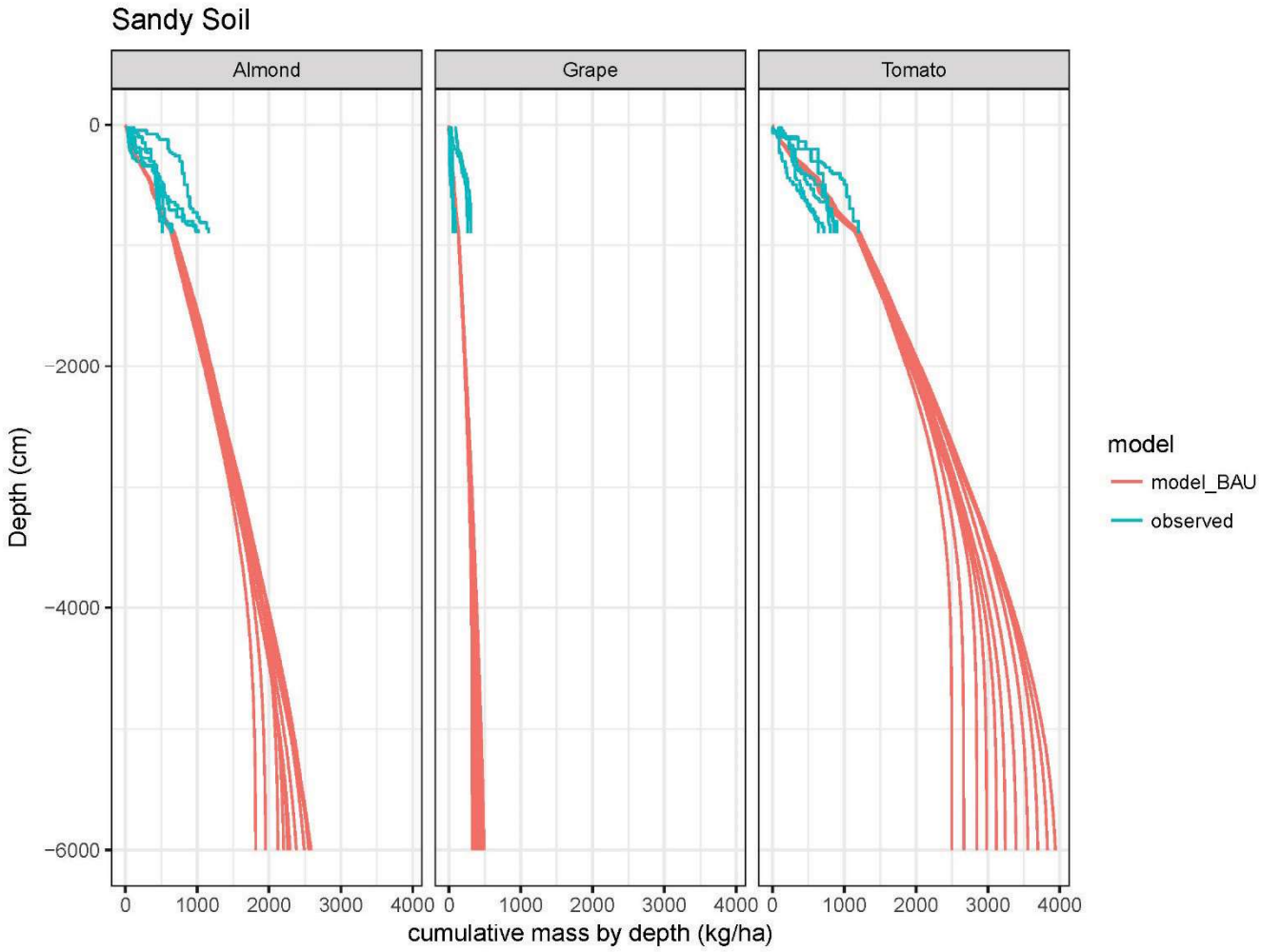


Figure 9. Boundary condition geometry and observations points

Locations represent observation points downstream of the OFFCR area. At each observation point, simulated groundwater is sampled at observed depths below the groundwater / vadose zone interface. These depths can be varied, as well as the observation points. At each location, groundwater quality can be monitored over time.

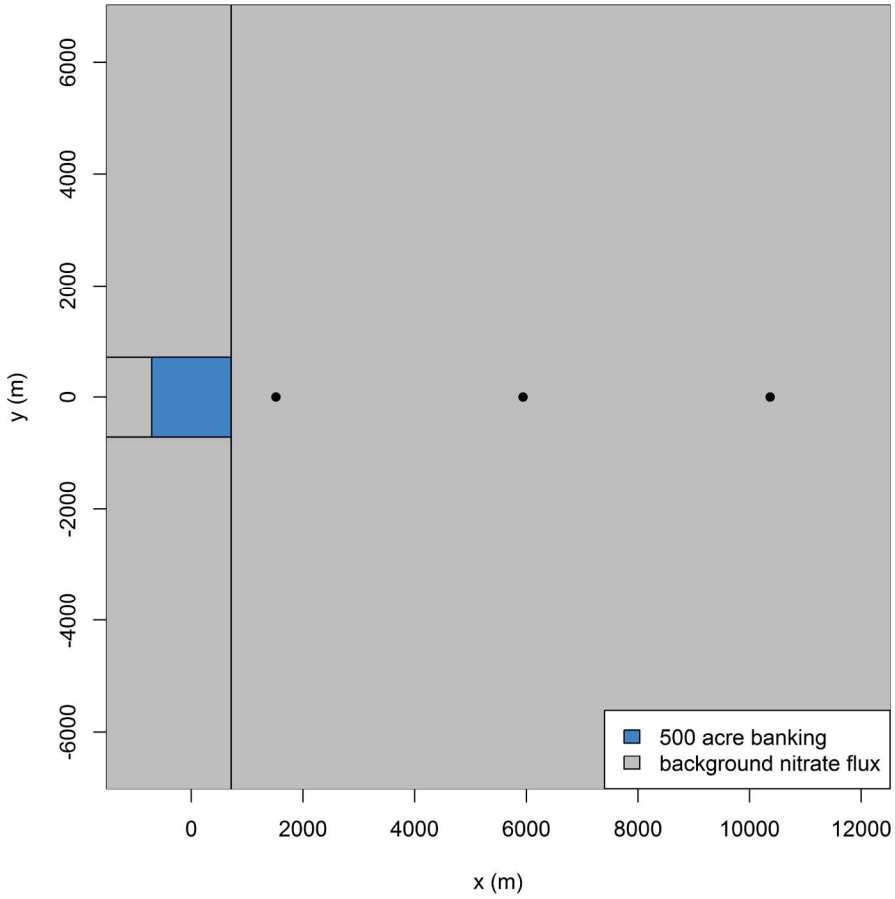


Figure 10.Changes in groundwater nitrate concentrations under low OFFCR rates.

This example is representative of lower recharge rates (2-ft recharge per recharge year) across 500 acres for groundwater velocities in the range typical for the Tulare Lake Hydrologic Region (Vx = 2 ft/d, Vz = 0.003 ft/d). Locations represent observation points downstream of the OFFCR area (2000, 6000, 10,000 m; approximately 1, 4 and 6 miles) at depths of 2, 11 and 20 m (6.5, 36 and 66 ft) below the groundwater/ vadose zone interface. Groundwater quality effects are most noticeable near the OFFCR area at the first-encountered groundwater, or near where the groundwater/vadose zone interface occurs. The magnitude of the effects decrease with distance from the OFFCR area, with the depth of groundwater sampled, and over time. Ambient groundwater concentration are defined here as 5 mg-N/L In this example, concentrations near the OFFCR location increase by 40% and stay elevated over 30 years due to continued leaching and transport of nitrate with ongoing OFFCR at the recharge site. For deeper locations, and for locations further downstream those effects are less and can effectively be negligible.

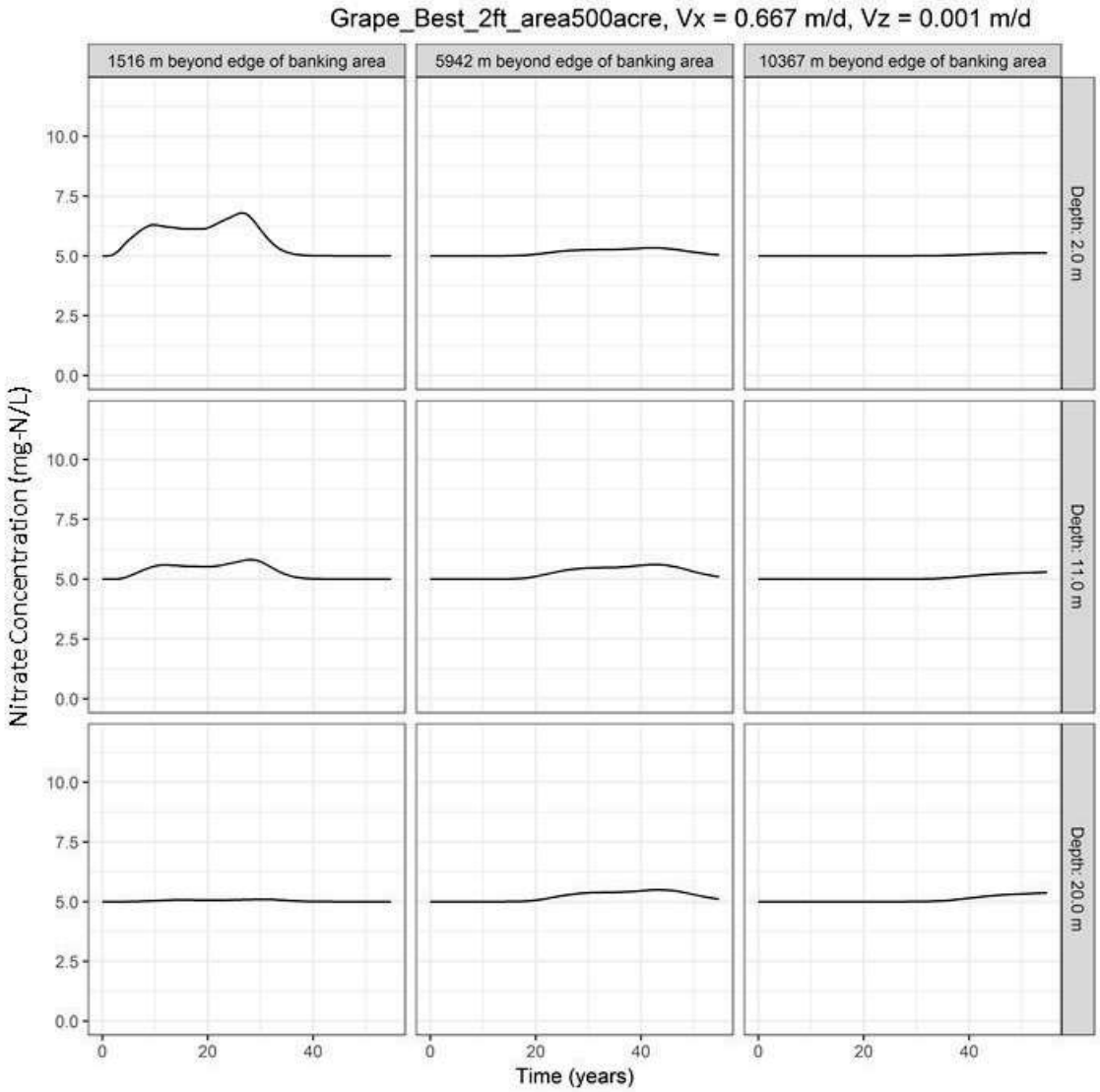
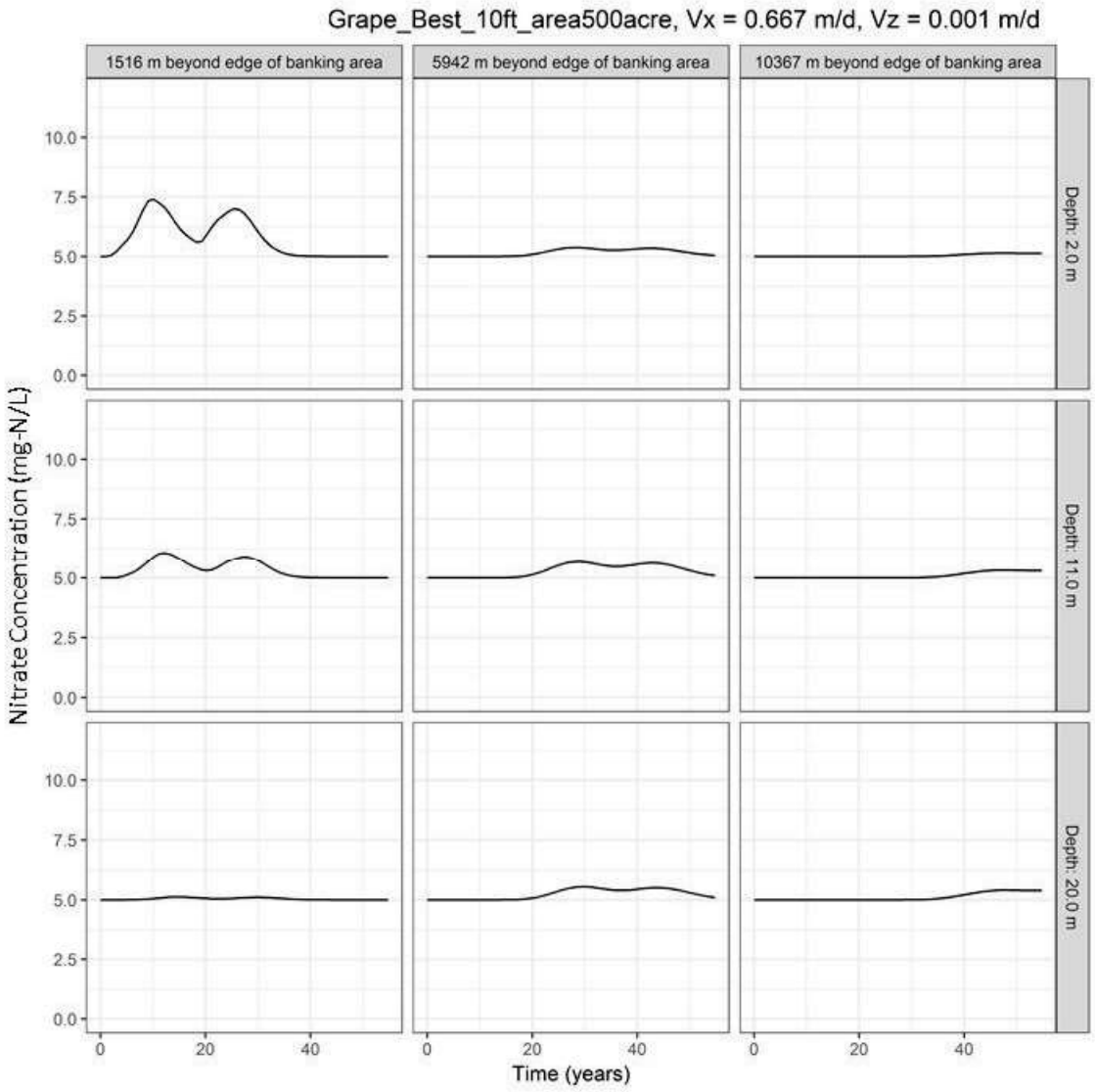


Figure 11. Changes in groundwater nitrate concentrations under higher OFFCR rates.
This example is representative of higher recharge rates (10-ft recharge per recharge year) across 500 acres for groundwater velocities in the range typical for the Tulare Lake Hydrologic Region (Vx = 2 ft/d, Vz = 0.003 ft/d). Locations represent observation points downstream of the OFFCR area (2000, 6000, 10,000 m; approximately 1, 4 and 6 miles) at depths of 2, 11 and 20 m (6.5, 36 and 66 ft) below the groundwater/ vadose zone interface. Groundwater quality effects are most noticeable near the OFFCR area at the first-encountered groundwater, or near where the groundwater/vadose zone interface occurs. The magnitude of the effects decrease with distance from the OFFCR area, with the depth of groundwater sampled, and over time. Ambient groundwater concentration are defined here as 5 mg-N/L In this example, concentrations near the OFFCR location increase slightly more than under lower OFFCR levels but for the most part are very similar. This figure suggests that the amount of recharge water is not the main driver for groundwater quality impacts but also the flushing of legacy constituents from the vadose zone as well as ongoing fertilization cultural practices.



PRACTICES THAT MINIMIZE NITRATE LEACHING ASSOCIATED WITH ON-FARM RECHARGE

*Prepared by **Daniel S. Munk** – Farm Advisor – Irrigation, Soils and Cotton, University of California Cooperative Extension, Fresno, California in partnership with **Sustainable Conservation** for Specialty Crop Block Grant project "Nitrate Leaching Risk from Specialty Crop Fields During On-Farm Managed Floodwater Recharge in the Kings Groundwater Basin".* *This project was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.*

California growers and irrigation authorities are increasingly turning to a combination of dedicated storage and on-farm recharge methods to percolate excess surface water into local groundwater systems. Storing excess surface water, when available, serves dual purposes including the recharge of over-drafted groundwater aquifers and the potential for improvement of groundwater quality. The total land area of dedicated groundwater storage facilities has recently grown to deal with the ever-increasing water demand by environmental, municipal and agricultural uses as well as in response to recent drought conditions in the State. Disadvantages of dedicated recharge facilities include the capital expenses required to develop the infrastructure, the on-going management and maintenance costs and the lost productivity of irrigated lands that are often the target of land conversion. These costs are among the principle reasons agricultural leaders are looking increasingly to on-farm recharge as a method to improve groundwater resource conditions. One of the chief concerns related to on-farm storage is the likely leaching of additional nutrients to groundwater systems and their impact on drinking water quality.

Nitrogen, especially in the nitrate form is particularly abundant in the crop root zone and is the chief nutrient applied by growers to maximize crop yield and quality. Nitrate is also very mobile in soil systems and readily moves with irrigation water. Irrigation water movement that percolates below the root zone is the chief mechanism for the transfer of nitrates to groundwater systems and can lead to maximum contaminant level exceedances established for drinking water. To minimize the movement of nitrates into local groundwater during recharge events, practices can be established that minimize the movement of nutrients and particularly nitrates into groundwater supplies while maintaining highly productive agricultural systems. Improved nitrogen management practices must also consider the timing of applied recharge waters in order to minimize the potential for nitrate leaching as well as the impacts on crop performance.

However, no single farm management practice should be considered as a primary means to limit nitrate movement to groundwater, rather a combination of practices can be incorporated into farm management plans that provide the grower the flexibility to adopt the series of practices that conform to the local farming system. The purpose of describing these practices is to identify a list of grower practices that have been field tested and can be considered in reducing the total amount of nitrogen available for leaching from the crop root zone or that have an impact on improving groundwater quality through on-farm recharge activities. And while this is not an attempt to report all potential practices that can be applied, it is intended to provide guidance on practical approaches to improve groundwater quality and quantity. The order in which the

management practices are presented does not imply their priority to be applied, nor should they be considered the only practices that can provide protection to groundwater systems. Local site soil and water conditions, available farm resources and the economics of water recharge will help establish the priority and strategy to be used if on-farm storage is to be considered.

Practice 1. ***Incorporate a seasonal nitrogen management plan approach during all years similar to the plan adopted by the Central Valley Regional Water Quality Control Board***

The Central Valley Regional Water Quality Control Board approved Nitrogen Management Plan is aimed at limiting the amount of nitrate movement to groundwater and provides a means to document individual activities that influence nitrogen balance in the field. This approach works to develop a nitrogen management budget that estimates the total quantity of nitrogen available to the crop. The total amount of nitrogen taken up by the crop and is balanced with the total amount of nitrogen removed at harvest. By following this approach, the remaining nitrogen is understood to be either stored in the crop root zone and available for future crop uptake or has the potential to be leached. This field nitrogen balance estimate assumes that gaseous nitrogen losses to denitrification and volatilization are minor as well as nitrogen that is lost to off-site runoff. Adherence to an in-season nitrogen balance approach can have a significant impact on the systems vulnerability to nitrate leaching since it reduces the quantity of residual soil nitrogen present at the end of the season.

Developing nitrogen balances on a field-by-field basis allows growers to construct estimates of residual soil nitrate as well as organic nitrogen sources including the nitrogen available from crop residues, organic amendments, and background soil organic matter that will be available to the crop during the season. Additionally, there are many cases in which irrigation water contains significant quantities of nitrate and an attempt should be made to quantify this potential source and include it in a nitrogen budget. These combined sources of nitrogen make up the estimate for the supply side of the nitrogen balance which must be weighed with the crop nitrogen requirements before developing a nitrogen fertilizer recommendation. Through this planning process, an initial assessment of crop nitrogen needs can be made early in the season based on anticipated crop yield. Later in the season additional information can be weighed including additional soil nitrate testing and plant tissue testing intended to reevaluate the need for additional or reduced in-season nitrogen fertilizer inputs should established guidelines warrant that change.

Once a good estimate of in-season plant available nitrogen has been made, the estimation of crop nitrogen uptake will aid in identifying any nitrogen balance deficiencies and a valid fertilizer recommendation can be made. Fortunately, good information exists on crop nitrogen uptake by many of the key crops grown in the State and nitrogen uptake as well as nitrogen removal at harvest can be reasonably estimated providing additional nitrogen balance information.

Practice 2. ***In-season water management practices***

Beyond the nitrogen budgeting approaches described in practice 1., additional in-season considerations embraced by the Central Valley water quality coalitions work to limit the movement of nitrate below the root zone and are consistent with supporting high nitrogen use efficiency. The inclusion of specific water management practices that limit the amount of leaching that occurs during the year further limits the need to apply additional late and post-

season fertilizers to the land. The wide variety of water management practices that work to improve distribution uniformity as well as application efficiency are particularly appropriate for use in on-farm recharge systems. Some of these water management practices support proper initial irrigation system design including the selection of an appropriate method for irrigation.

Sites that are often good candidates for on-farm recharge can be poor sites for using surface irrigation and conversion to pressurized systems including sprinklers and micro-irrigation often offer the gains in irrigation system efficiency desired. Proper design, operation and maintenance of pressurized systems will support the uniformity and efficiency objectives most important for in-season water management. It should also be noted that removing surface water delivery infrastructure severely limits the sites capacity for conducting recharge activities. Dual purpose irrigation systems can be highly effective in managing in-season applied water where high efficiency is a desired goal in contrast to the winter and spring recharge goals. The use of a high capacity surface irrigation systems allows water to be applied in a timely manner and increases the flexibility of how rapidly flood water can be used. Retaining high capacity irrigation systems in place can also be useful in supporting techniques such as alternate furrow or alternate check irrigation management which can be particularly useful in managing crop health and limiting crop damage during recharge activities.

Additional water management practices that limit the amount of water moving beyond the root zone include improved irrigation scheduling. The use of tools that provide estimates of crop evapotranspiration or stored soil moisture can be particularly useful in scheduling irrigation events. DWR's CIMIS program in combination with appropriate crop coefficients can improve irrigation scheduling while soil moisture sensors aid in managing soil water deficits during the season. Perhaps one of the most valuable tools that can be used in combination with other irrigation scheduling support systems is the flow meter. Regular tracking of field applied water can provide instantaneous feedback to water managers who wish to compare applied water with that intended for individual irrigation events and can be valuable when evaluating system deficiencies including changes in irrigation system efficiency.

Practice 3. *Post-season nitrogen evaluation*

Above and beyond using sound in-season nitrogen management practices to limit the amount of post-season soil nitrogen present in the root zone, growers can opt to conduct additional post-harvest sampling that confirms a reasonable in-season nitrogen balance was achieved. In the case of on-farm recharge, this sampling captures an estimate of potentially leachable nitrates during winter recharge events and should be tailored for the intended purpose.

While typical residual soil nitrogen sampling is conducted on the top foot or two of soil, growers may opt to more thoroughly evaluate to total leachable N by sampling at deeper levels of the soil surface. For this purpose, sampling nitrate concentration at each foot of soil to a depth 3 or 4 feet will provide a much better estimate of potentially leachable nitrogen. This sampling can also be conducted just prior to anticipated recharge events.

In some crops such as almonds, there can be a recommendation to apply nitrogen containing fertilizers following harvest. Use soil nitrate or plant tissue tests to confirm the need for post-

harvest nitrogen applications and limit those applications according to developed University of California guidelines.

Practice 4. *Eliminate or delay pre-plant and pre-season nitrogen applications*

It is becoming less common for growers to apply nitrogen fertilizers prior to the planting of annual crops or prior to bloom or leaf-out in permanent cropping systems. Increasingly, research has consistently shown that unless residual soil nitrate levels are extremely low, delayed applications of nitrogen fertilizers are likely not harmful to crop health and seldom lead to a reduction in yield with only a few exceptions. It is even more important in on-farm recharge sites to limit these early applications of nitrogen that might otherwise be leached below the root zone becoming unavailable for its intended purpose. This practice also supports practice #3 since sampling can be used to evaluate the soil nitrogen status prior to considering any early nitrogen fertilizer applications.

Practice 5. *Limited use of organic amendments*

Many growers use a variety of organic amendments during the season as a nutrient rich source of fertilizer intended to supplement or replace synthetic fertilizers. Further, these amendments can have the effect of improving soil health and improving soil properties such as increasing soil infiltration rate and soil water holding capacity. These applications are often made during the fall, winter or spring months to give time for the soil to break down the more complex nitrogen based organic compounds to be converted to crop available nitrogen by soil microorganisms.

The concern with using large amounts of organic soil amendments is linked to the fact that organic amendments are continuously being broken down through the mineralization process followed soon after by nitrification which converts mineralized nitrogen to the soluble and mobile nitrate form. These materials therefore are released during periods when nitrogen is not taken up by the plant and soil nitrate accumulation occurs. Limiting the use of organic amendments to those materials that have high carbon to nitrogen ratios and those that convert relatively high proportions of available nitrogen rapidly can increase early nitrogen uptake by the crop and limit rising soil nitrate concentrations during periods when leaching is more likely to occur. During times when recharge activities are uncertain, delaying or reducing the application of organic soil amendments can reduce N leaching potential.

Practice 6. *Consider crop type*

The potential list of crops that can conceivably be used for on-farm recharge is as numerous as the crops currently being grown in areas where surface water is available. Each crop or crop grouping is unique with respect to the magnitude and timing of crop nitrogen needs. Crop nitrogen uptake, utilization and harvested N characteristics are unique to each crop type and can be considered as a nitrogen management tool if the desired result is to limit nitrogen leaching to the groundwater. However not all crops can endure lengthy periods of water ponding and the limited oxygen levels that are associated with more extensive water ponding practices. There are also complex soil reactions and plant metabolic responses that occur in the root zone of flooded systems that can impact crop productivity and quality uniquely across the major crop types. Nitrate leaching potential also varies between crop types based on nitrogen requirements, uptake characteristics and cropping system flexibility.

Grapevines for instance have a much lower requirement for nitrogen than either processing tomatoes or almonds and are therefore less likely to have high levels of residual nitrogen present during the optimum window for recharge. Processing tomatoes on the other hand have a much higher nitrogen requirement but can have the added flexibility of delaying planting dates to accommodate the potential opportunity for on-farm recharge activities. Almonds also have a relatively high demand for nitrogen and have the added concern that there is relatively little known about the metabolic impacts to the crop during the physiologically active period between bloom and early fruit growth when recharge waters are most likely available.

Practice 7. *Select the right nitrogen fertilizer source*

Eliminating the use of nitrate containing fertilizers during the winter and spring months can delay and limit the movement of nitrogen with the irrigation water. When soil temperatures are low, the use of ammonium and urea containing fertilizers will delay the soils capacity to nitrify ammoniacal sources and limit the conversion to nitrate. Cool winter soil temperatures as well as flooding events with cold water can result in soil nitrogen fertilizer stabilization and limit nitrogen's mobility in the soil. Additionally, there are nitrification inhibitors, urease inhibitors and controlled release fertilizers that reduce the likelihood that soil nitrates will increase in instances when winter or early spring fertilizers are required. As part of a total in-season fertility program, the inclusion of foliar fertilizers can also provide flexibility in the timing and amount of soil or irrigation applied fertilizers.

Practice 8. *Use of cover crops*

The use of cover crops in irrigated farming systems can serve multiple roles including the improvement of soil physical characteristics, increased nutrient and water holding capacity and enhanced nutrient cycling. A less common role for incorporating cover crop use in cropping systems is the intentional uptake of residual soil nitrogen thereby reducing the amount of surface soil nitrate. Particularly if given an opportunity to establish high root densities in the soil profile, cover crops can essentially act as a sponge by taking up nitrates and immobilizing them in the cover crop plant tissues rendering this nitrogen temporarily unavailable. Leguminous cover crops are being used in many irrigated farming systems to not only enhance soil quality but also to act as a nitrogen source later in the season to supplement or replace synthetic fertilizer use.

Cover crops have also been used to increase infiltration rates in soils providing additional reasons why they might provide value to on-farm recharge activities. Cover crops can reduce the amount of energy imposed on the surface soil layer by irrigation water movement thereby stabilizing the soil surface and limiting the amount of surface aggregate dispersal that occurs during irrigation events. The dispersion of surface soil aggregates is largely responsible for the plugging of large soil pores responsible for the bulk of high infiltration rate soils and works to develop impenetrable soil crusts. Continuous use of cover crops also aid in increasing soil organic matter often associated with promoting high aggregate stability.

Practice 9. *Selecting soil type and infiltration rate capacity*

While reducing the amount of nitrogen in the soil profile through various means is thought to be a key principle in limiting nitrogen movement to the groundwater, the total volume of water that percolates through the soil system can also influence the amount and concentration of nitrate moving below the root zone. Though it can and has been argued that small differences in total

infiltrated water may have little impact on reducing nitrogen movement to groundwater, it has also been demonstrated that large differences in total applied water from high quality water sources can significantly reduce the concentration of nitrates to the point that groundwater quality in the local aquifer can be improved. Selecting sites that have high infiltration capacities and utilizing those sites for extended recharge periods can have a significant impact on the quality of water leaching below the root zone. The use of the soil agricultural groundwater banking index (SAGBI) https://casoilresource.lawr.ucdavis.edu/sagbi/ can be a useful tool in identifying sites that are most likely to experience high infiltration rate characteristics. This index uses five factors to evaluate a sites potential for groundwater recharge including its potential for deep percolation in addition to evaluating root zone residence time, surface soil topography, chemical limitations and surface soil condition.

References:

Dzurella, K., et al. 2012. Nitrogen source reduction to protect groundwater. Technical report 3. Report for the State Water Resources Control Board Report to the Legislature. University of California, Davis, Center for Watershed Sciences.

Sustainable Conservation

Specialty Crop Block Grant SCB14028: Nitrate Leaching Risk from Specialty Crop Fields During On-Farm Managed Floodwater Recharge in the Kings Groundwater Basin

OUTREACH PLAN

Objective

Development of a nitrate leaching risk model for Specialty Crops represents a significant advance in the ability to evaluate the spatial and temporal effect of on-farm managed floodwater recharge on groundwater quality. The model will allow for comparison of different recharge scenarios representative of conditions within the Central Valley and can inform water managers and regulatory decision makers. Publicizing the findings of this report and subsequent model runs through scientific papers and outreach to a variety of professional and industry audiences will establish credibility, build awareness, advance key pieces of the science, and accelerate the achievement of better water management outcomes through informed decision-making.

Peer Reviewed Scientific Papers

The project team (Bachand, P.A.M., S.M. Bachand, H. Waterhouse, J. Rath, M. Ung, V. Kretsinger, B. Dalgish, W. Horwath, H. Dahlke, C. Creamer, J. Choperena and S. Roy) is currently preparing a Technical Memorandum based on this project entitled *Modeling Nitrate Leaching Risk from Specialty Crop Fields During On-Farm Managed Floodwater Recharge in the Kings Groundwater Basin and the Potential for its Management*. The Technical Memorandum is funded through this and other grant projects and chapters will be submitted as individual peer reviewed manuscripts in late 2017.

Outreach Strategy

TIMING
Following completion of additional scenario runs in the nitrate leaching model, the project team will initiate contact with the following groups to present the findings, gain support, and promote on-farm recharge management strategies to minimize water quality impact and maximize groundwater replenishment.

- Present project results to Central Valley Regional Water Quality Control Board: September 2017
- Present management guidance recommendations to Irrigated Land Regulatory Program (ILRP) Management Practice Evaluation Program to ensure consistency with existing outreach and education strategies: Winter 2017-2018
- Present project findings to CV-SALTS to assure an overall benefit to the aquifer if on-farm recharge is practiced according to guidance from this study: Winter 2017-2018
- Introduce results to water districts/GSAs that are encouraging recharge on farmland: Fall 2017
- Submit conference proposals – as needed

MESSAGING

- Benefits of Groundwater Recharge
- Nitrate Leaching Modelling Results
- Nutrient Management and Recharge Method Guidance
- Measuring the Effects and Benefits on Water Quality

AUDIENCES

- Water Districts/GSAs
- DWR: SGMA implementation program
- SWRCB – Water Quality
- Councils of Governments (COG)
    - Fresno COG
    - Sacramento COG
- Industry Groups
    - Almond Board of California
    - California Association of Winegrape Growers
    - Fresh Fruit Associations
    - Farm Bureau
    - California Water Action Collaborative
    - Western Growers
- Professional Organizations
    - Association of California Water Agencies (ACWA)
    - Groundwater Resources Association of California
    - American Society of Agronomy
    - California Certified Crop Advisor Council
- Media

UC CE Sustainable Conservation

GUIDANCE IN ESTABLISHING ON-FARM RECHARGE SITES FOR GROUNDWATER BASINS

On-farm recharge is the practice of taking surface water supplies that are more transient in availability and applying these waters to actively farmed lands for the purpose of recharging groundwater systems. The practice of on-farm recharge is particularly useful in agricultural areas that rely on groundwater to provide a significant portion of the annual crop water needs and is a tool to achieve sustainable groundwater levels over time.

This guide is intended to provide support to growers, agencies and policy makers who are considering developing a successful on-farm recharge management program including operational elements, while addressing regional water quality needs.

Is the Field Suitable for On-farm Recharge?

Several factors will determine the suitability and priority of a site for on-farm recharge including:

- Local groundwater conditions – Is the sub-basin considered a regional priority and is recharge therefore being considered for funding and regional support? Reviewing GSA basin management plans can be an important part of this process and provides perspective on local site relevance.
- Access to recharge water – Does the site being considered have the required water delivery infrastructure as well as a way to adequately distribute water on the site? Access to water via canals, open ditches and river systems is crucial to securing necessary volumes of recharge water.
- Site recharge capacity – The site's capacity to transfer water from the surface to the groundwater is highly variable and depends on local surface soil infiltration characteristics as well as the capacity of subsurface strata to transmit infiltrated water. One tool for evaluating recharge potential is the Soil Agricultural Groundwater Banking Index (SAGBI). SAGBI recharge scores are focused on the top 6 feet of soil. LandIQ® is a recent development based on SAGBI, but provides additional details about deeper soil horizons. Mapping resources can be found online at http://earthgenomevm.cloudapp.net/GRATViewer/
- Soil and water quality of site, groundwater and surface supply – Not only does on-farm recharge help to increase groundwater storage and water available for future pumping, typically surface water supplies are lower in salinity, nitrates and other potential drinking water contaminants. Sites having relatively low levels of these contaminant stored in the surface soil or that have a high site recharge capacity are most likely to have a beneficial impact on aquifer water quality.

- Overall site suitability – Sites with the best potential for success have a high need for groundwater replenishment, have the necessary infrastructure in place to deliver and uniformly spread large volumes of water and have the soil infiltration and subsurface strata characteristics capable of transporting and storing large water volumes during limited surface water access periods such as flood events.

Crop Suitability and On-farm Recharge

Not all crops are equally suited for on-farm recharge. Crop type together with the timing of recharge should be considered when evaluating site suitability and farm economics. Although there is a significant lack of research trial information available on the impacts of crop type to periodic flooding, some anecdotal information is available from growers and the research community who have experience with extended periods of field ponding.

Annual Crops – Perhaps the best way for a crop to cope with extended periods of flooding is to delay or decide not to plant a crop as in the case of annual crops. Many annual crops have the flexibility of being planted later in the year or can be planted to an alternative crop depending on the timing of available surface water. Prioritizing annual cropping systems for recharge eliminates the potential for yield and quality crop impacts that can affect permanent crops over multiple years thereby limiting farm economic risk exposure. Crops such as cotton, tomatoes and many melon varieties can be planted later in the season (April and beyond) often with little or no impact on yield and quality.

Permanent Crops – The physiologic and economic impacts of extended or intermittent ponding on permanent crops is poorly understood and complicated by site factors such as time of year, climatic condition, crop stage, crop age, site infiltration rate as well as other factors.

- Alfalfa – Numerous observations have shown considerable crop resilience to extended periods of flooding particularly when ponding occurs after the first year of establishment.
- Grape vines – Growers have noted that vines are less sensitive to extended periods of in- season ponding. Optimum timing for flooding is thought to occur prior to bud break, however early and post bud break periods also show crop resilience to flooding. Limit flooding during berry sizing period and avoid ponding on hot days. Little information is known about ponding in table grapes and practices should be considered separately from wine, juice and raisin production systems.
- Almonds – The limited information available on almonds suggests that extended periods of ponding should be avoided where possible. However, practices such as alternate row irrigation and limited duration ponding may be practical for these systems. Particular caution has been expressed by university scientists that point to the potential for multiyear yield impacts.
- Peaches, nectarines, plums – Rootstocks, bloom and leaf-out periods are similar to almonds; similar cautions and concerns over extended period flooding have been raised. Significant nutrient and crop physiology differences between almonds and the stone fruit are noteworthy. Stone fruit nitrogen demands are much lower than in almonds and varietal differences between stone fruits suggest late-season varieties may be more suitable to periodic winter flooding.

Practices That Improve Site Suitability

Growers do have some control over site suitability through the farming practices they implement. Alternate furrow, row or check irrigation can extend the period of field flooding while limiting or eliminating impacts to crop yield and crop quality. Where hardpans or contrasting soil layers are present within the plow zone, deep ripping or slip plow operations can dramatically improve soil infiltration characteristics. The use of cover crops can similarly increase soil infiltration rates and can have the added benefit of taking up residual soil nitrogen at the end of the season. Soil amendments including gypsum, acids and organic materials can have positive effects on infiltration depending on site soil and water chemistry.

Site Fertility Management

In an effort to limit the degradation of groundwater resources, numerous practices can be incorporated to improve the nitrogen use efficiency of a farming system and limit nitrating leaching below the root zone.

- Develop a nitrogen management plan each year to minimize the chance for over fertilization which can lead to higher residual (leachable) soil nitrate levels.
- Maintain high water application efficiencies that limit in-season movement of nitrates.
- Consider collecting post-harvest soil nitrate tests to confirm farm nitrogen use is in balance.
- Eliminate or limit pre-plant and pre-season applications of synthetic fertilizer.
- Limit the use of organic amendments. There is of particular concern when high rates are used during the fall and winter months over multiple years making winter leaching of nitrates likely.
- Delay the application of organic amendments including composts and manures.
- Follow University guidelines to evaluate the rates and timing of nitrogen fertilizers.
- Where feasible, incorporate the use of slow-release fertilizers and consider the use of nitrification and urease inhibitors.

Summary

California agriculture is rapidly undergoing a change in how surface and groundwater are managed. The passage of the Sustainable Groundwater Management Act has facilitated a new urgency aimed at implementing on-farm practices that help address the issue of long-term groundwater overdraft. Accessing expertise from local agronomists, water agencies and advisors as well as guidance from University of California crop, nutrient and irrigation management materials can help identify the potential benefits of on-farm recharge and evaluate regional priorities for specific site development.

Prepared by **Daniel S. Munk** – Farm Advisor – Irrigation, Soils and Cotton, University of California Cooperative Extension, Fresno, California in partnership with **Sustainable Conservation** for Specialty Crop Block Grant project "Nitrate Leaching Risk from Specialty Crop Fields During On-Farm Managed Floodwater Recharge in the Kings Groundwater Basin". This project was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

Specialty Crop Block Grant SCB14028: Nitrate Leaching Risk from Specialty Crop Fields During On-Farm Managed Floodwater Recharge in the Kings Groundwater Basin

WORKSHOP

Sustainable Conservation organized the Specialty Crop Nitrogen Management Workshop. It was held on June 14, 2017 at the Terranova Ranch, California.

Out of 155 invited guests, 58 attended the workshop. The attendees fall into the following broad categories:

- 12 growers
- 12 representatives from the crop industry
- 11 government representatives
- 6 water managers
- 3 consultants/agronomists
- 2 agribusiness lenders
- 1 agribusiness real estate investor
- 5 Sustainable Conservation staff
- 6 speakers/project partners

Below is a copy of the invitation. The sign-in sheet is available upon request.

Capturing Excess Water for the Future

June 14 Workshop @ Terranova Ranch



Dear <<First Name>>,

After 5 years of drought, we find ourselves with abundant surface water in much of California. This spring we have heard many people asking: ***Why aren't we capturing the excess waters to meet our future needs?***

Sustainable Conservation has been working with our partners this spring to demonstrate and evaluate how farmers can divert floodwaters affordably and safely onto specialty crop farmland to recharge our depleted aquifers. This approach may be able to significantly increase groundwater replenishment in wet years when combined with recharge infrastructure such as unlined canals and dedicated basins. By maximizing recharge in wet years, farmers, communities, and the environment will be better prepared for future droughts.

Please join us for a grower and industry workshop to hear and see the latest on the science, policy, and practice of on-farm recharge.

On-Farm Recharge Workshop @ Terranova Ranch
16729 W. Floral Ave. | Helm, CA 93627
Wednesday June 14, 2017
10:00 am – Noon
Lunch and field tour following the workshop
12:00 – 2:00 pm

RSVP by June 9: Danielle Duncan at dduncan@suscon.org or 209.408.0612

The workshop will focus on how farmers and irrigation districts can use active and fallow farmland to increase groundwater recharge while avoiding crop health problems, nutrient leaching, or disruption of annual farm operations. Speakers include:

- Don Cameron, Terranova Ranch: 2017 on-farm recharge practices and achievements
- Phil Bachand, Bachand & Associates: Nutrient leaching and on-farm recharge model results for specialty crops
- Dan Munk, UC Cooperative Extension: Nutrient management practices for on-farm recharge
- Matt Efird: grower experience on almonds and grapes
- Madera and Tulare Irrigation Districts: ID perspectives on recharge strategies under SGMA
- Ken Shackel, UC Davis almond and alfalfa crop health studies

Project support and partnership for this event provided by:

Almond Board of California
Bank of America Foundation
Bonneville Environmental Foundation
California Department of Agriculture
Specialty Block Grant Program
California Department of Water Resources
California Water Foundation
Coca-Cola North America
Madera Irrigation District
Miller-Coors
Terranova Ranch, Inc.
Tulare Irrigation District
University of California
Cooperative Extension
University of California, Davis
Wells Fargo Foundation

RSVP by June 9: Danielle Duncan at dduncan@suscon.org or 209.408.0612

Sustainable Conservation

Specialty Crop Block Grant SCB14028: Nitrate Leaching Risk from Specialty Crop Fields During On-Farm Managed Floodwater Recharge in the Kings Groundwater Basin

SURVEY RESULTS

Sustainable Conservation conducted two surveys of grower receptivity, one before the Specialty Crop Nitrogen Management Workshop on June 14, 2017, and one after the workshop (referred to as pre- and post-workshop surveys). The pre- and post-workshop survey forms we used are shown below.

A comparison of grower receptivity from pre- and post-workshop surveys shows the following results:

Respondents:

- **Number of people that signed in at workshop (excluding project team and presenters):** 45
- **Number of people that completed surveys (excluding project team and presenters):** 39 (87% of attendees)
- **Number of people that indicated having responsibility for farming**: 30 (77% of survey respondents)

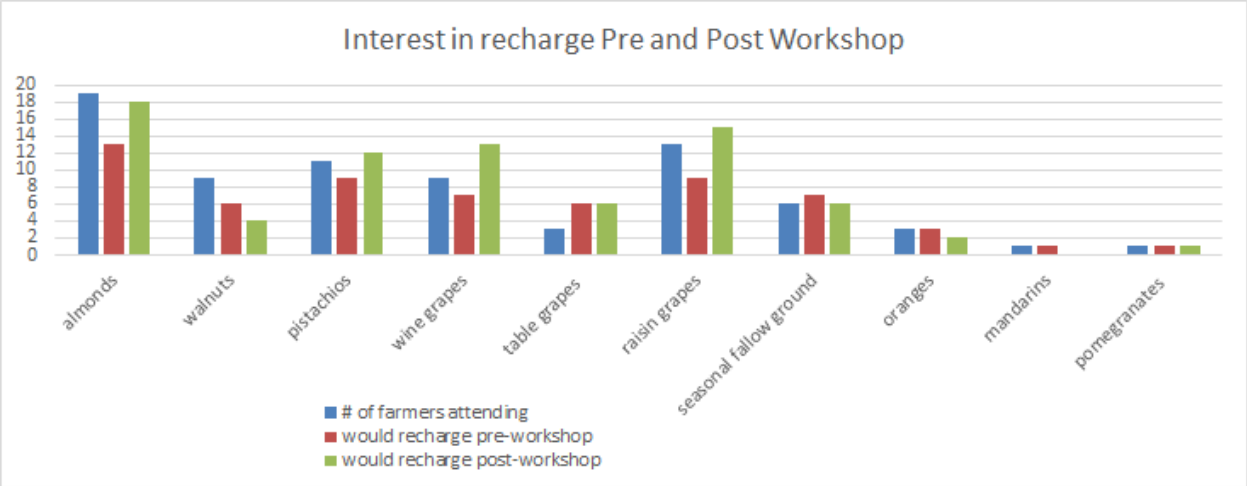
Survey Responses:

1. **Has an attendee ever applied <u>more</u> surface irrigation water than their crop needs to help with groundwater recharge?** 15 farmers replied yes (50% of farmers).

2. **How likely was the attendee to apply more water that your crop needs to help with groundwater recharge**? On average, there was a high likelihood of applying water for recharge pre-workshop (4.2 on a 5 point Likert scale) and this remained the same after the workshop.

3. **Number of farmers that indicated that they would recharge some cropland:** 19 (63% of farmers) indicated they would recharge at least one crop <u>before</u> the workshop and 28 (93% of farmers) would <u>after</u> the workshop. This is a 47% increase in interest as a result of the workshop.

   The change in the number of farmers that would do recharge varied by crop. Farmers of almonds, pistachios, wine grapes and raisin grapes all indicated an increase in willingness to practice recharge after the workshop (see figure below). The willingness of farmers of table grapes, oranges, mandarins and pomegranates did not change as a result of the workshop. The number of walnut farmers interested in recharge declined as a result of the workshop due to discussion of potential walnut Phytophthora with excess water.



4. **How concerned is an attendee about increased groundwater leaching of fertilizers or nutrients they had applied <u>in the last 12 months</u> if they were to apply excess water for recharge?** On average, attendees before the workshop were neither concerned or unconcerned with leaching (3.2 on a 5 point Likert Scale) and only slightly less concerned (3.1) after the workshop for a 3% reduction in concern from pre- to post-workshop about leaching current year nutrients.

5. **How concerned is an attendee about leaching <u>historically accumulated</u> fertilizers/nutrients from the sub-soil to groundwater if they were to apply excess water for recharge?** On average, attendees before the workshop were only slightly concerned with leaching (3.3 on a 5 point Likert Scale) and only slightly less concerned (3.1) after the workshop for a 5% reduction in concern from pre- to post-workshop about leaching legacy nutrients.

6. **How satisfied are attendees with the information they currently have to make decisions about participating in groundwater recharge on their agricultural lands?** On average, attendees before the workshop were slightly dissatisfied with available information (2.8 on a 5 point Likert Scale) but were significantly more satisfied (3.7) after the workshop for a 34% increase in level of satisfaction with having needed information from pre- to post-workshop.

7. **How likely were the attendees to change their nutrient management practices because of what they heard during the workshop?** On average, attendees reported that they are somewhat likely (3.6 on 5 point Likert Scale) to change their management practices.

8. **Specific concerns and uncertainties that should be addressed**: In the final section of the survey, attendees could free-write the concerns or uncertainties they have, and want to see addressed before practicing recharge on their agricultural land. The concerns were grouped into five categories:

Concern	# Concerned Pre-workshop	# Concerned Post-workshop
Water access	7	2
Crop health effects	9	7
Nitrogen management/leaching	8	6
Cultural practices and timing	2	1
Economic impact and credit	4	0

Other write-in issues to address included uncertainty about site suitability, role of the county, and public perception of wasting water.

Pre-workshop Survey Questions

Please complete this side of the sheet before the workshop starts

1. Have you ever applied <u>more</u> surface irrigation water than your crop needs to help with groundwater recharge?	Yes ☐ No ☐
2. How likely are you to apply <u>more</u> water than your crop needs to help with groundwater recharge?	Unlikely <----------> Likely 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
3. Of the following crops please check those that you farm and those on which you would be willing to apply excess water for recharge?	I farm this crop / I would do recharge on this crop
Almonds	☐ ☐
Walnuts	☐ ☐
Pistachios	☐ ☐
Wine grapes	☐ ☐
Table grapes	☐ ☐
Raisin grapes	☐ ☐
Seasonal fallow ground	☐ ☐
Other – please specify:	☐ ☐
4. How concerned are you about increased groundwater leaching of fertilizers or nutrients you have applied <u>in the last 12 months</u> if you were to apply excess water for recharge?	Not Concerned <----------> Very Concerned 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
5. How concerned are you about leaching <u>historically accumulated</u> fertilizers/nutrients from the sub-soil to groundwater if you were to apply excess water for recharge?	Not Concerned <----------> Very Concerned 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
6. How satisfied are you with the information you currently have to make decisions about participating in groundwater recharge on your agricultural lands?	Not Satisfied <----------> Very Satisfied 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
7. What are your biggest concerns or uncertainties about participating in groundwater recharge on your agricultural lands?	

Post-workshop Survey Questions

Please complete this side of the sheet after the workshop and turn in for a lunch ticket

1. How likely are you to apply <u>more</u> water than your crop needs to help with groundwater recharge?	Unlikely <----------->Likely 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
1. Of the following crops please check those on which you would be willing to apply excess water for recharge?	I would do recharge on this crop
Almonds	☐
Walnuts	☐
Pistachios	☐
Wine grapes	☐
Table grapes	☐
Raisin grapes	☐
Seasonal fallow ground	☐
Other – please specify:	☐
	☐
2. How concerned are you about increased groundwater leaching of fertilizers or nutrients you have applied <u>in the last 12 months</u> if you were to apply excess water for recharge?	Not Concerned <----------> Very Concerned 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
3. How concerned are you about leaching <u>historically accumulated</u> fertilizers/nutrients from the sub-soil to groundwater if you were to apply excess water for recharge?	Not Concerned <----------> Very Concerned 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
4. How likely are you to change your nutrient management practices because of what you have heard today?	Unlikely <----------->Likely 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
5. How satisfied are you with the information you currently have to make decisions about participating in groundwater recharge on your agricultural lands?	Not Satisfied <----------> Very Satisfied 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
6. What are the most important issues you want to see addressed before you participate further in groundwater recharge on your agricultural lands?	

5

Sustainable Conservation

Specialty Crop Block Grant SCB14028: Nitrate Leaching Risk from Specialty Crop Fields During On-Farm Managed Floodwater Recharge in the Kings Groundwater Basin

CONFERENCE PRESENTATIONS

Sustainable Conservation and project partners gave the following four presentations that included discussion of management to minimize nitrate leaching:

Daniel Mountjoy, Sustainable Conservation, "On-Farm Recharge: Acceptance and Use by Farmers and Water Managers in the San Joaquin Valley, California", International Groundwater Conference, 2016.

Daniel Mountjoy, Sustainable Conservation, "Optimizing Groundwater Recharge Using Farmland", Groundwater Resources Association of California, 2016.

Dan Munk, University of California, Agriculture and Natural Resources, "Nitrogen Management Practices and On-farm Recharge", Specialty Crop Nitrogen Management Workshop, 2017.

Philip Bachand, Bachand & Associates, "Local On-farm Flood Capture and Recharge Opportunities and Challenges", Specialty Crop Nitrogen Management Workshop, 2017.

The presentations follow in the order listed above.

PRESENTATION 1

Daniel Mountjoy, Sustainable Conservation, “On-Farm Recharge: Acceptance and Use by Farmers and Water Managers in the San Joaquin Valley, California”, International Groundwater Conference, 2016.

On-Farm Recharge: Acceptance and Use by Farmers and Water Managers in the San Joaquin Valley, California

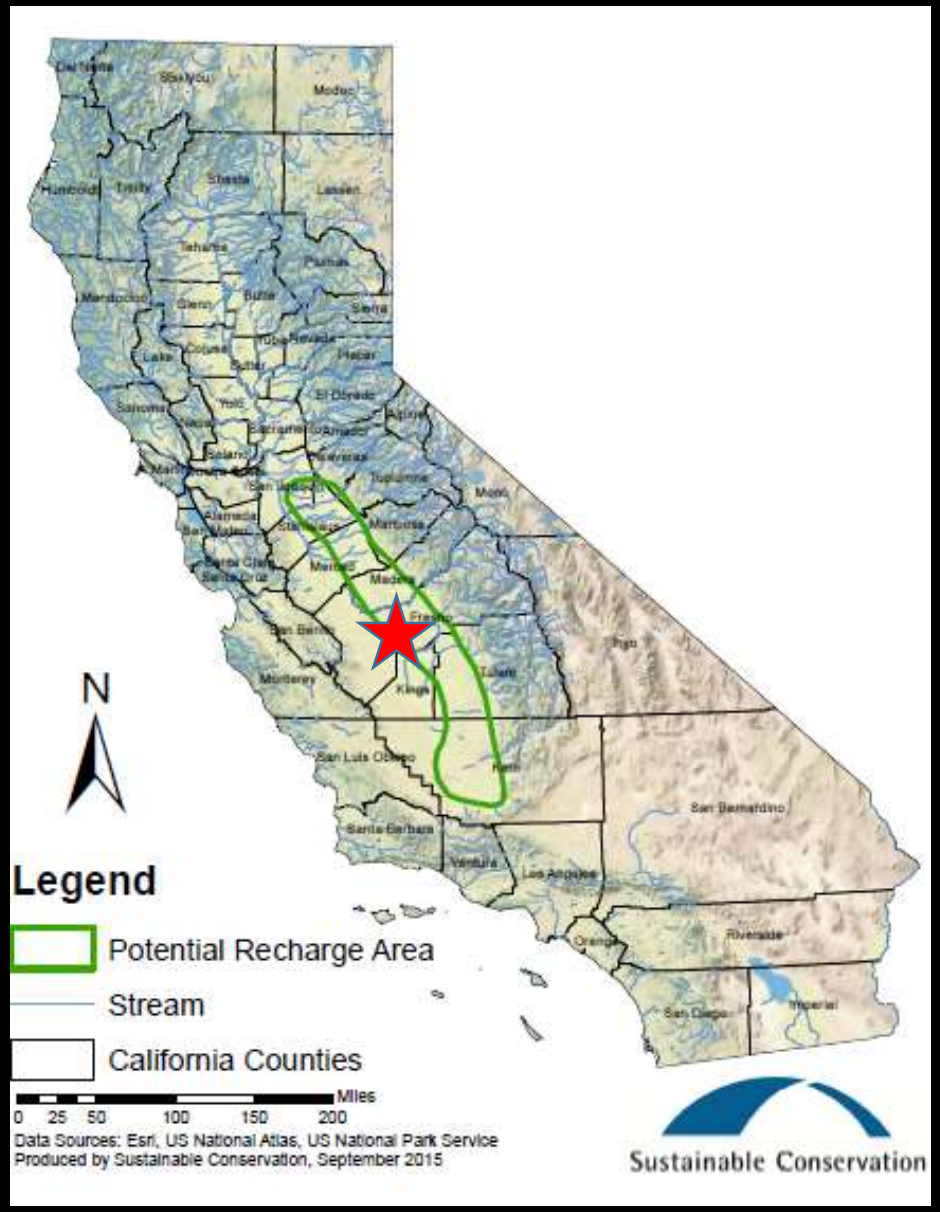
Daniel Mountjoy
Director of Resource Stewardship

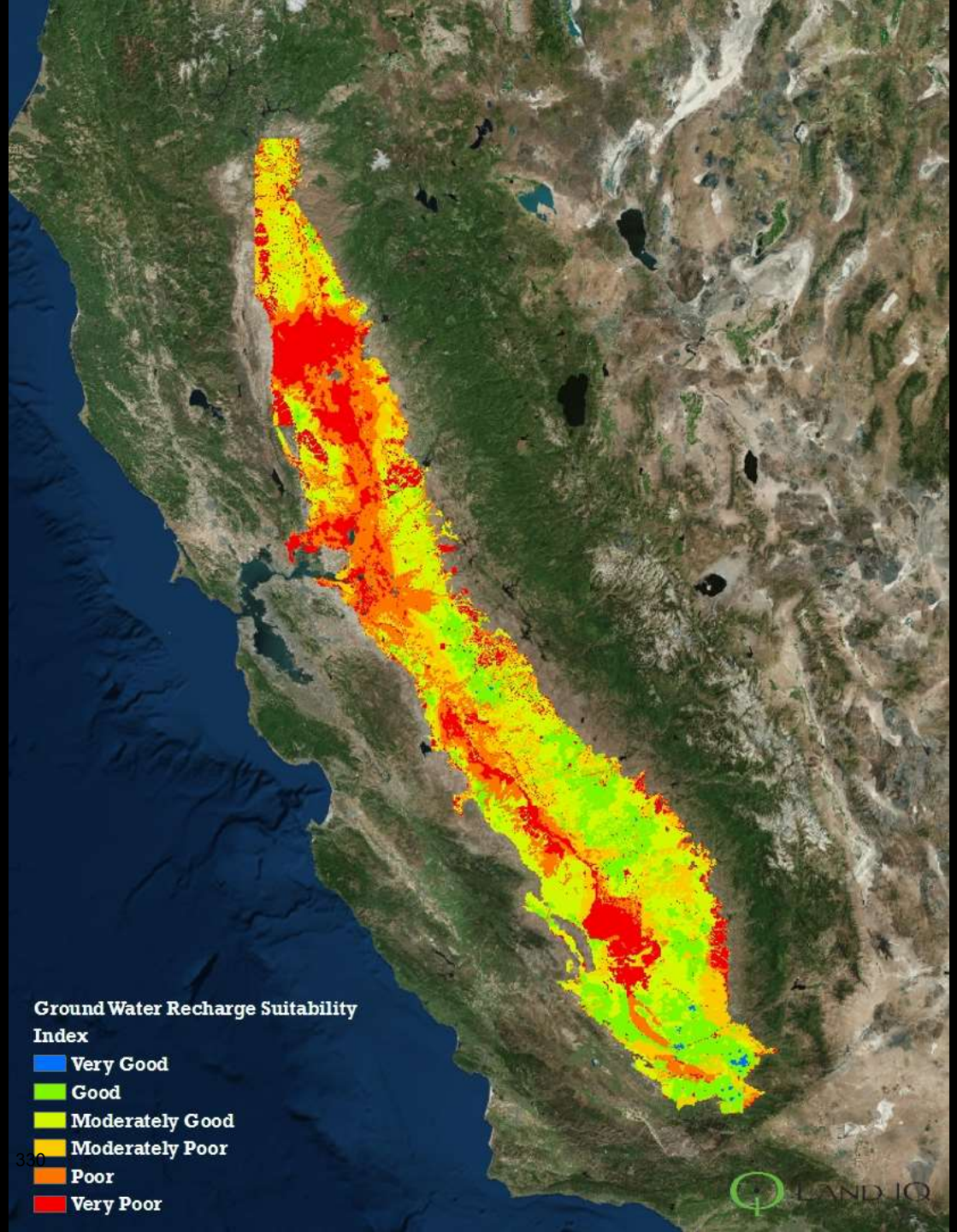
Sustainable Conservation



June 29, 2016 | International Groundwater Conference

Accelerated Groundwater Recharge Strategy Area





Terranova Ranch

Helm, CA



January/February 2011







SGMA Supply Side Options:
Recharge Basins



SGMA Supply Side Options:
Farmland Recharge



SGMA Supply Side Options:
Fallow Land Recharge



Cost Comparison of Recharge Options

on-farm



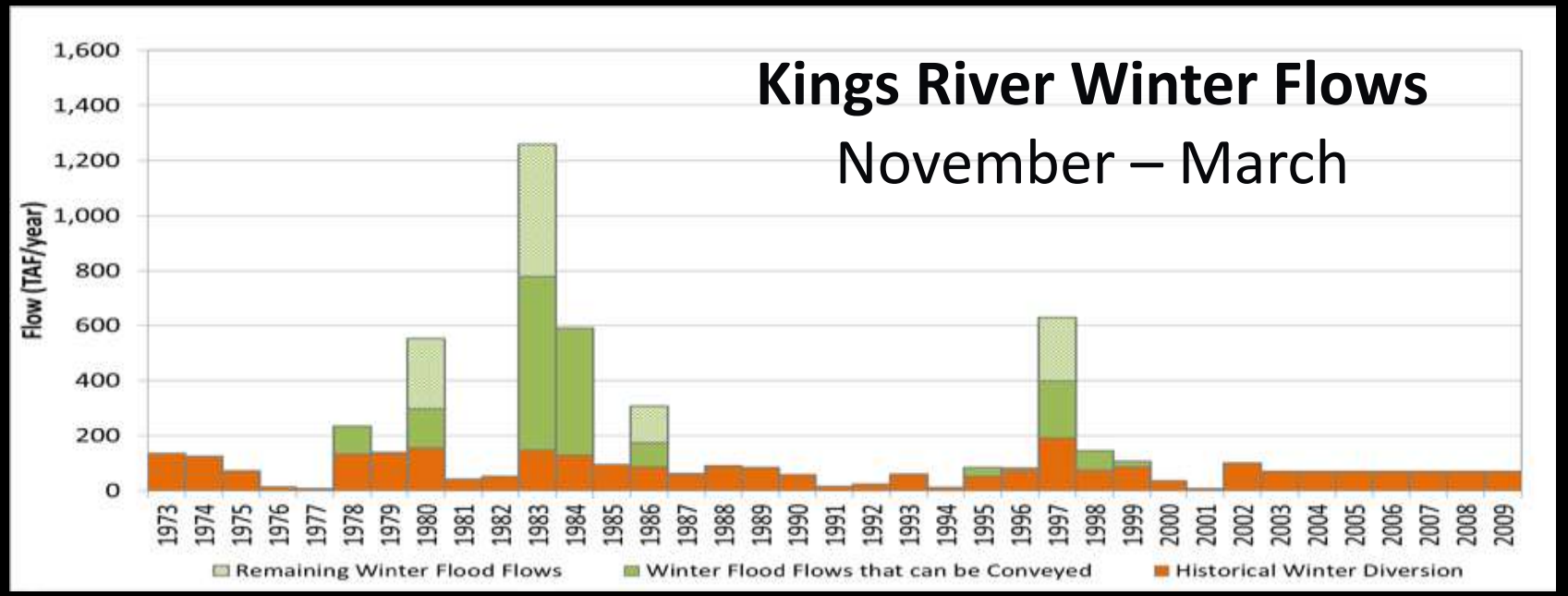
$40 - 107/AF

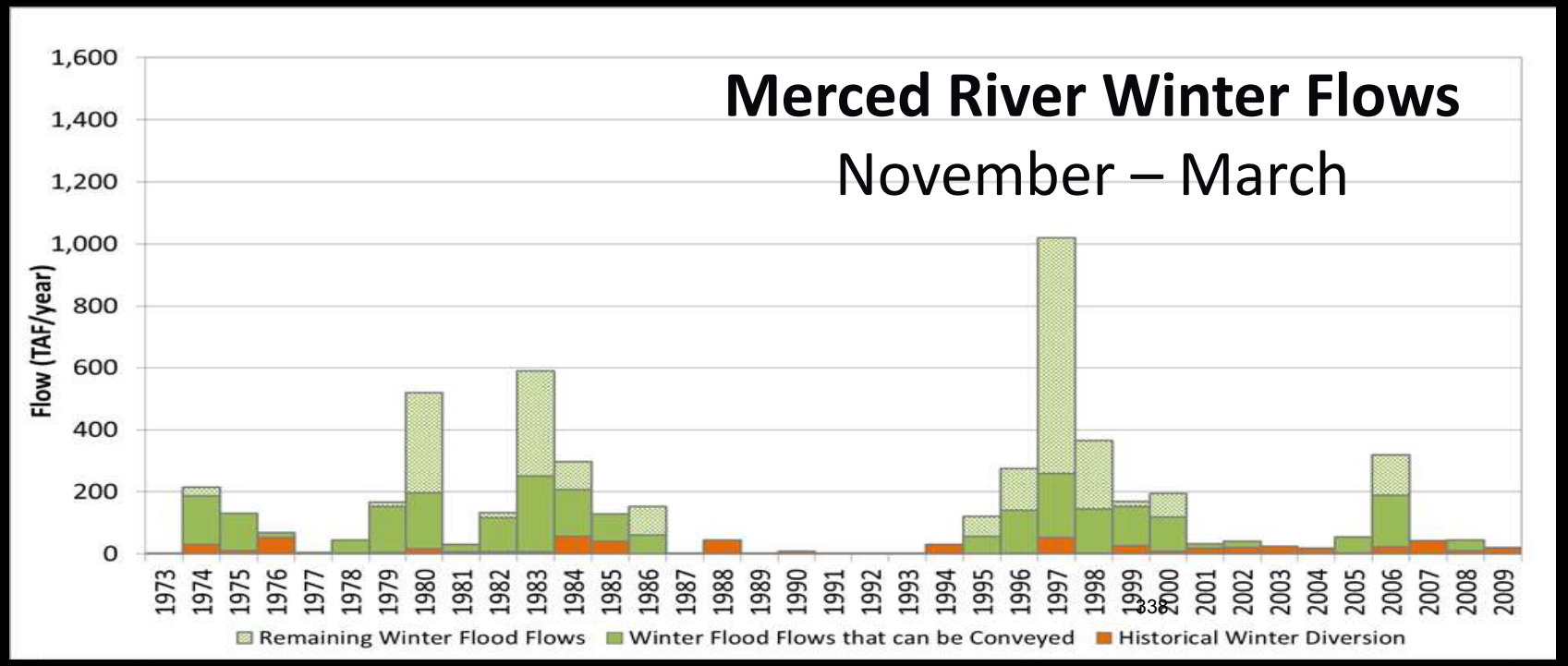
dedicated basin



$124/AF

(Capital and operating costs amortized over 20 years)





Available Flood Water Resources

- Current Winter Diversion
- Winter flood flows that can be conveyed
- Remaining winter flood flows

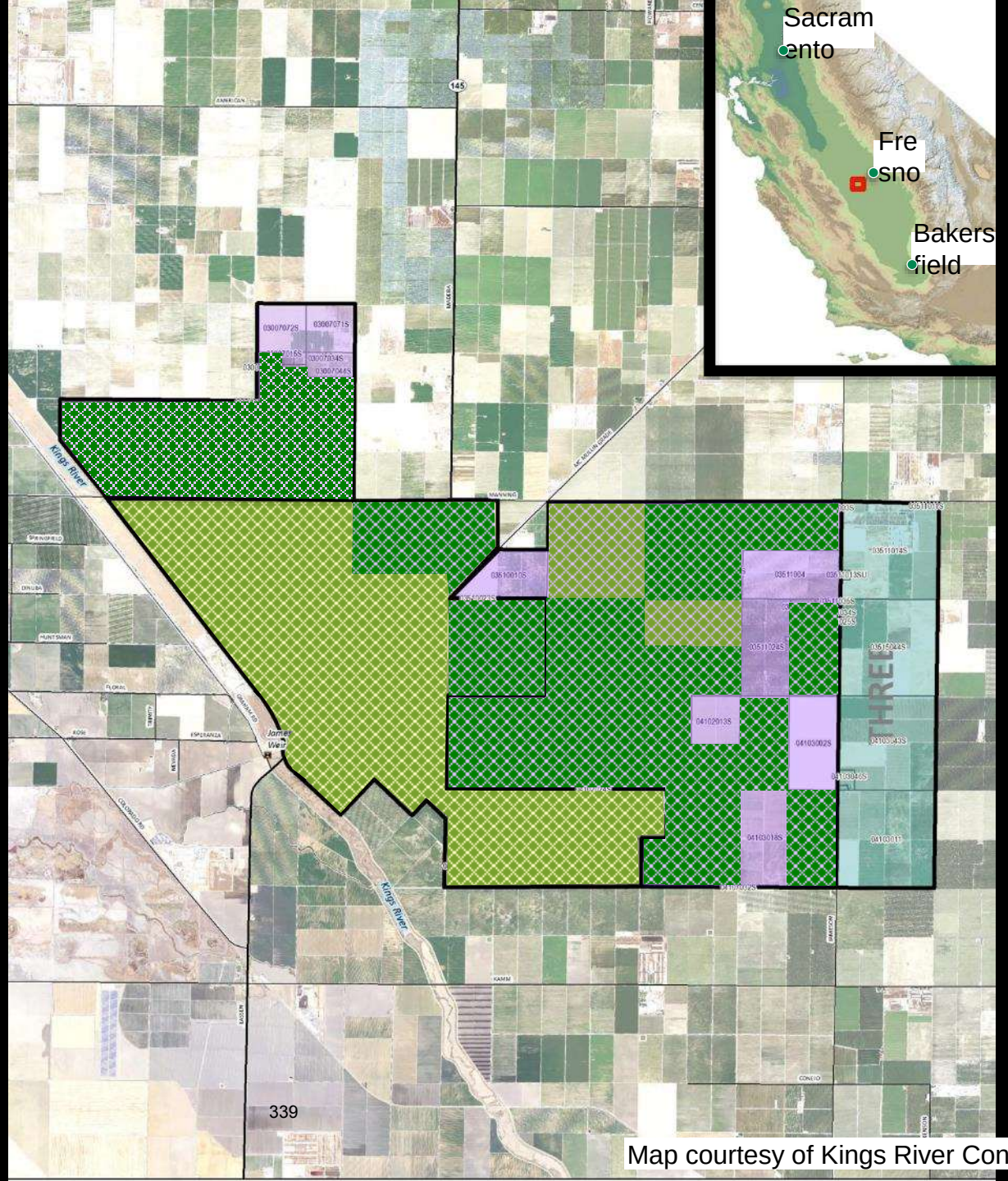
McMullin On-Farm Flood Capture and Recharge Project Grower Surveys











Map courtesy of Kings River Conservation District

McMullin Survey Summary of Findings

1. Control of amount and timing of water received

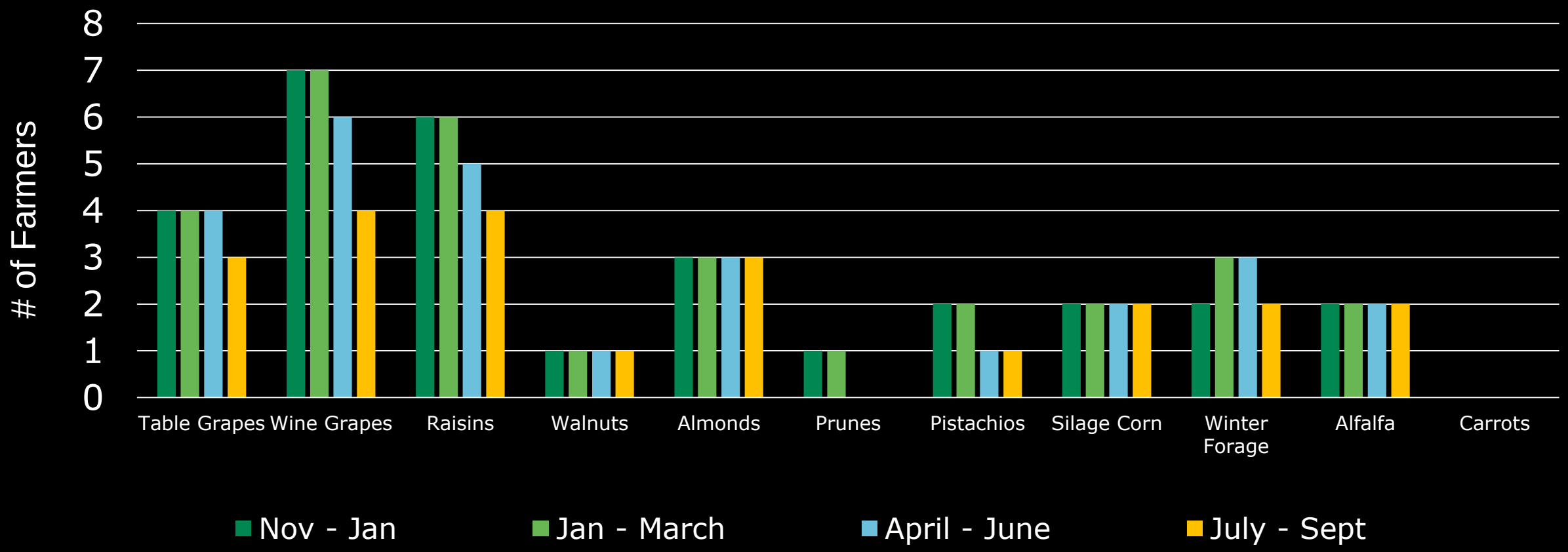




Control of amount, timing, and location of flood water use

MORE LIKELY TO PARTICIPATE IF YOU COULD:	YES	NO
Specify maximum amount of floodwater grower is willing to use per flood event?	12	0
Specify certain fields for recharge any time floodwater is available?	10	2
Specify the number of acres for recharge any time floodwater is available but retain choice of which fields?	9	3
Dedicate land as permanent recharge basin rather than flooding cropland?	0	12

Crop type and seasonality of recharge



Growers interviewed are willing to divert floodwater to their crops well into the summer.

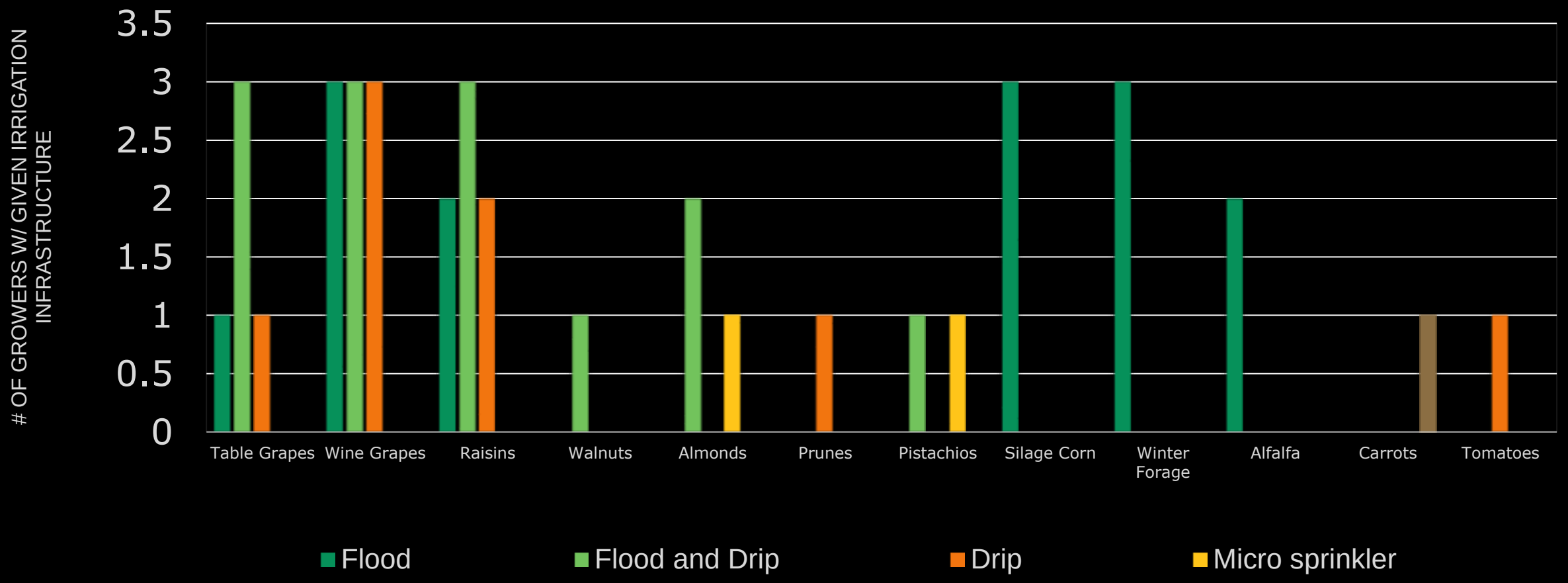
McMullin Survey Summary of Findings

1. Control of amount and timing of water received
2. Larger diversified farms have more flexibility to accept floodwater
3. Flood water delivery costs vary by District and source
4. Uncertain risk to crop yield and plant health
5. Lack of irrigation infrastructure





Crop type and irrigation infrastructure

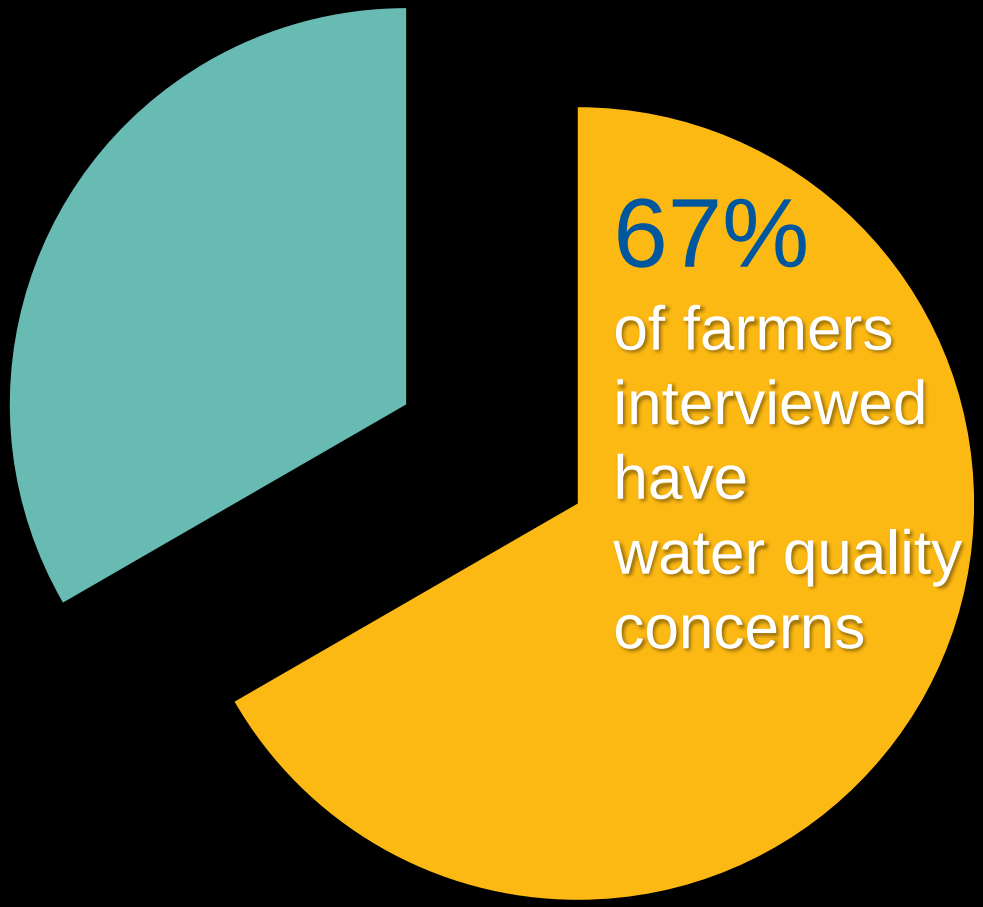


Most crops grown, and acreage represented, have existing irrigation infrastructure compatible for on-farm recharge but may require expanded capacity.

McMullin Survey Summary of Findings

1. Control of amount and timing of water received
2. Larger diversified farms have more flexibility to accept floodwater
3. Flood water delivery costs
4. Uncertain risk to crop yield and plant health
5. Lack of irrigation infrastructure
5. Ground water quality

Groundwater quality concerns




Grower Workshop
Partners
KRCD



GENERAL MILLS

Campbell's

Coca-Cola

OLAM

Nestlé

E&J. Gallo Winery

CALIFORNIA FRESH FRUIT ASSOCIATION



california almonds
Almond Board of California

Farmers

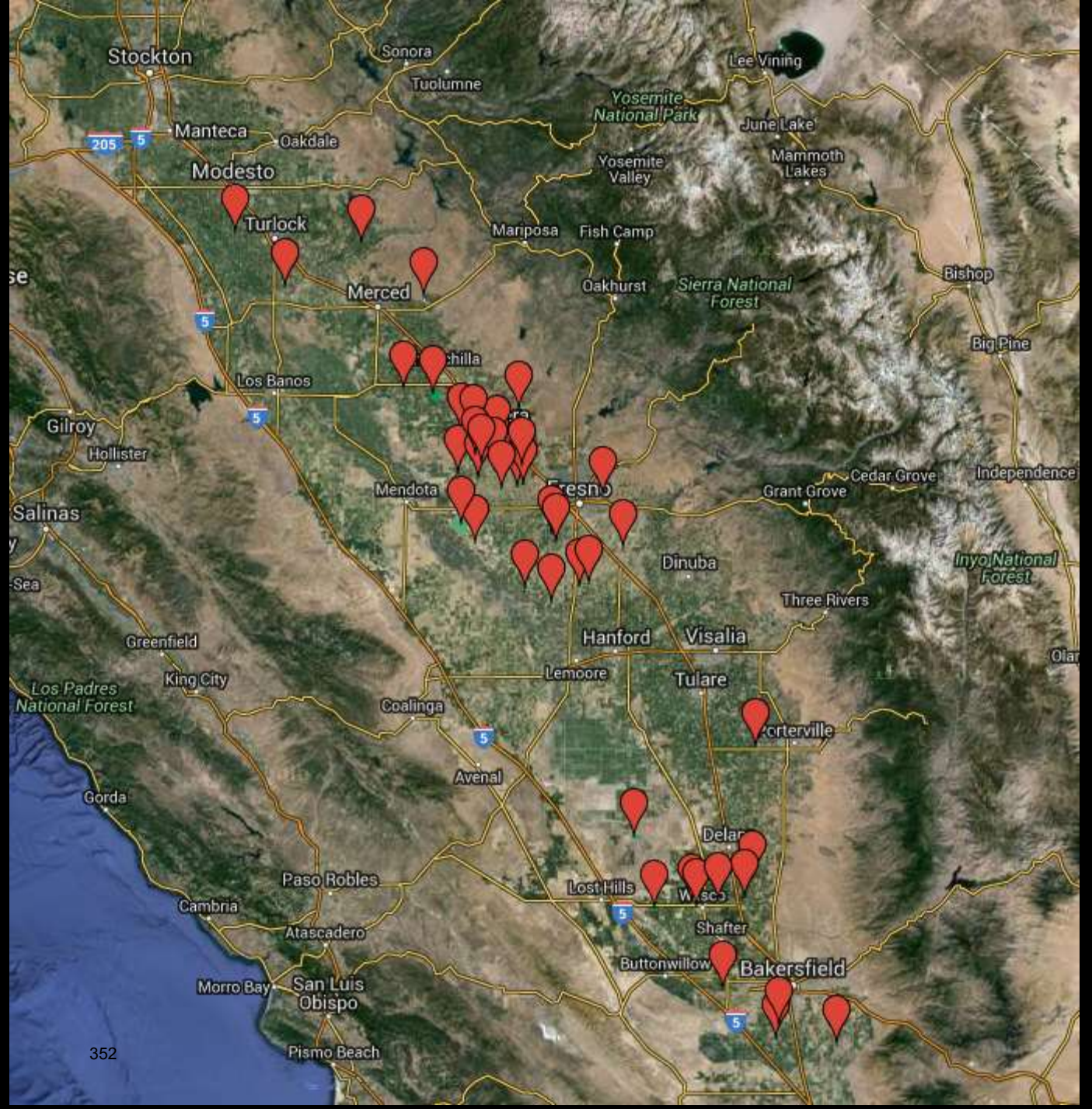
Irrigation Districts

Outreach to recruit growers interested in
Testing and Demonstrating on-farm recharge
in the San Joaquin Valley

Demonstration Sites 2015-16

- 131 sites
- 10 crops
- 14,723 acres

- Purpose: Assess constraints and measure water that can be applied in excess of crop demand

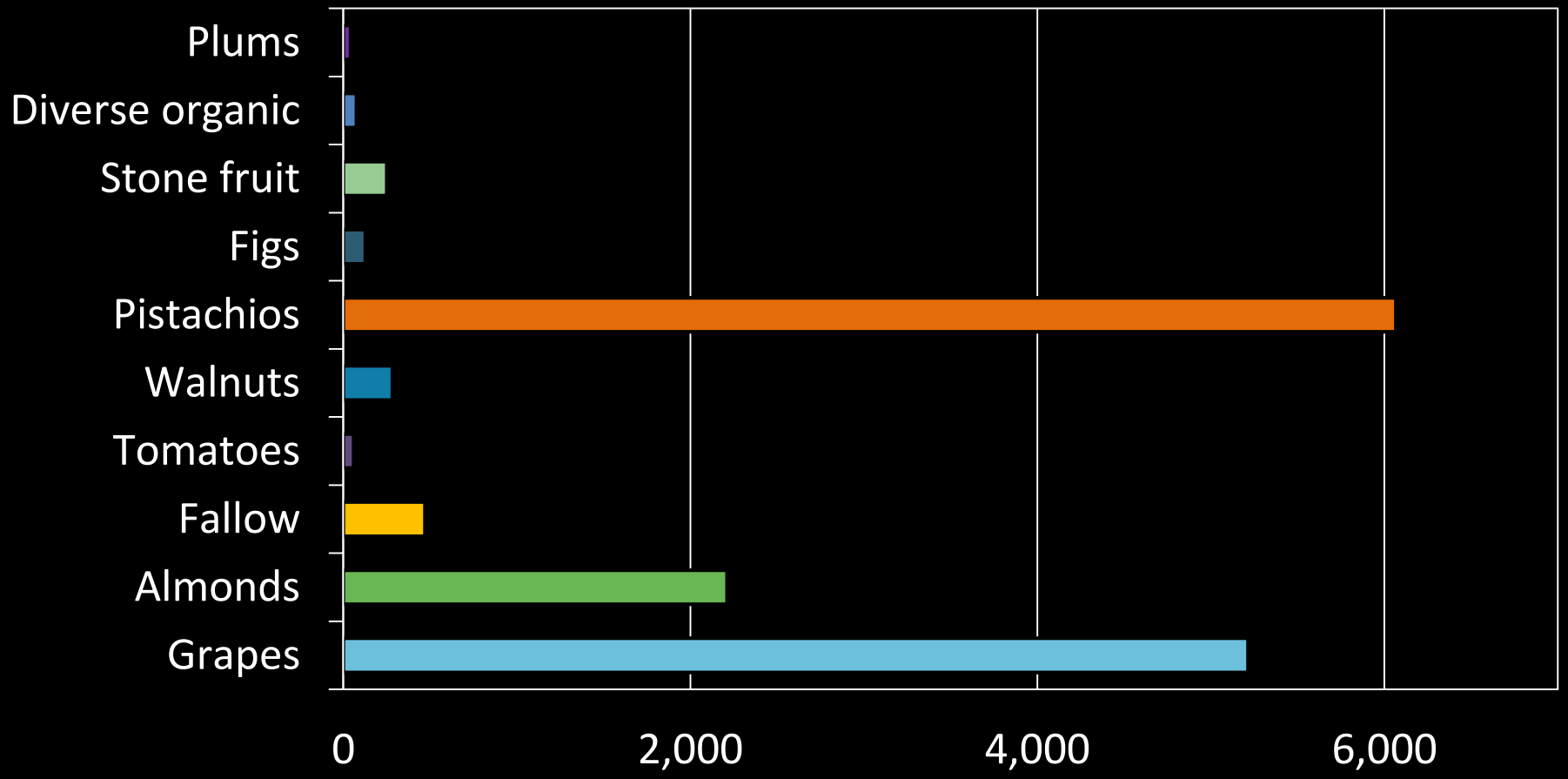


23

landowners, multiple sites

14,723

acres



Growers with on-farm recharge experience:

- On-farm recharge has been used on 27 of 131 fields (21%)

  Definition: application of water in excess of crop demand for purpose of recharge

  Crop Type:

  - 15 Almond sites
  - 8 Grape sites
  - 2 Row crop open ground sites
  - 1 Pistachio
  - 1 Walnut

Growers with on-farm recharge experience:

- On-farm recharge has been used on 27 of 131 fields (21%)
- Method of application: flood irrigation (3 sites used drip)
- Amount applied: 6” and repeat
- Fertilizer Management:
  - Most apply post harvest in October
  - Typically apply again in February – March
  - All agreed they could delay by 1 or 2 months

Recharge water application

Latest month farmer is willing to over-irrigate for recharge

	Feb-Mar	April-May	June-July
Almonds	● ● ● ●	● ●	● ●
Grapes	● ● ● ●		●
Pistachios		● ●	
Walnuts	●		●
Figs		●	
Row crops	●		●

Recharge water application

Latest month farmer is willing to over-irrigate for recharge

	Feb-Mar	April-May	June-July
Almonds	🟡🟡🟡🟡	🔵🔵	🔵🔵
Grapes	🟡🟡🔵🔵		🔵
Pistachios		🔵🔵	
Walnuts	🔵		🟡
Figs		🟡	
Row crops	🟡		🔵

🟡 Willing to try on-farm recharge 🔵 Has used on-farm recharge

Fertilizer application

Typical first spring application month

	Feb	March	April	May
Almonds	●	● ● ●	●	
Grapes	●	● ●	● ● ●	
Pistachios			●	●
Walnuts		●		

Fertilizer application

Typical first spring application month and willingness to delay

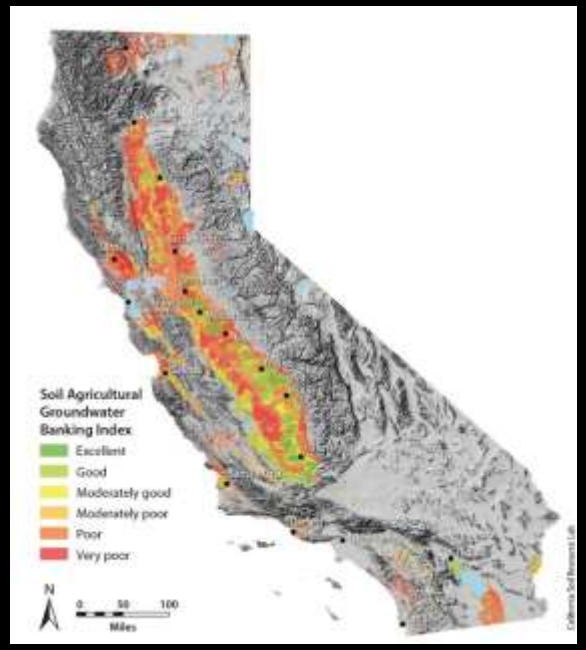
	Feb	March	April	May
Almonds	●	● ● ●	●	
		● ●	● ●	● ● ●
Grapes	●	● ●	● ● ●	
		●	●	
Pistachios			●	●
				●
Walnuts		●		
			●	

● Typical first fertilizer application ● Willing to delay application

Site Recharge Suitability

Comparison of grower site offering with suitability indices

SAGBI

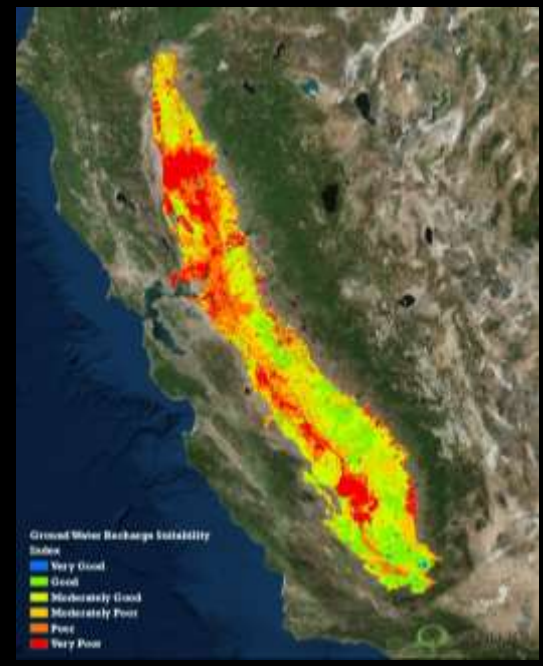


Source: UC Davis

	Soil Agricultural Groundwater Banking (SAGBI) avg.	Subsurface avg.	Combined index avg.
All sites offered	3.8	4.6	4.0
Sites with prior on-farm recharge	3.4	4.9	3.9

Scale: 1 = poor; 5 = excellent

Combined



Source: LandIQ





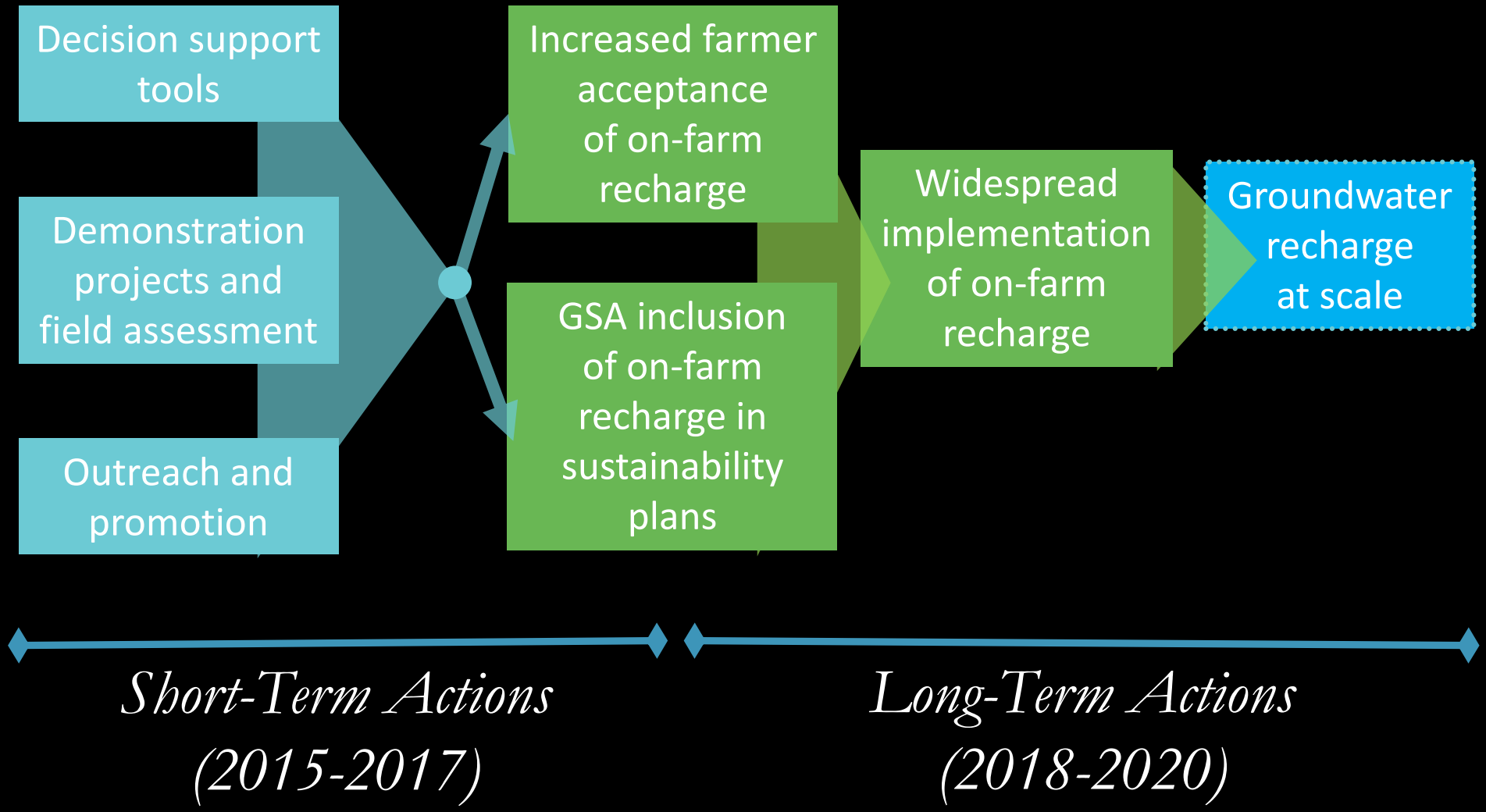


Challenges to accelerated use of on-farm recharge:

1. Concerns about nitrate leaching and crop suitability
2. Lack of clarity about water rights to flood water and recharged groundwater
3. Lack of incentives to reward farmers for the benefit they provide to all
4. Irrigation district preference for centralized water projects

Leveraging Knowledge and Partnerships

for Groundwater Recharge



PRESENTATION 2

Daniel Mountjoy, Sustainable Conservation, “Optimizing Groundwater Recharge Using Farmland”, Groundwater Resources Association of California, 2016.

Optimizing Groundwater Recharge Using Farmland

Daniel Mountjoy
Director of Resource Stewardship

Sustainable Conservation



June 9, 2016 | GRA Conference

Sustainable Conservation













Sustainable Conservation helps California thrive by uniting people to solve the toughest challenges facing our land, air, and water, in ways that make economic sense.

Change in Groundwater Storage in the Central Valley: 1920-2010









Don Cameron, Terranova Ranch *Helm, CA*

Bachand and Associates *Davis*

2011 The Kings River returns to its flood plain







SGMA Supply Side Management Actions: Farmland Recharge



SGMA Supply Side Management Actions:
Fallow Land Recharge



SGMA Supply Side Management Actions:
Recharge Basins



Sustainable Groundwater Management Planning

- What is the potential role for active and fallow farmland in replenishing groundwater supply?
- What is the optimal combination of recharge in dedicated basins and on farmland to maximize capture of available water?

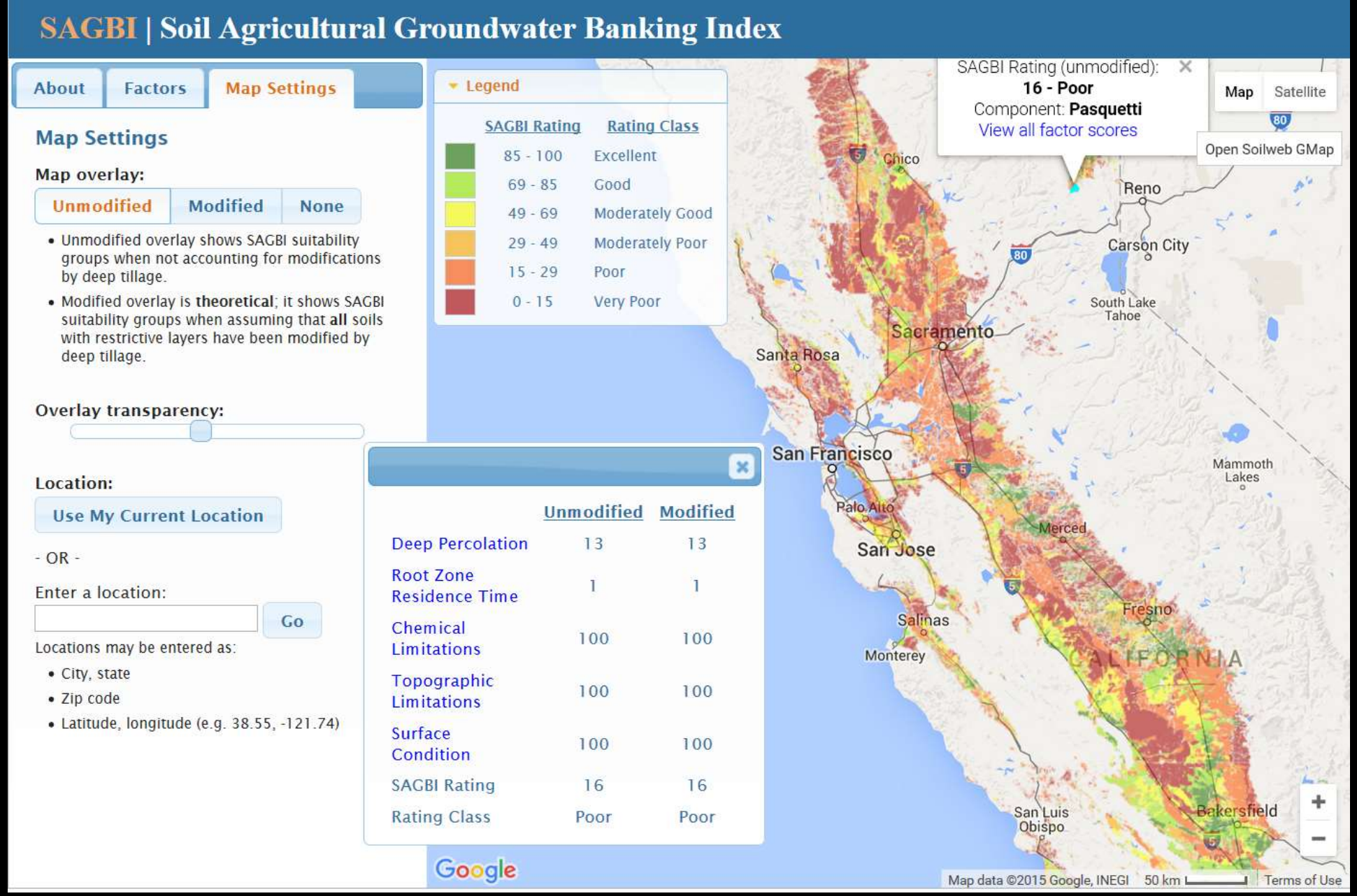


LAND AND CROP SUITABILITY

soil suitability	geologic suitability	depth to groundwater
crop compatibility	conveyance infrastructure	available floodwater

LAND AND CROP SUITABILITY

soil suitability	geologic suitability	depth to groundwater
crop compatibility	conveyance infrastructure	available floodwater



http://casoilresource.lawr.ucdavis.edu/sagbi/

O'Geen et al., 2015. California Agriculture, July issue

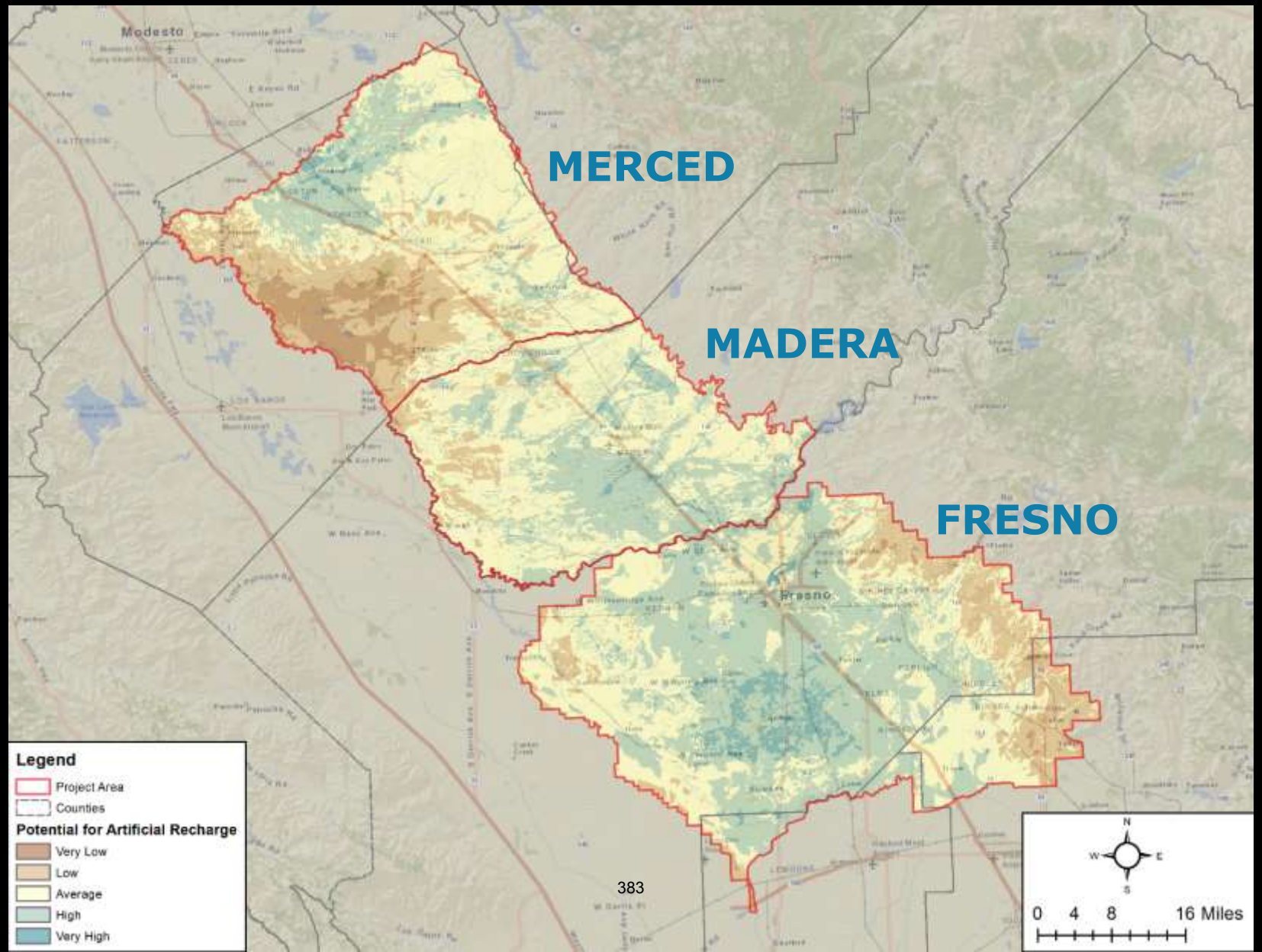
LAND AND CROP SUITABILITY

soil suitability	geologic suitability	depth to groundwater
crop compatibility	conveyance infrastructure	available floodwater

RMC Recharge Suitability Data Sets

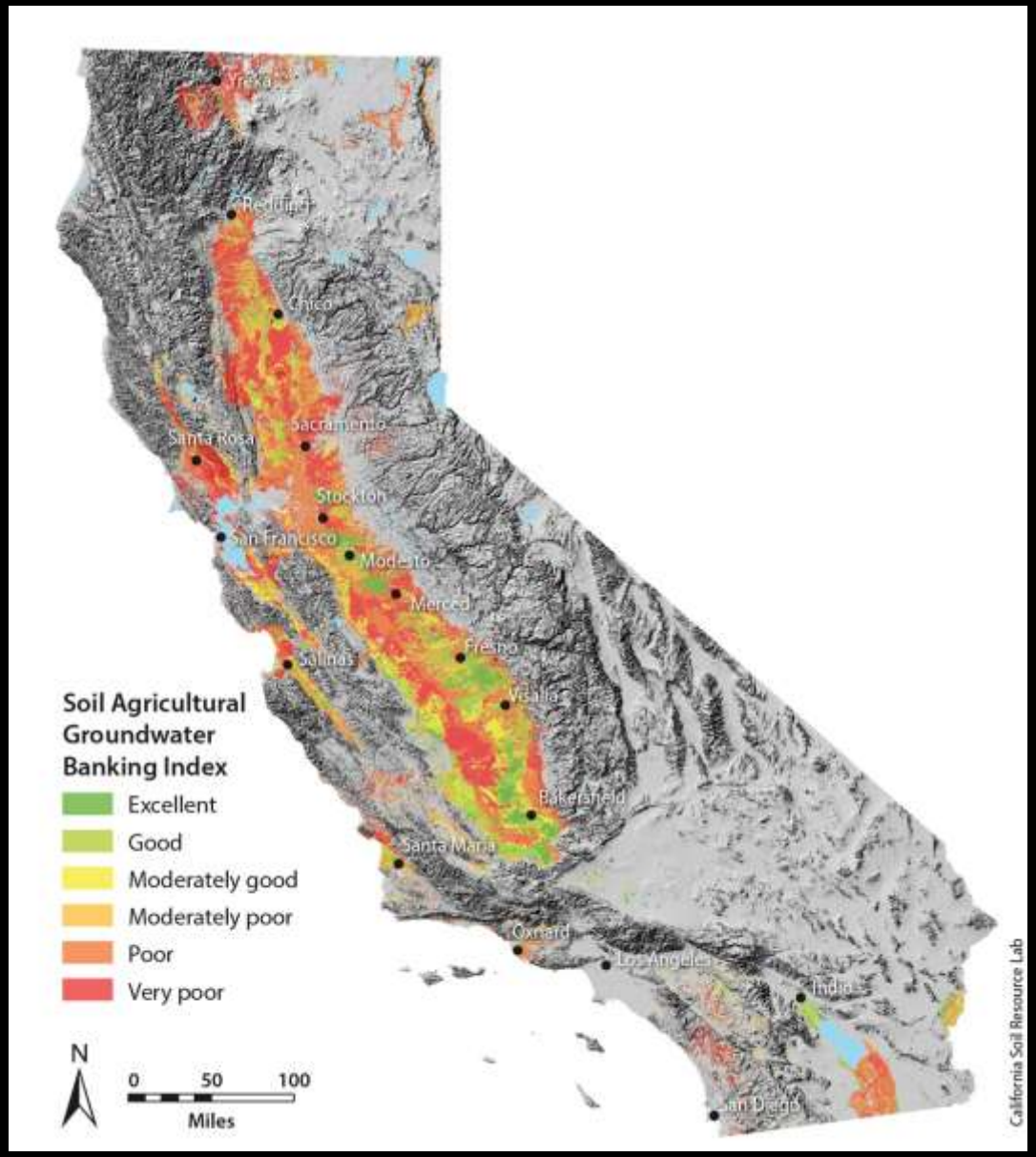
- Soil type (*USDA Hydrologic Soil Group classification*)
- Deep ripping (*O'Geen & Saal, 2013*)
- Subsurface materials, 3 depth intervals (*USGS texture data*)
    - 0 – 50 feet below ground surface
    - 50 – 100 feet below ground surface
    - 100 – 150 feet below ground surface
- Corcoran Clay thickness
- Depth to water

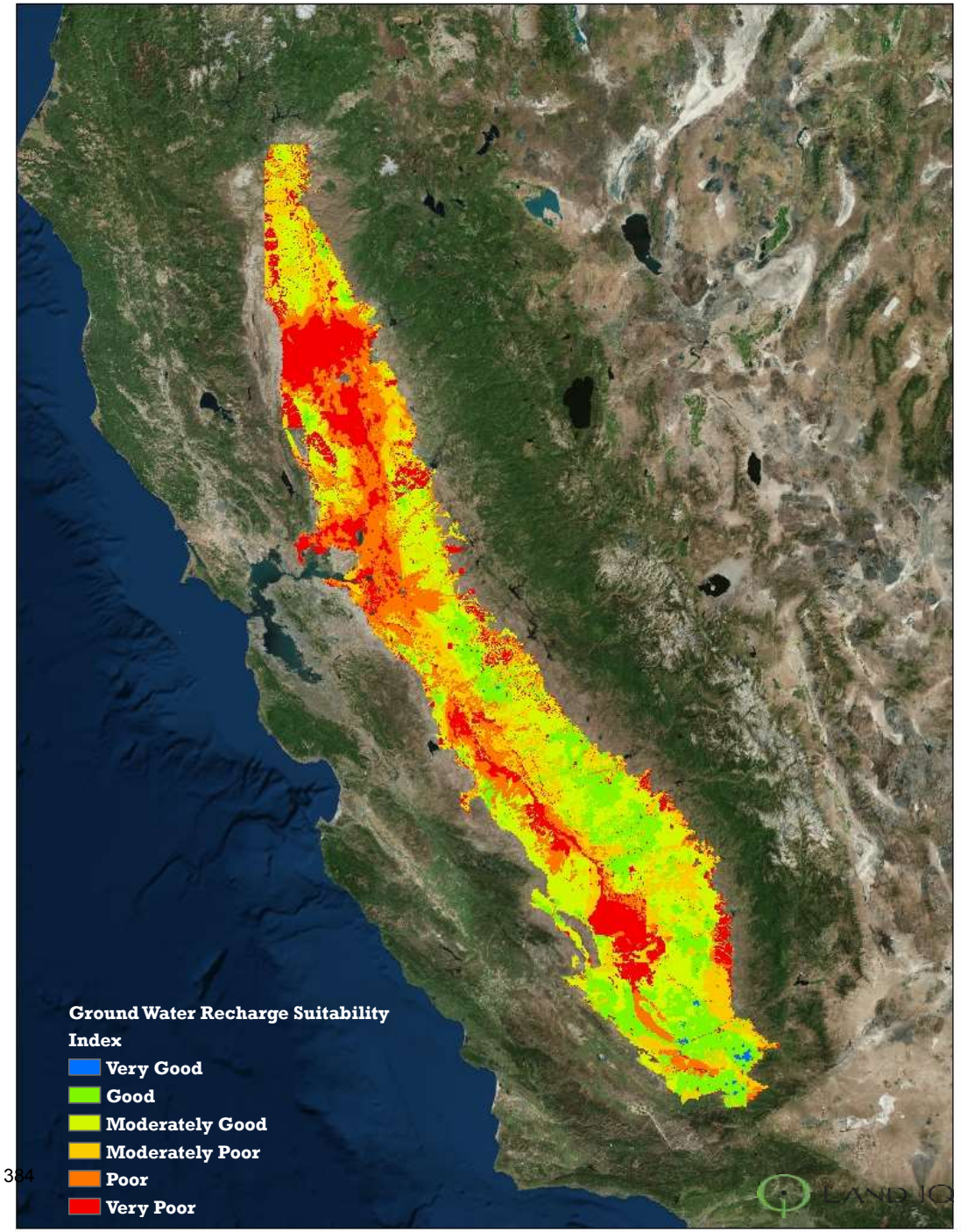
Regional Recharge Potential



Source: RMC 2015

Soil and Geologic Suitability





LAND AND CROP SUITABILITY

soil suitability	geologic suitability	depth to groundwater
crop compatibility	conveyance infrastructure	available floodwater











Crops of interest



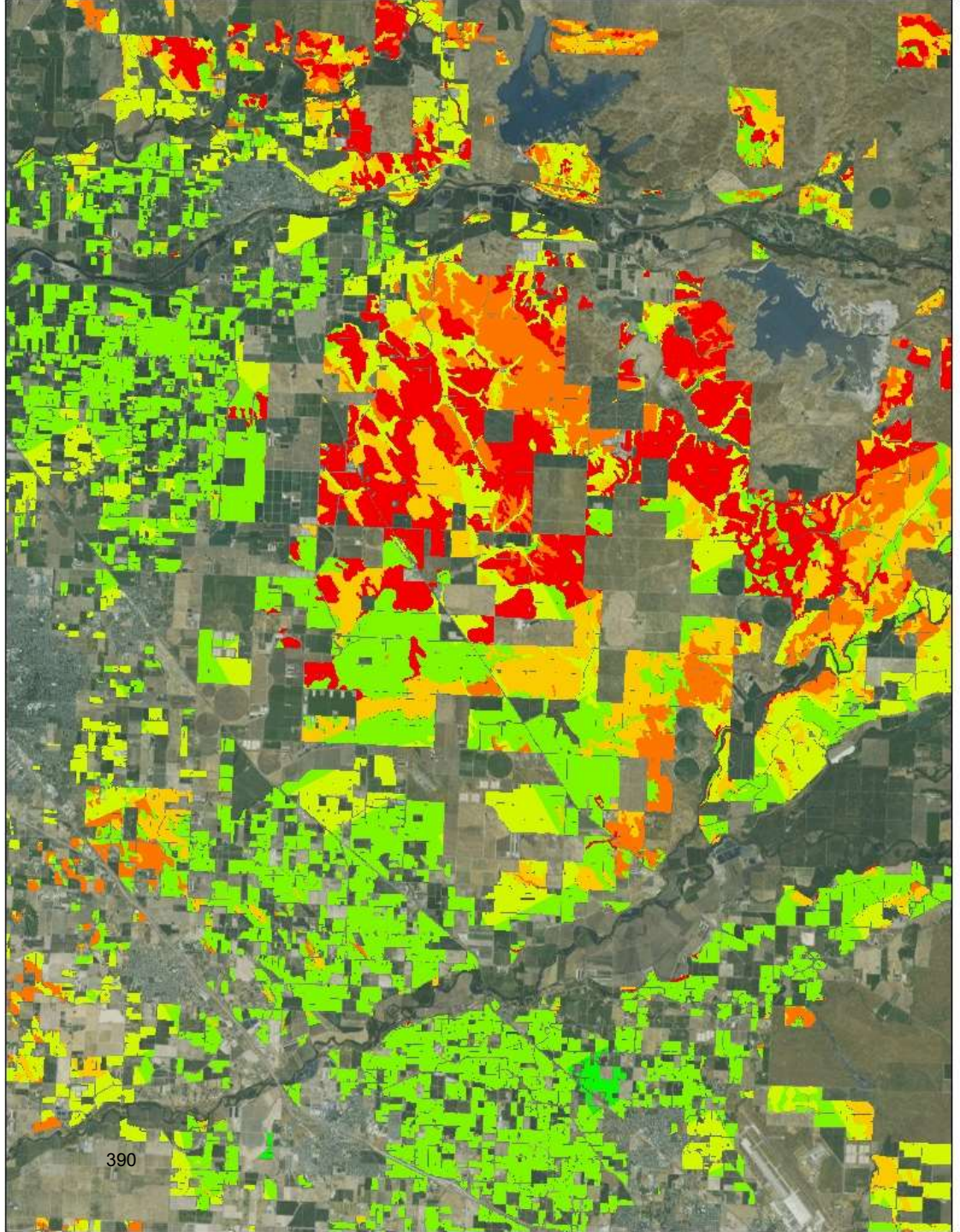






Land IQ Mapping Findings

- Statewide Almond Mapping
  - Field level delineations (orchard blocks)
  - 97+% accuracy
- Almond-Specific Groundwater Recharge Suitability
  - Acres Suitable
    - Very Good (4,119 acres)
    - Good (271,509 acres)
    - Moderately Good (396,790 acres)
- In Good + Very Good suitability areas, could apply 500,000 acre-feet annually for recharge

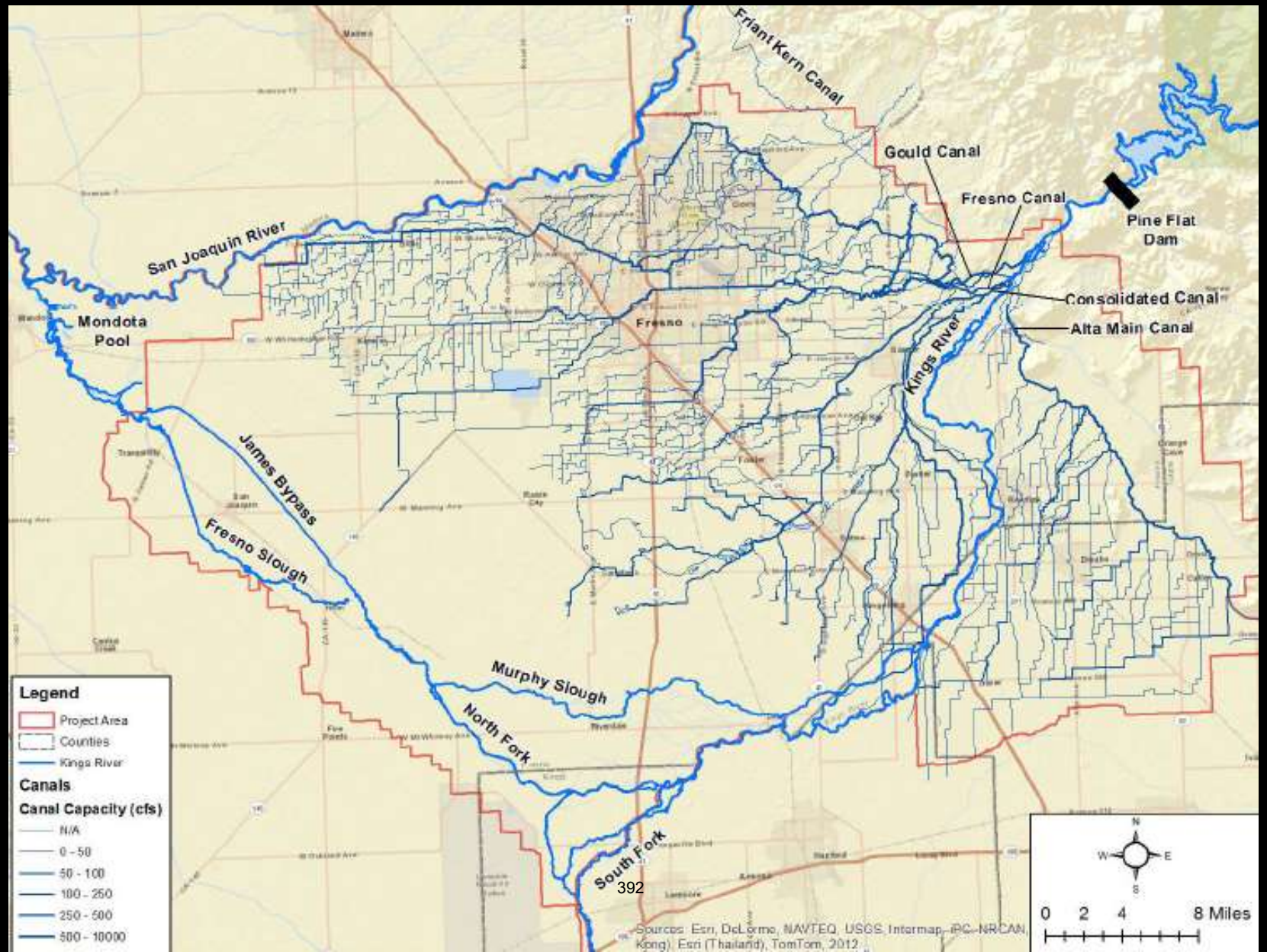


california almonds
Almond Board of California

LAND AND CROP SUITABILITY

soil suitability	geologic suitability	depth to groundwater
crop compatibility	conveyance infrastructure	available floodwater

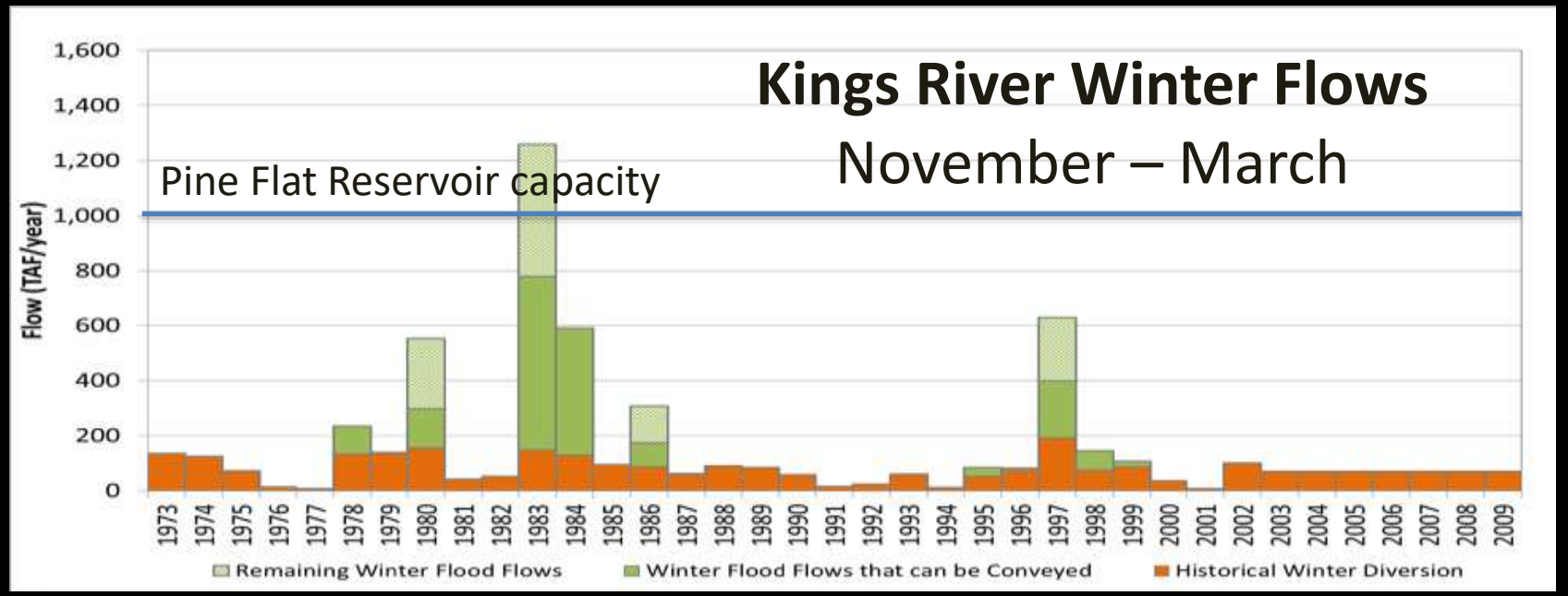
Kings River Conveyance System

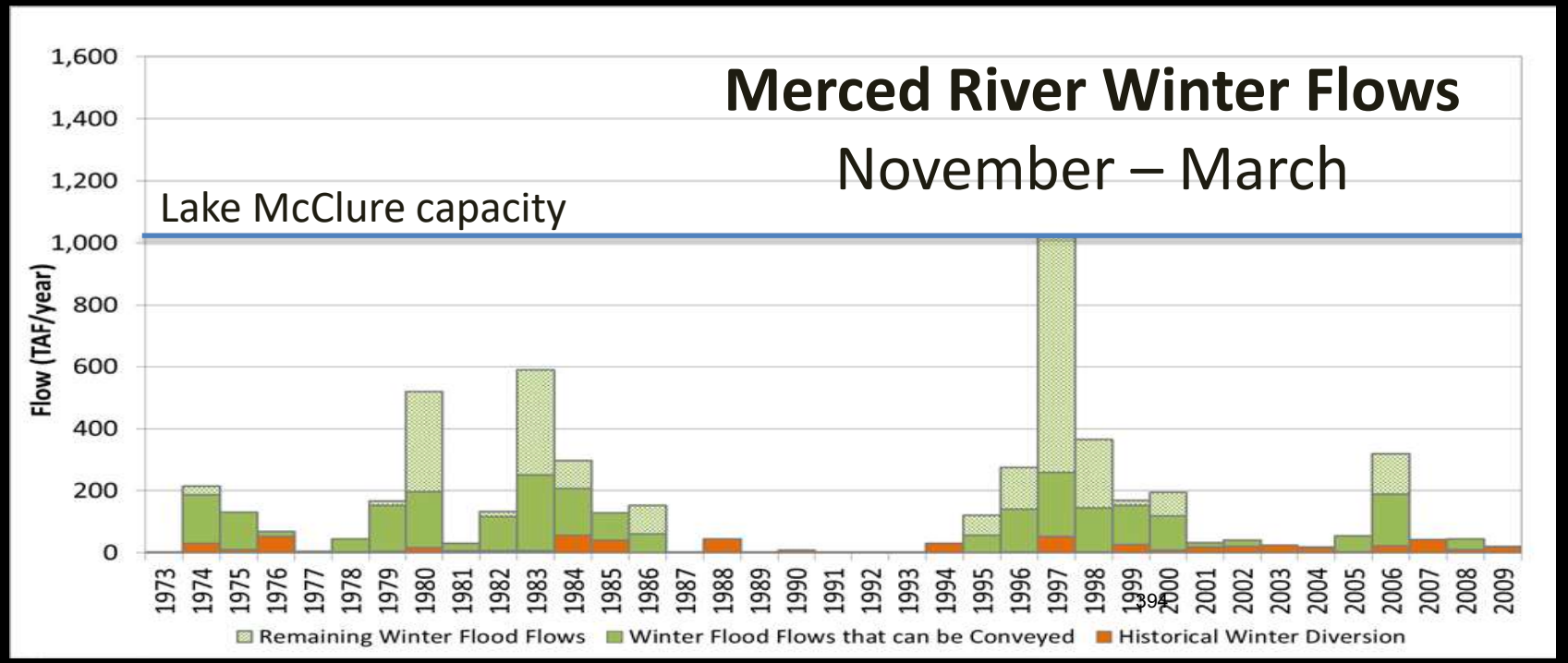


Source: RMC 2015

LAND AND CROP SUITABILITY

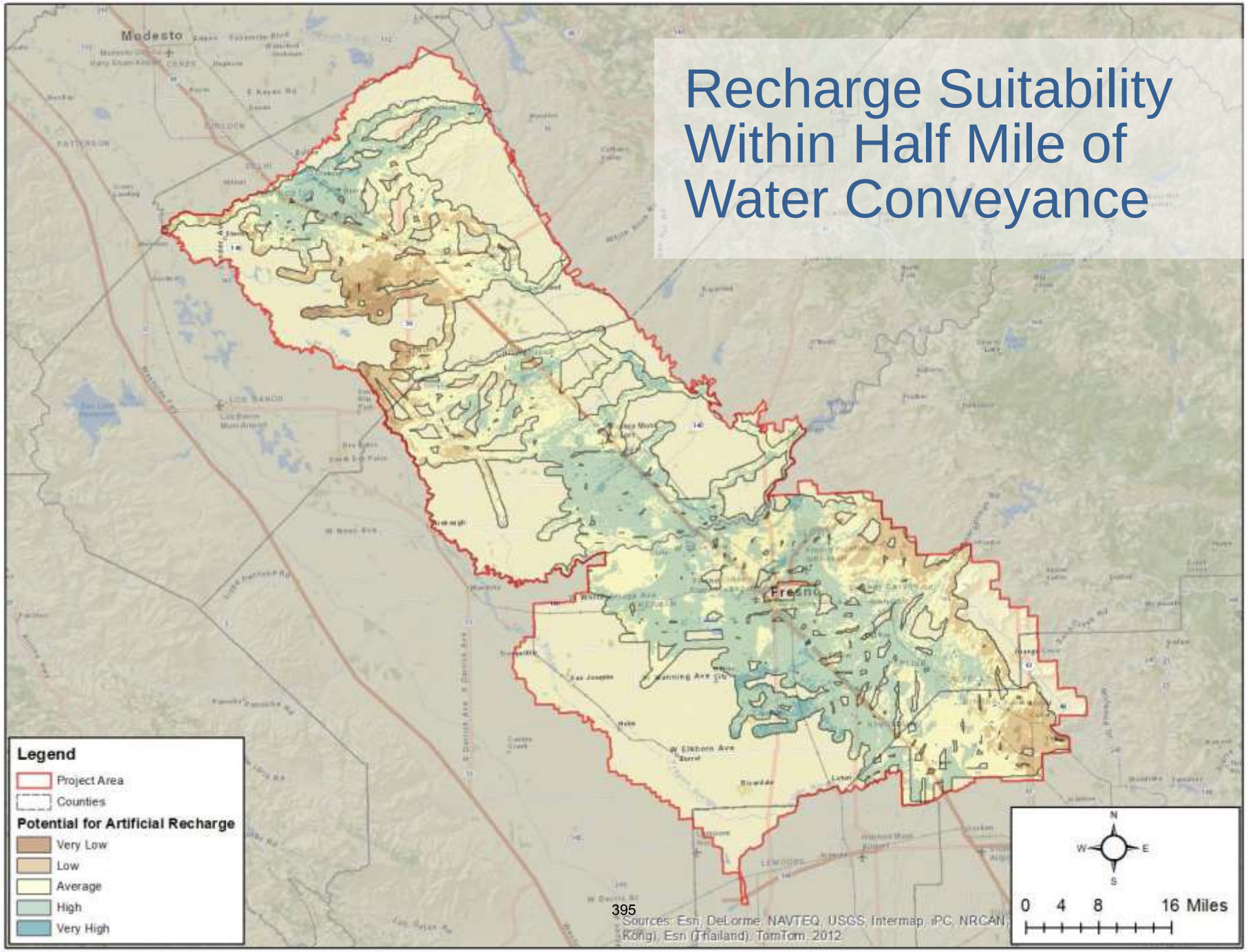
soil suitability	geologic suitability	depth to groundwater
crop compatibility	conveyance infrastructure	available floodwater



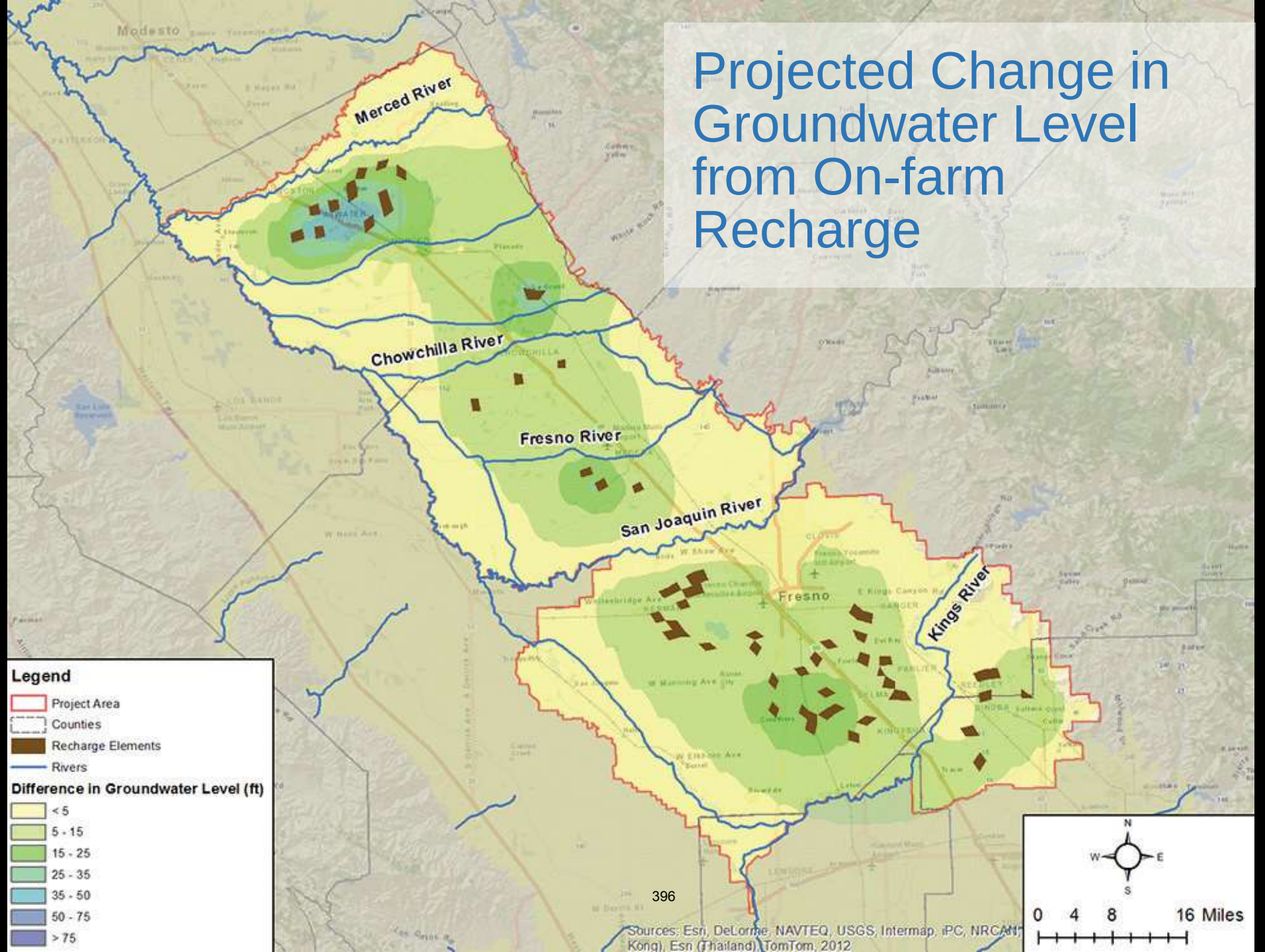


Available Flood Water Resources

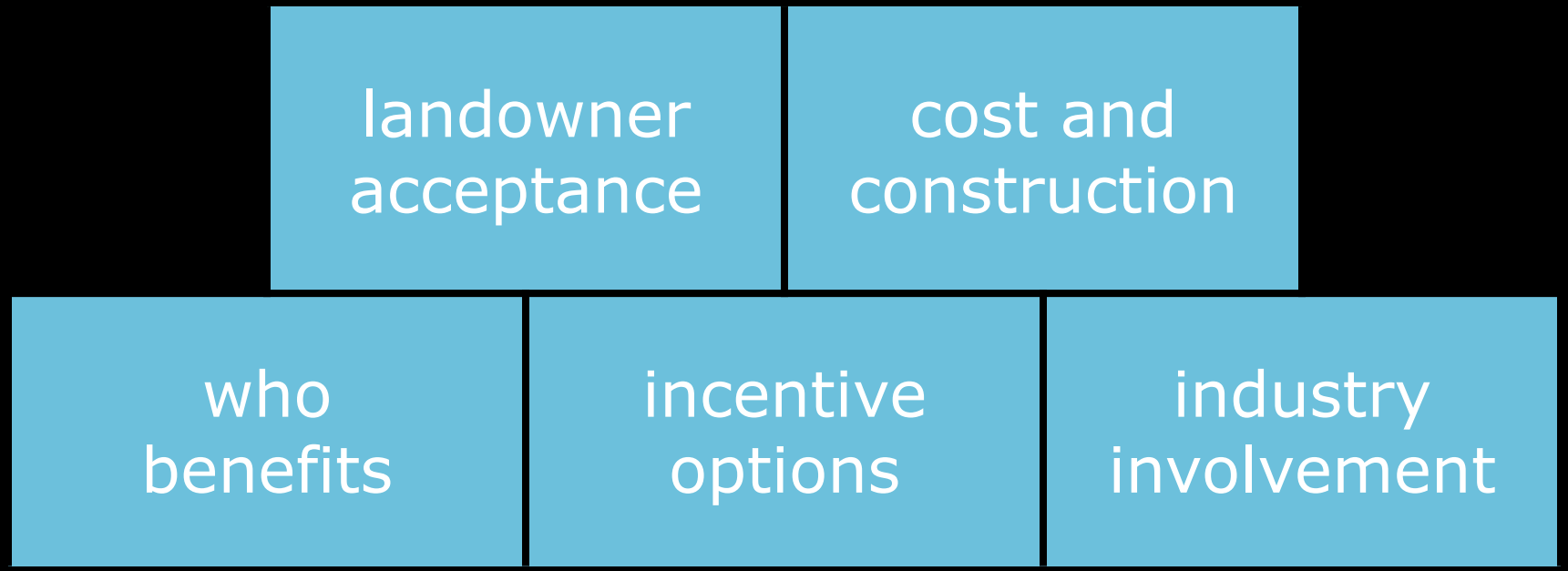
Recharge Suitability Within Half Mile of Water Conveyance



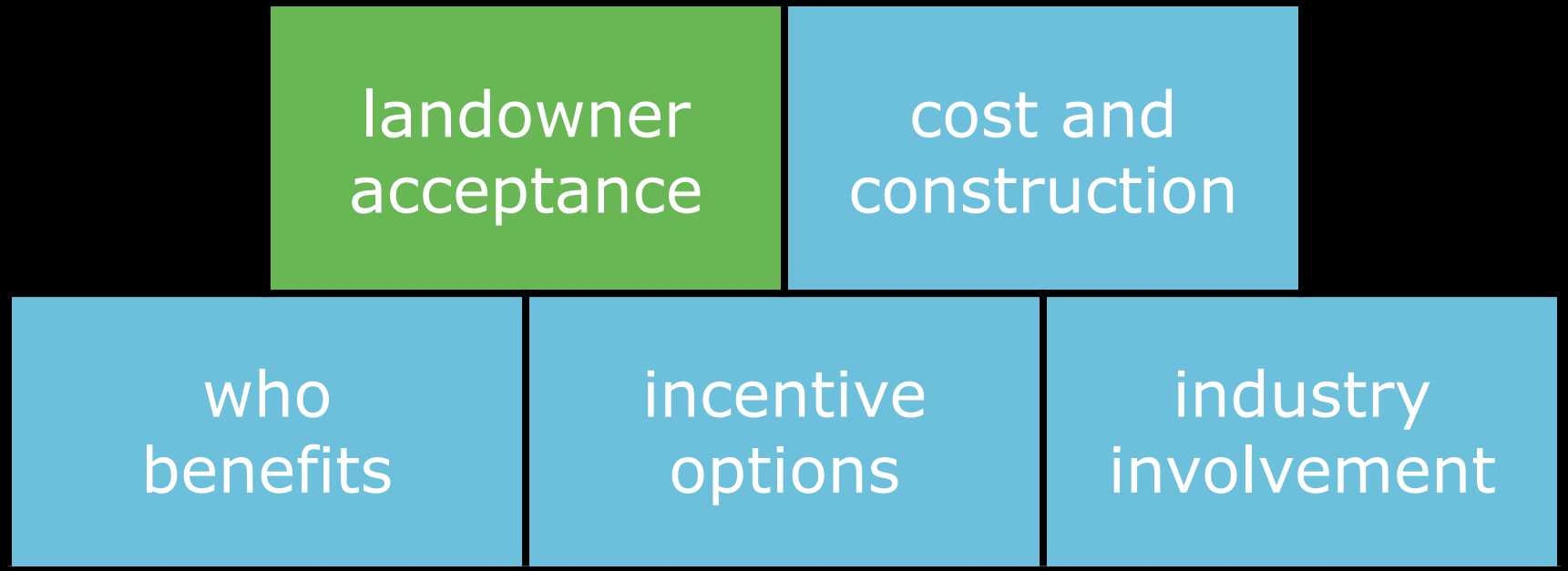
Projected Change in Groundwater Level from On-farm Recharge



COST AND WHO BENEFITS



COST AND WHO BENEFITS

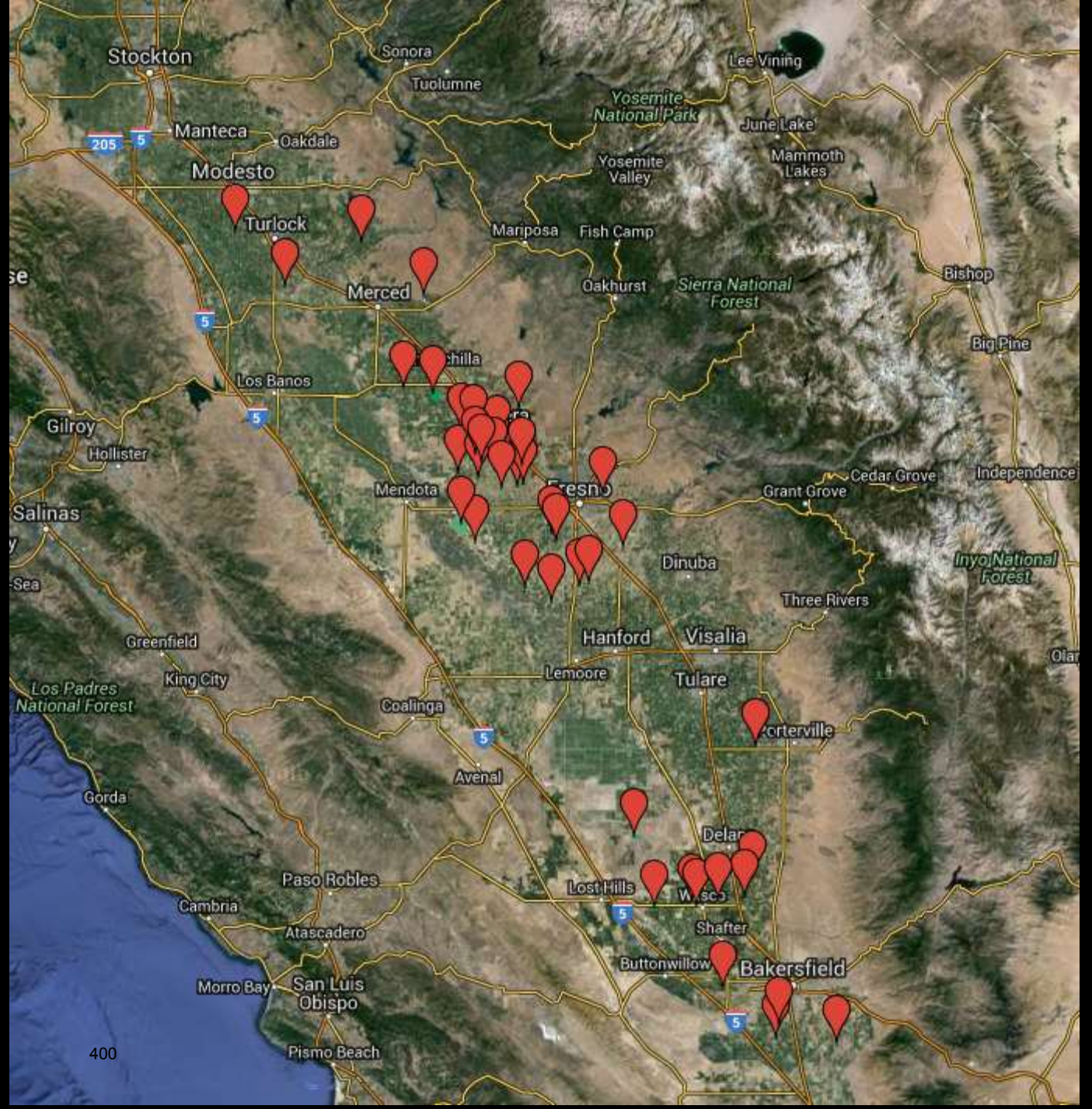



Grower Workshop
Partners

Demonstration Sites 2015-16

- 130 sites
- 10 crops
- 14,000 acres

- Purpose: Assess constraints and measure water that can be applied in excess of crop demand



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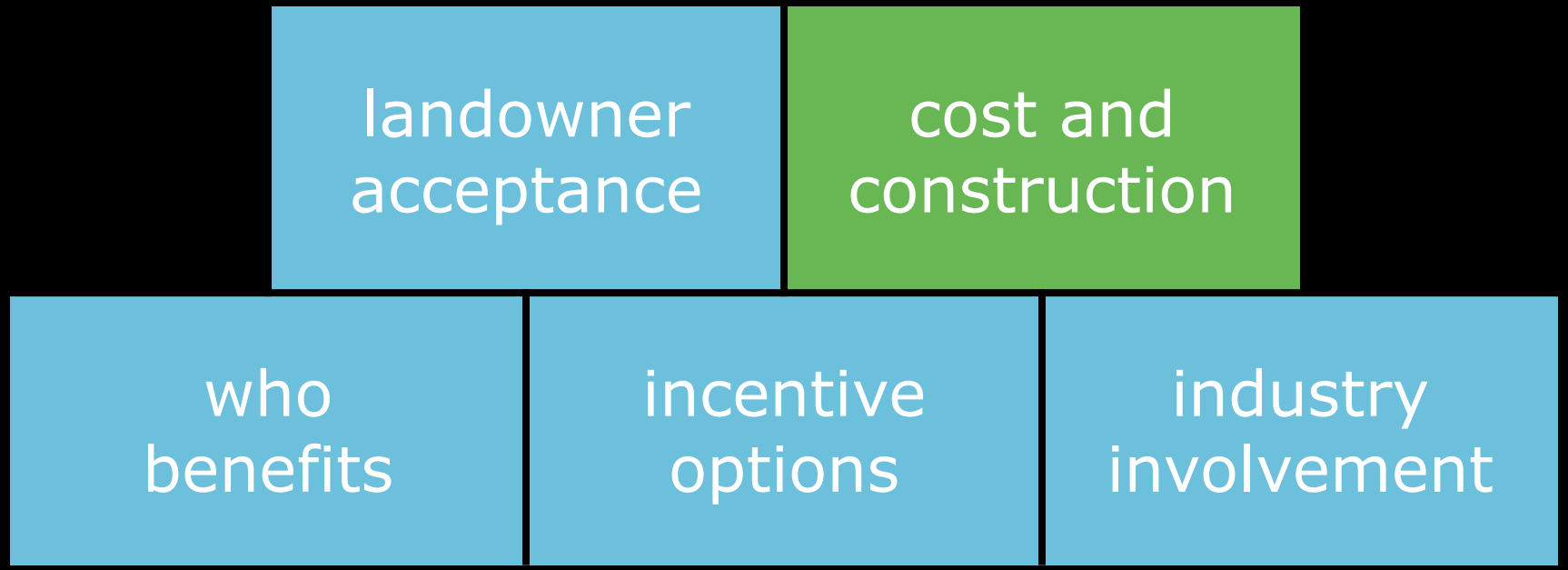


Cost Comparison of Recharge Options

On-farm



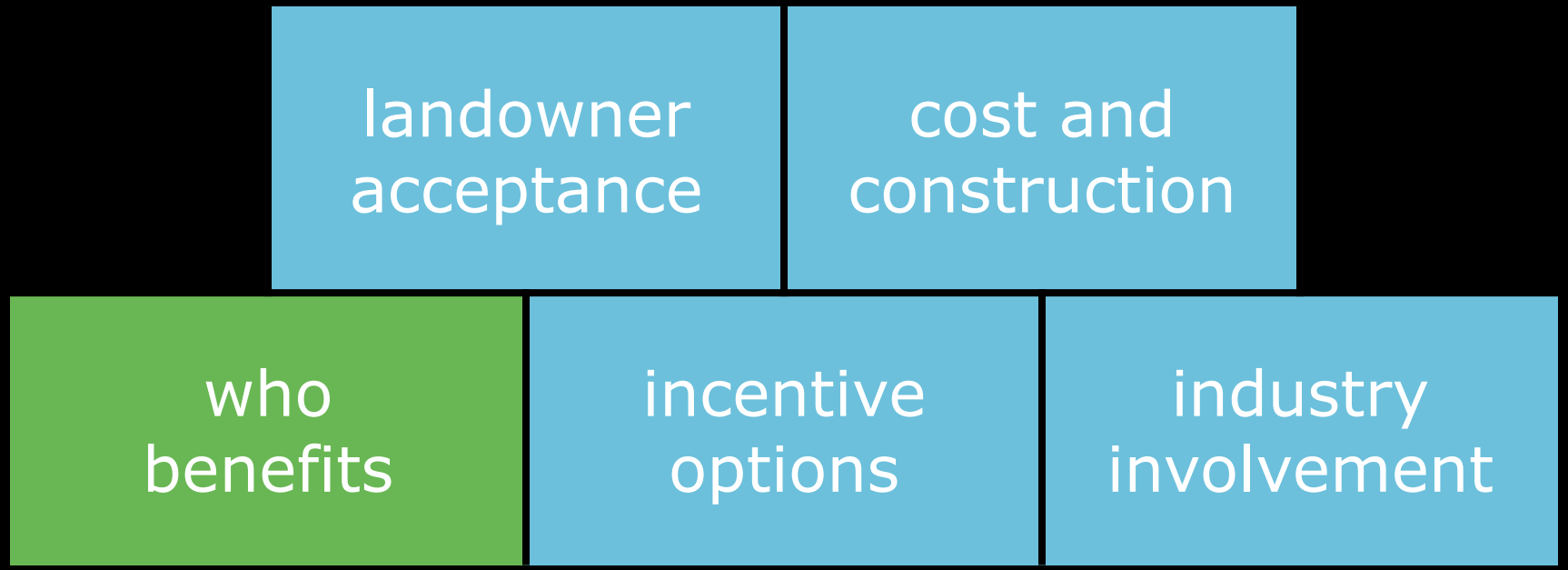
$40 - 107/AF

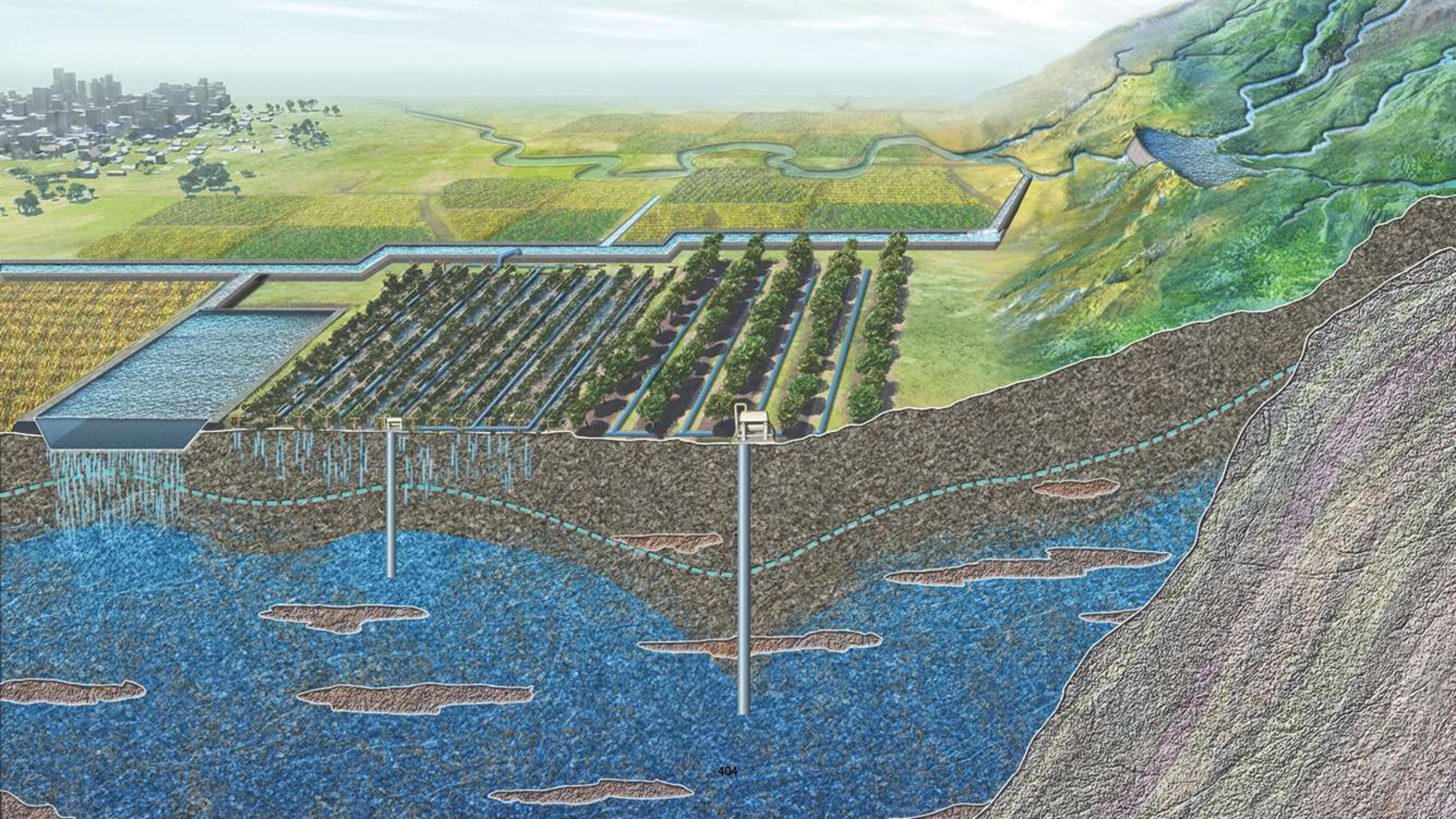
Dedicated basin



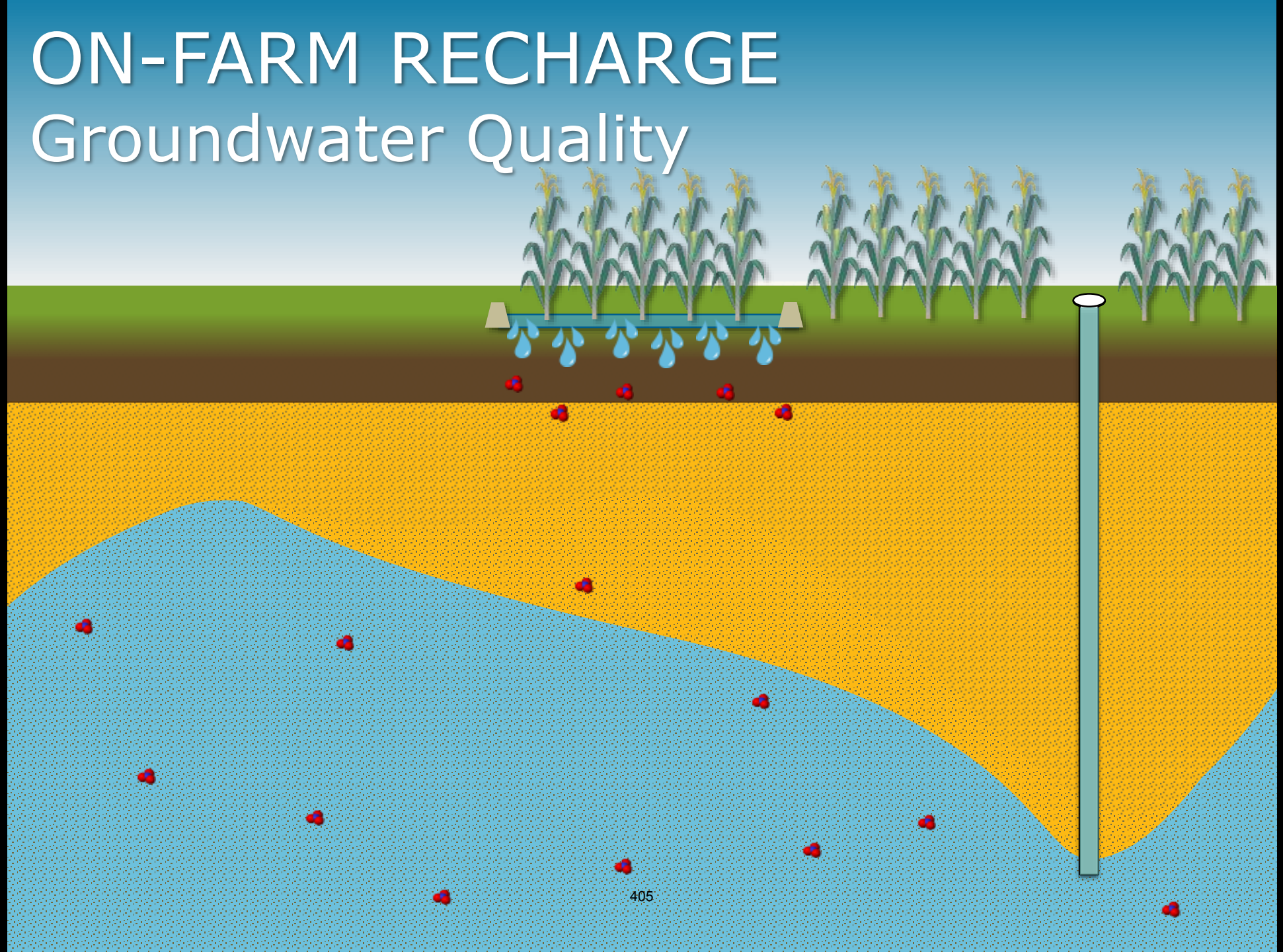
$124/AF

COST AND WHO BENEFITS





ON-FARM RECHARGE
Groundwater Quality



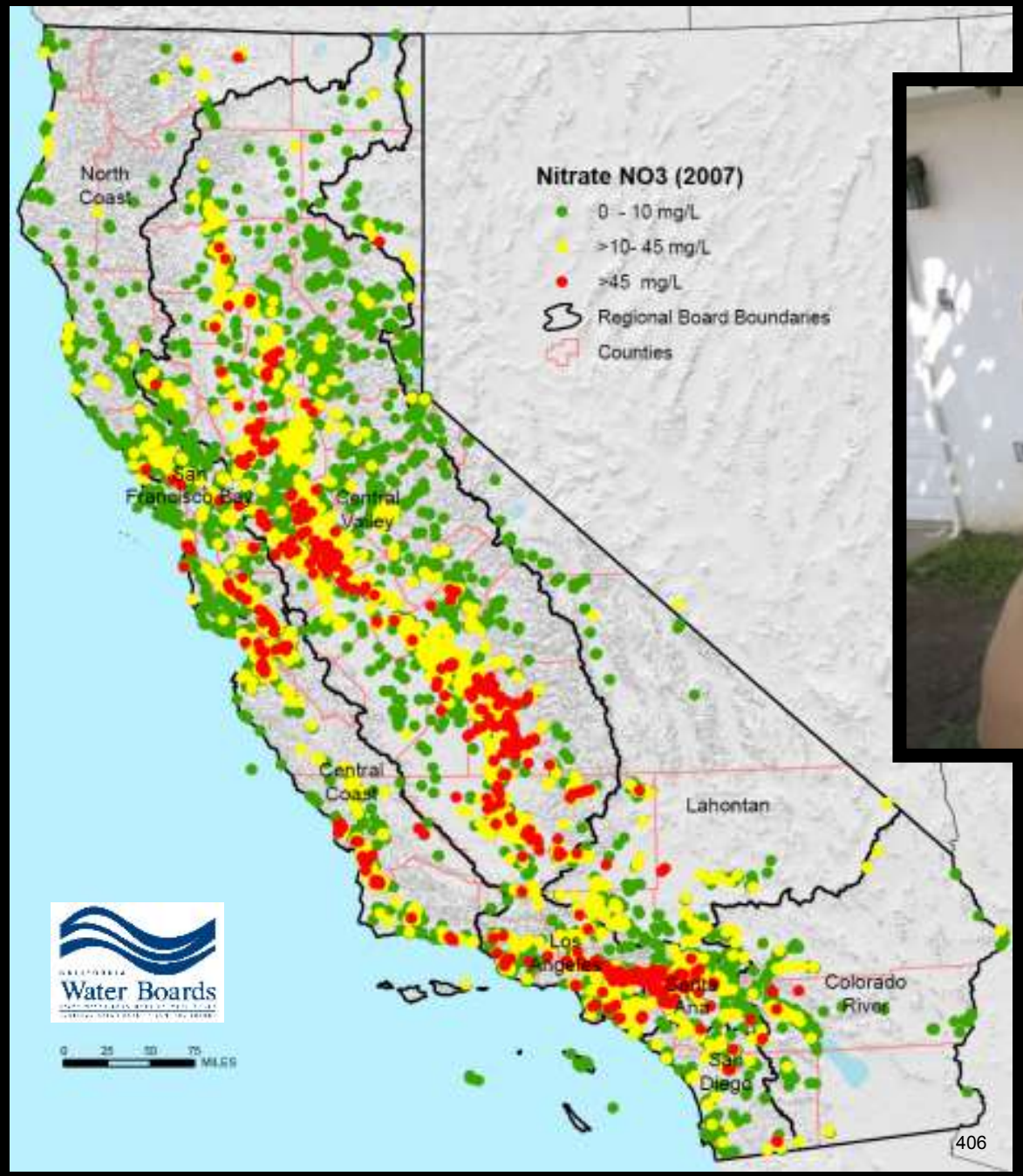
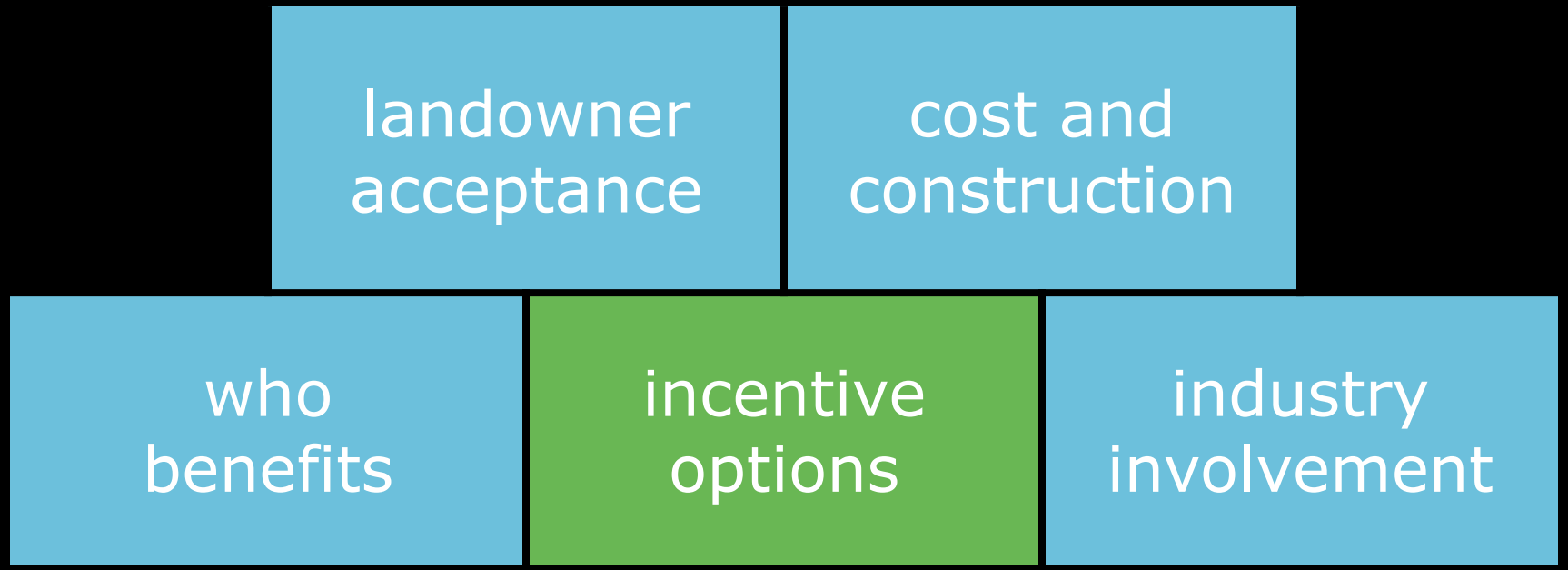




Photo source:
Community Water Center

COST AND WHO BENEFITS



Incentive Options for On-farm Recharge

Preferential pumping

Credit for replenishing aquifer

Direct payments to participants from beneficiaries

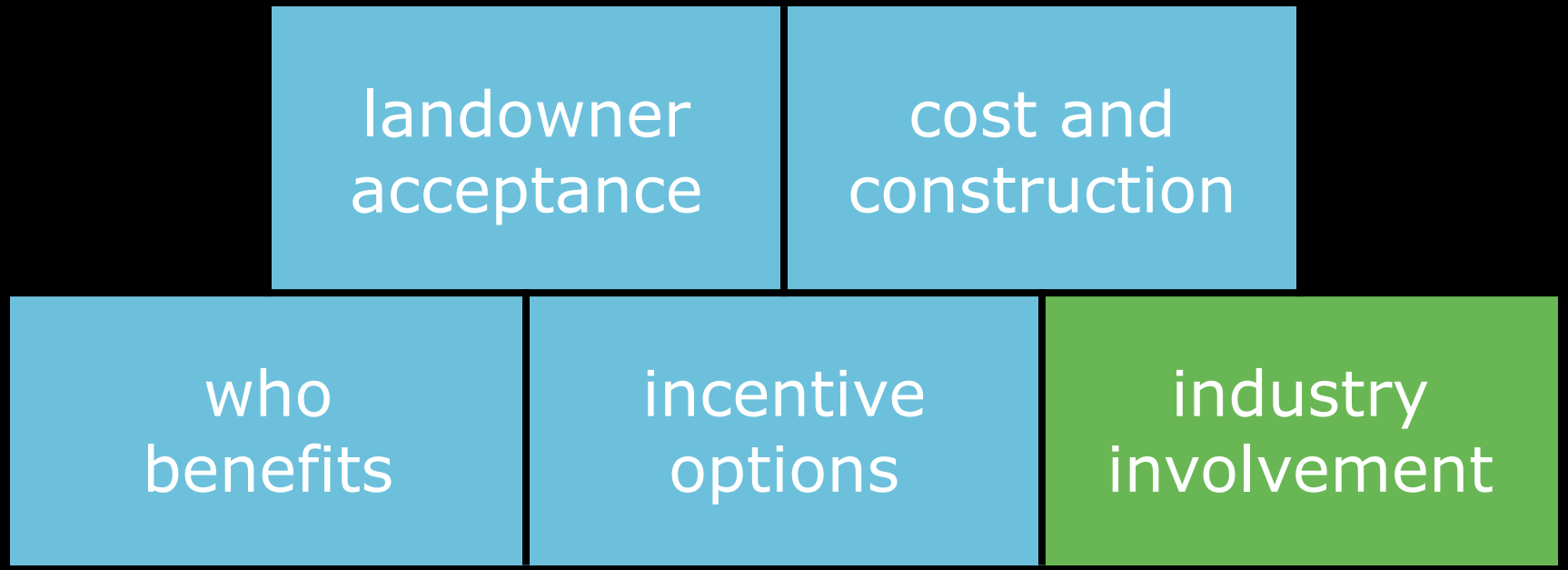
Assessment districts, conjunctive use payments, flood mitigation fees

Crop insurance and flood easements

Flood control beneficiaries compensate growers for taking water

Source: M.Cubed

COST AND WHO BENEFITS





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Almond Board of California

California Water Action Collaborative















Groundwater Recharge Planning Tool

- What is the optimal combination of recharge in dedicated basins and on farmland to maximize capture of available water?
- Allowing for data uncertainty and local GSA priorities



Groundwater Recharge Planning Tool (GWRPT)
Iterative Co-Creation Process

Data
(Information relevant to SJV)

Science/Translation
(Translating Data)

Tools/Apps
(Highly visual, insight dissemination)

Decision Makers
(Changed/improved decisions)

Technology Platform
(Scalability, interoperability)

Groundwater Recharge Planning Tool (GWRPT)
Iterative Co-Creation Process

Key Considerations

- **Where**. Where could an Irrigation District do recharge?
- **What**. What combination of recharge methods (dedicated basins, on-farm fallow land, or on-farm cropped land)?
- **When**. When could recharge be done to optimize capture of available flood flows?

Main Constraints

- **Water availability**: How much surface water is available, based on hydrologic variability and any water rights constraints using existing conveyance capacity;
- **Recharge suitability**: Where is land use suitable for recharge, given land characteristics (soil, topography, geology, and hydraulic conductivity)
- **Land use compatibility**: What are the human aspects that affect where and how much recharge is possible, including crop compatibility, land values, and ownership.

Tool Development

1. Listen: Identify GSA information needs, context and SGMA requirements
2. Synthesize: Data requirements, delineate tradeoffs, draft design
3. Convene: GSAs and other stakeholders to confirm draft design
4. Create: gather data, confer on analytic model, design visuals
5. Launch: test, train, share insights

Have we fully considered the potential of using farmland for recharge?

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Sustainable Conservation



PRESENTATION 3

Dan Munk, University of California, Agriculture and Natural Resources, “Nitrogen Management Practices and On-farm Recharge”, Specialty Crop Nitrogen Management Workshop, 2017.

Nitrogen management practices and on-farm recharge

On-farm Recharge Workshop

June 14, 2017 Terranova Ranch

Dan Munk
dsmunk@ucanr.edu

Outline

- ILRP and GW nitrate issue
- Crop nitrogen balance
- Movement of nitrates in soil and migration to GW
- N Management practices that limit the leaching of N
- Research needs and visioning future recharge systems

Water Quality Regulation (ILRP)

- CVRWQCB (region 5) is responsible authority to protect surface and groundwater resources
- Uses Waste Discharge permits, Waivers, General Orders to protect waters of the state
- Conditional Waivers adopted in 2006, addressed surface water quality
- Allowed Coalitions to be formed
- East San Joaquin Dec. 2012, Tulare Lake Basin Sept. 2013
- Recent modification of order to include MPEP
  - Demonstration of practices that limit GW degradation
  - Demonstration of practices that improve GW quality

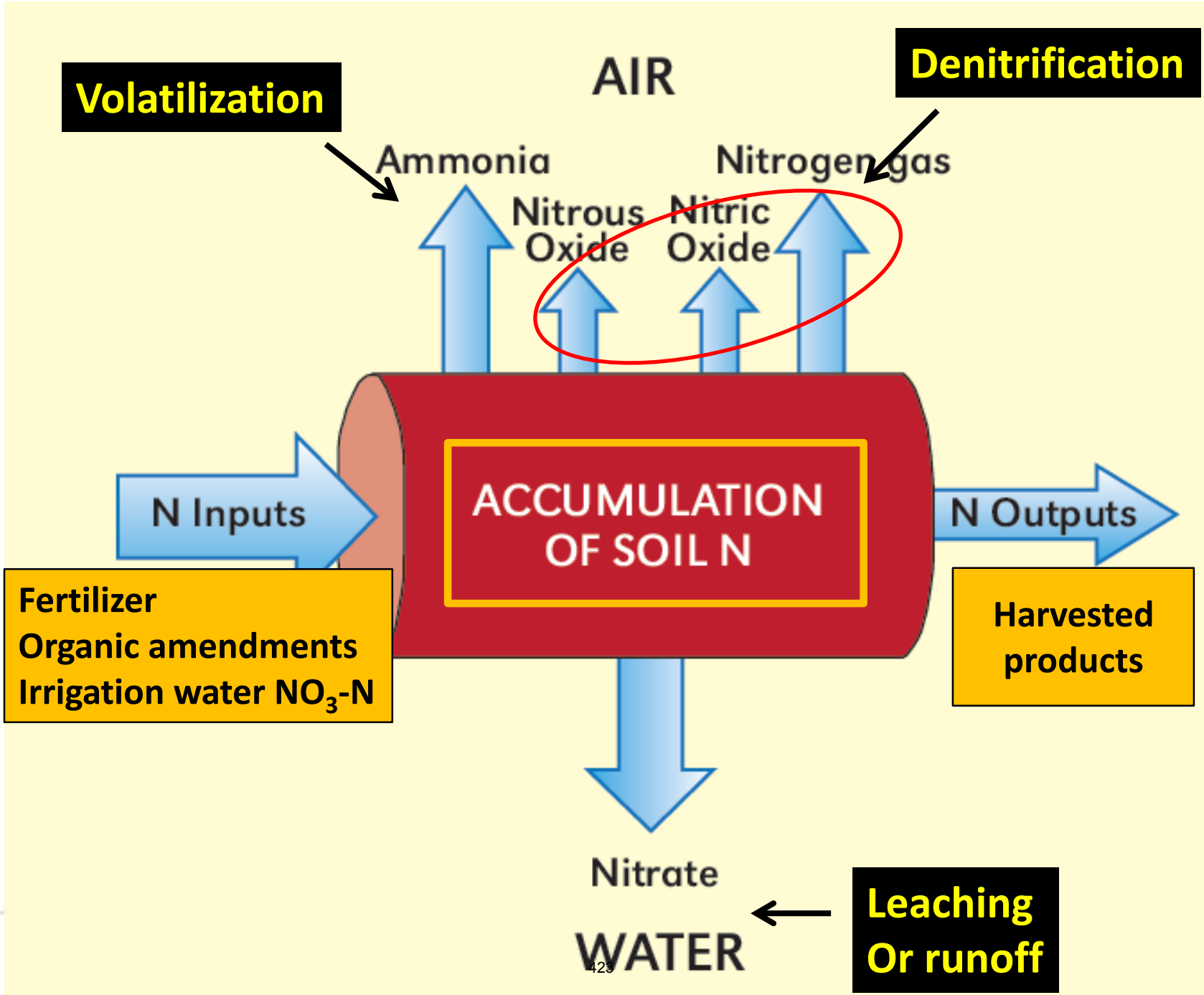
Grower Requirements

Three Major Obligations are Mandated by the General Order

1. Sediment and Erosion Control Plan (some)
2. Farm Evaluation Reports
3. Nitrogen Management Plan & Summary Report

Nitrogen Management Plans

- Worksheet Required of every member regardless of vulnerability
- Summary Reports required from High Vulnerability Areas only
- Coalition will summarize reports by Township and submit to the Regional Board
- Individual member information will not be submitted


Volatilization
AIR
Denitrification
Ammonia
Nitrogen gas
Nitrous Oxide
Nitric Oxide
N Inputs
ACCUMULATION OF SOIL N
N Outputs
Fertilizer
Organic amendments
Irrigation water NO_3-N
Harvested products
Nitrate
WATER
Leaching Or runoff

Nitrogen Management Plan

1. Crop Year, (Harvested):		4. APN(s):	5. Field(s) ID:
2. Member ID#			
3. Name:			

CROP NITROGEN MANAGEMENT PLANNING		N APPLICATIONS/CREDITS	26. Recommended/ Planned N	27. Actual N
6. Crop:		**15. Nitrogen Fertilizers**		
7. Production Unit:		16. Dry & Liquid N (lbs/ac)		
8. Projected Yield (Units/Acre):		17. Foliar N fertilizers (lbs/ac)		
9. N Recommended (lbs/ac):		**18. Organic Material N**		
10. Acres:		19. Available N in Manure/Compost (lbs/ac estimate)		
Post Production Actuals		**20. Total Available N Applied** (lbs per acre)	0	0
11. Actual Yield (Units/Acre):		**21. Nitrogen Credits (est)**		
12. Total N Applied (lbs/ac):	0	22. Available N carryover in soil (annualized, lbs/ac)		
13. ** N Removed (lbs N/ac):		23. N in Irrigation water (annualized, lbs/ac)		
A/Y Ratio (lbs N/unit/ac):	#DIV/0!	**24. Total N Credits** (lbs per acre)	0	0
14. Notes:		**25. Total N Applied & Available**	0	0

PLAN CERTIFICATION		
28. CERTIFIED BY:	29. CERTIFICATION METHOD	X
	30. Low Vulnerability Area, No Certification Needed	
	31. Self-Certified, approved training program attended	
DATE:	32. Self-Certified, UC or NRCS site recommendation	
	33. Nitrogen Management Plan Specialist	

University of Califo
Agriculture and Natural

Nitrogen Management Plans

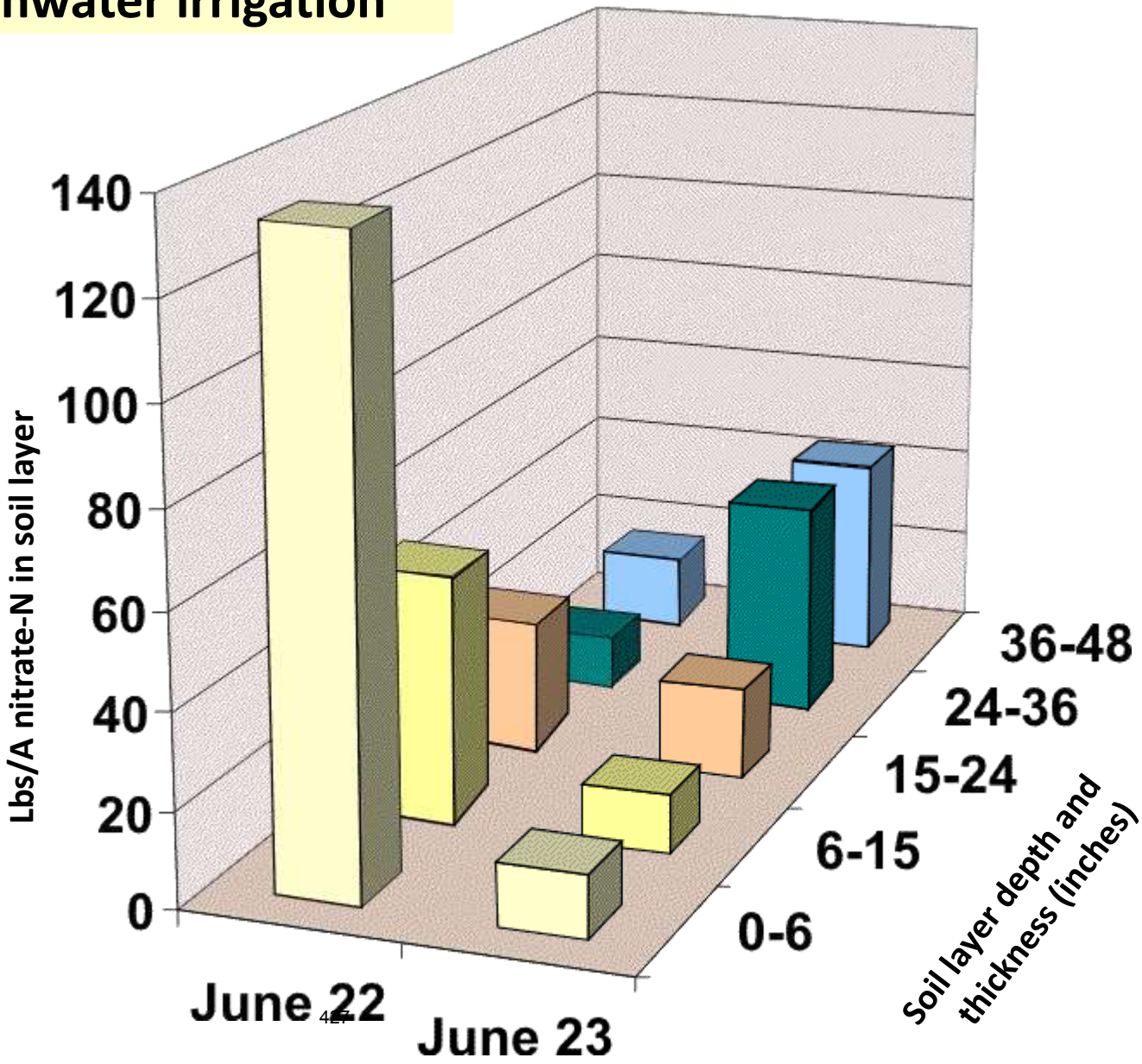
- Works to ensures growers have a plan to estimate seasonal N applications in individual fields.
- Documents actual applications of N in fertilizers, amendments and irrigation waters.
- Attempts to balance N applied & N available with crop N requirements.
- Works to identify fields that are significantly imbalanced

Is on-farm recharge consistent with Board developed WQ objectives?

- Should use N management plan approach
- Demonstrate process does not hasten GW degradation
- Can on-farm recharge improve water quality?

Nitrate-N losses (lbs/acre) from a single freshwater irrigation

N. San Joaquin Valley
silage corn
1st irrigation
6.7 ac-in
fine sandy loam



Current Tools for Nutrient Planning and Management

In-season

N application related

- Residual N Soil test
- Tissue N Levels
- Organic Amendment N content, amount applied
- Timed applications
- Precision application
- Slow release N Sources
- Many others

Irrigation related

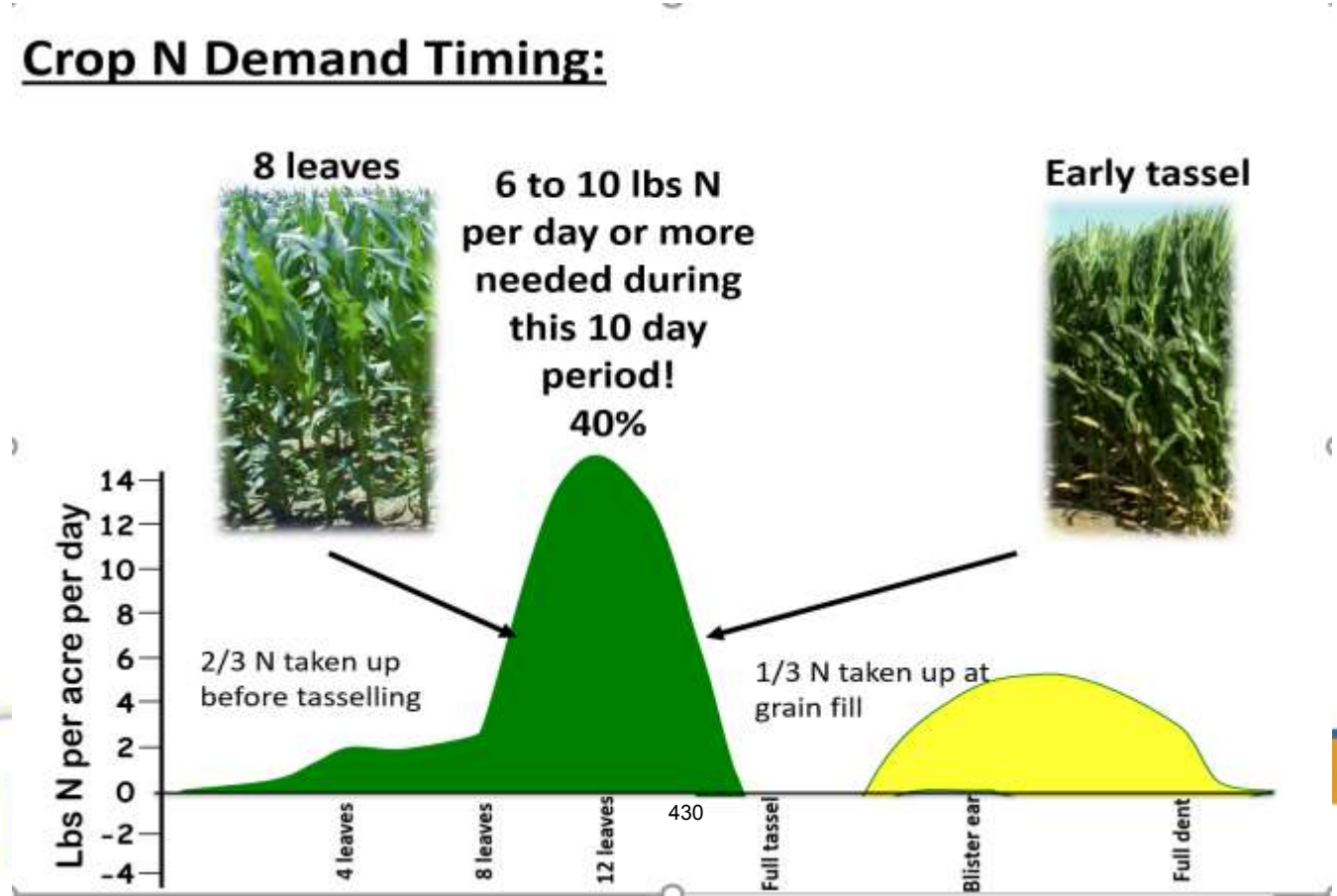
- Drip/micro Irrigation
- Sprinkler irrigation
- Crop ET estimation
- Monitor Applied water and runoff
- Irrigation System monitoring and management
- Fertigation

Practices that minimize winter/spring N leaching
(BMP's)

- Use N management plan to establish reasonable N balances.

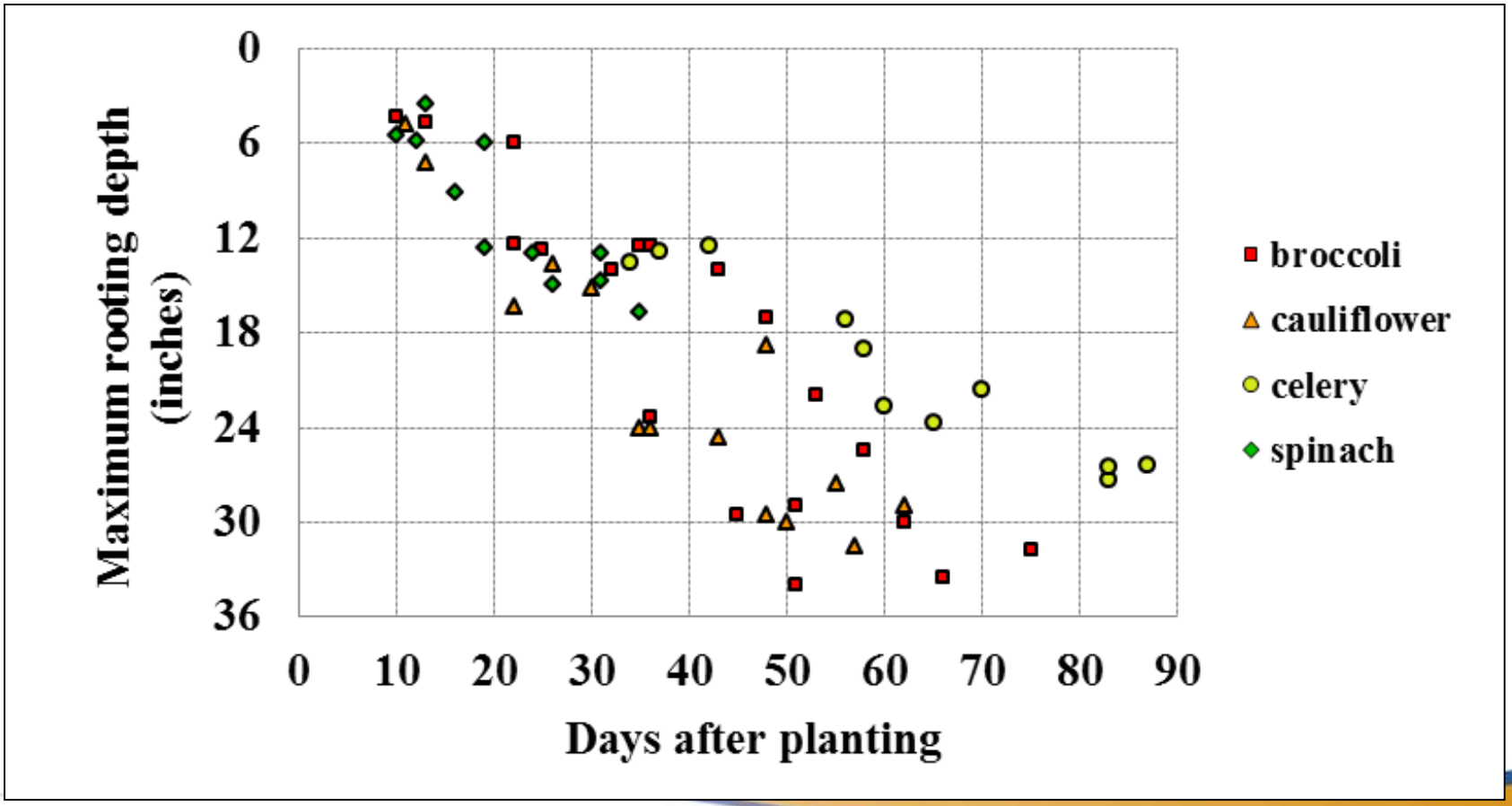
Practices that minimize winter N leaching (BMP's)

- Practice proper timing of applied N that correspond to crop uptake



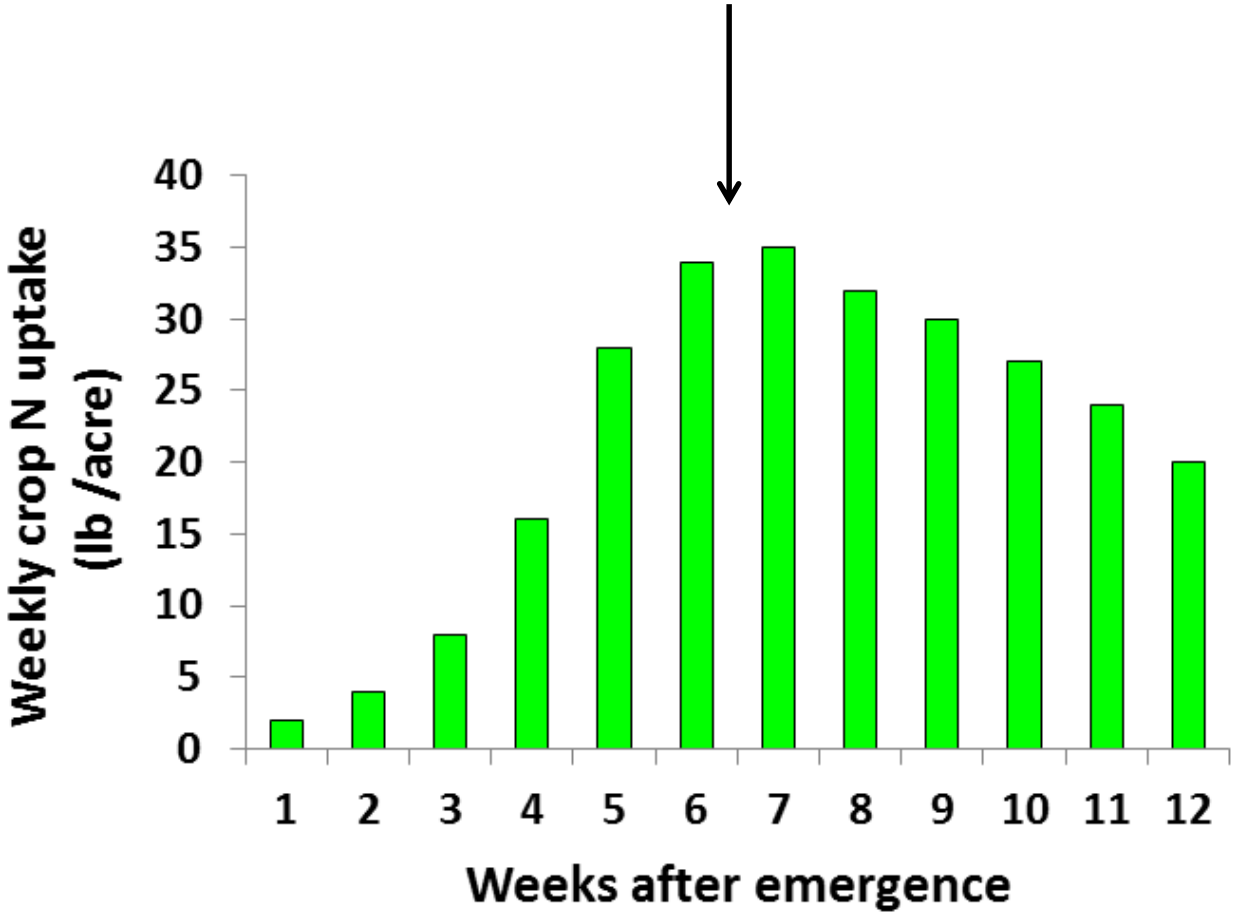
Apply N 'just in time' :

- **Root development takes time, and nitrate leaching is a special hazard early in the season:**



Typical peak N uptake rates for vegetable crops:

- 3-4 lb / acre / day in cool conditions
- 4-6 lb / acre / day in warm conditions

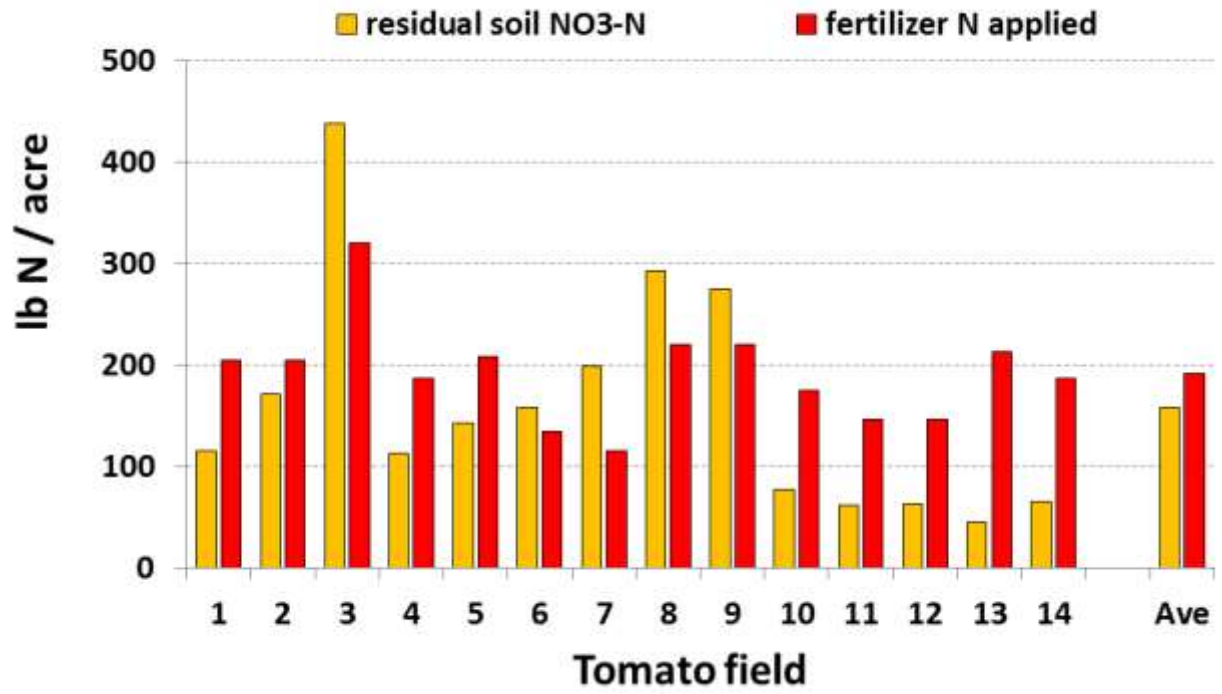


Practices that minimize winter N leaching (BMP's)

- Accounting for residual N early season

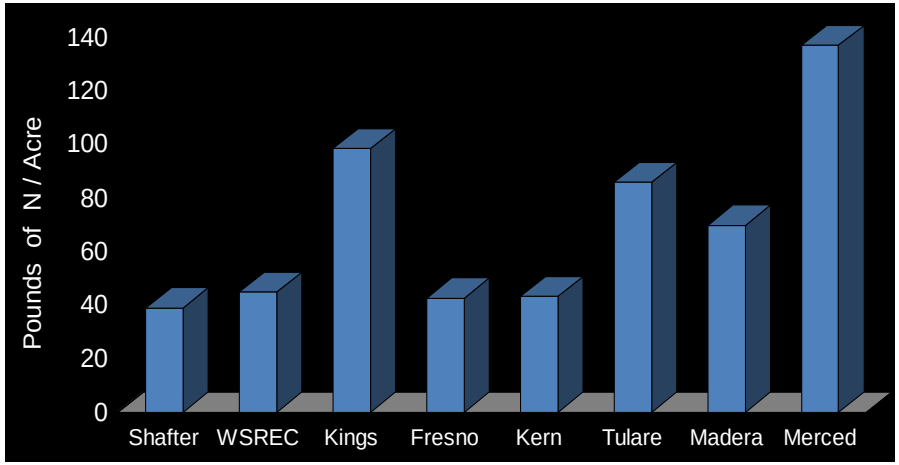
Practices that minimize winter N leaching (BMP's)

- Accounting for residual N early season



Practices that minimize winter N leaching (BMP's)

- Accounting for residual N early season



Practices that minimize winter N leaching (BMP's)

- Use N management plan to establish reasonable N balances.
- Monitor residual N post-harvest
- Limit late season N applications

Practices that minimize winter N leaching

(BMP's)

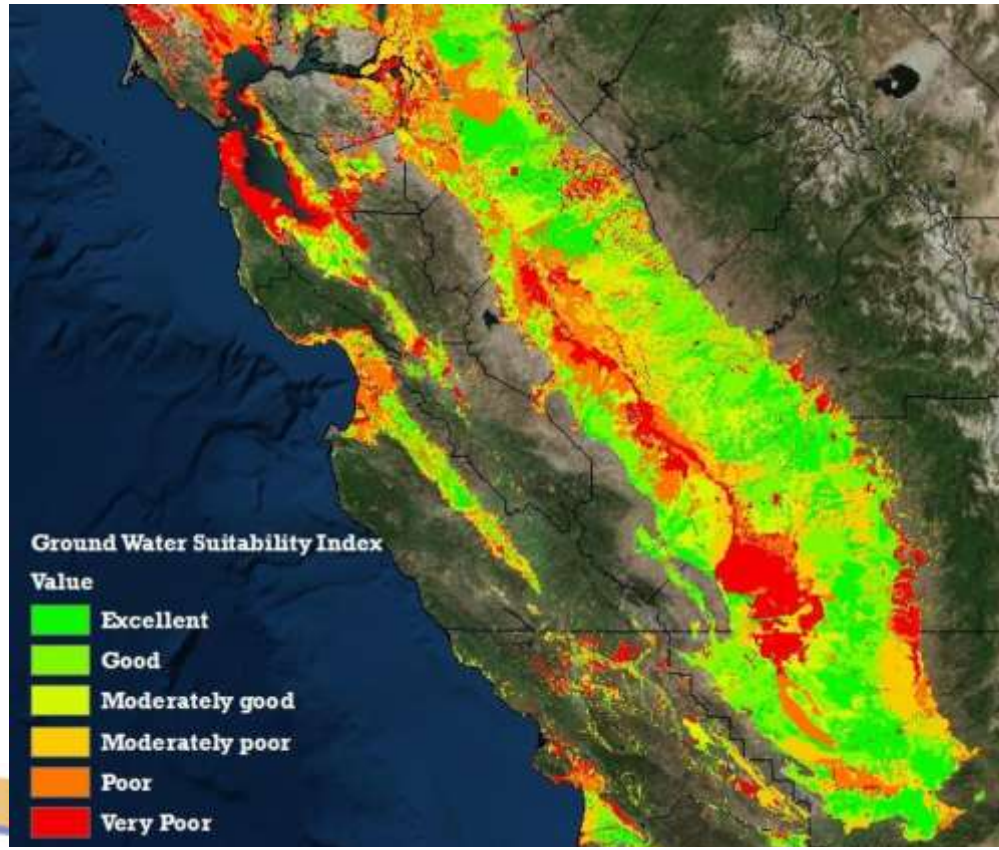
- In permanent crops
  - encourage late season N uptake post-harvest (almonds- rate, timing, tree health)
  - Consider cover cropped middles
  - Crop selection
- Annual cropping systems
  - Eliminate pre-plant N applications
  - Delay applications of composts and manures
  - Change crop to be planted

Questions?

Site characteristics vary widely- needs include:

- Identify areas of high potential for recharge

- Soil Agricultural GW banking index

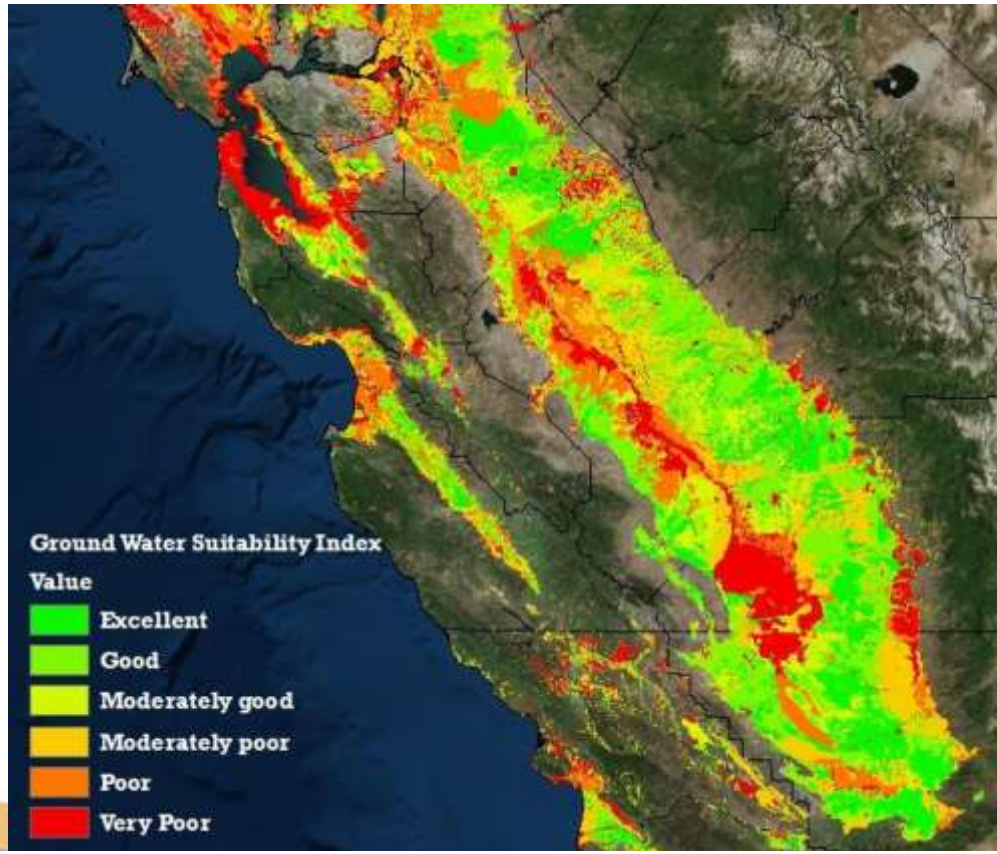


http://casoilresource.lawr.ucdavis.edu/sagbi

Site characteristics vary widely- needs include:

- Identify areas of high potential for recharge
- Develop field information on actual infiltration characteristics

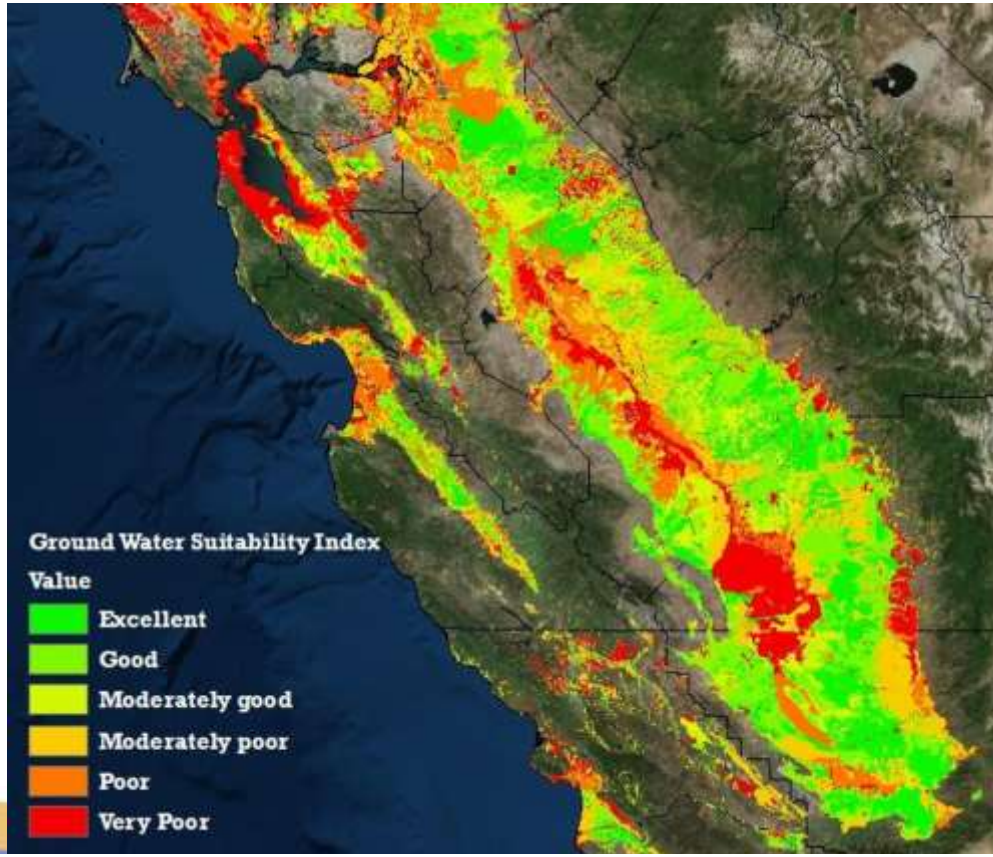
- Soil Agricultural GW banking index



Site characteristics vary widely- needs include:

- Identify areas of high potential for recharge
- Develop field information on actual infiltration characteristics
- Design and manage On-farm recharge systems

- Soil Agricultural GW banking index



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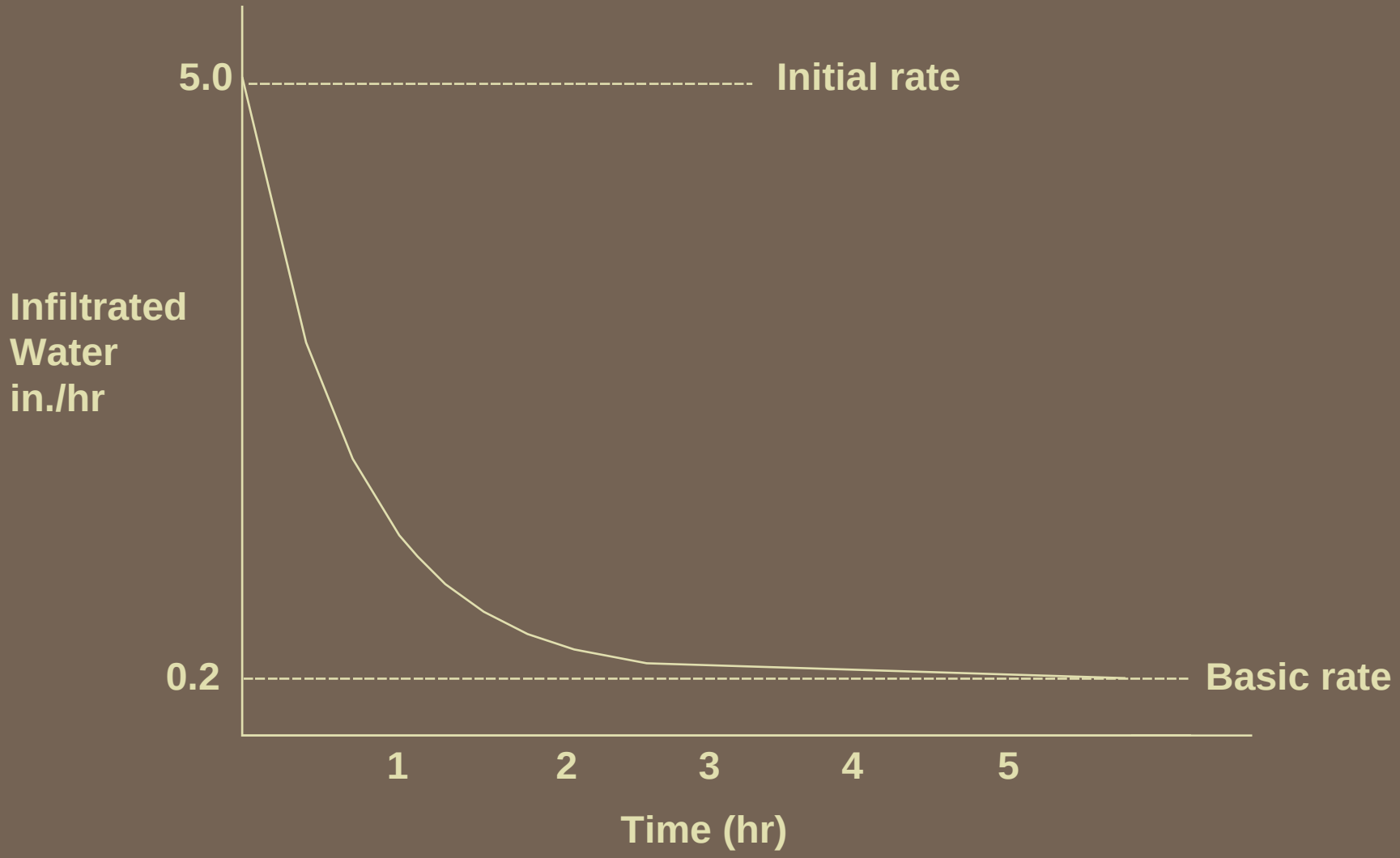
Agriculture and Natural Resourc

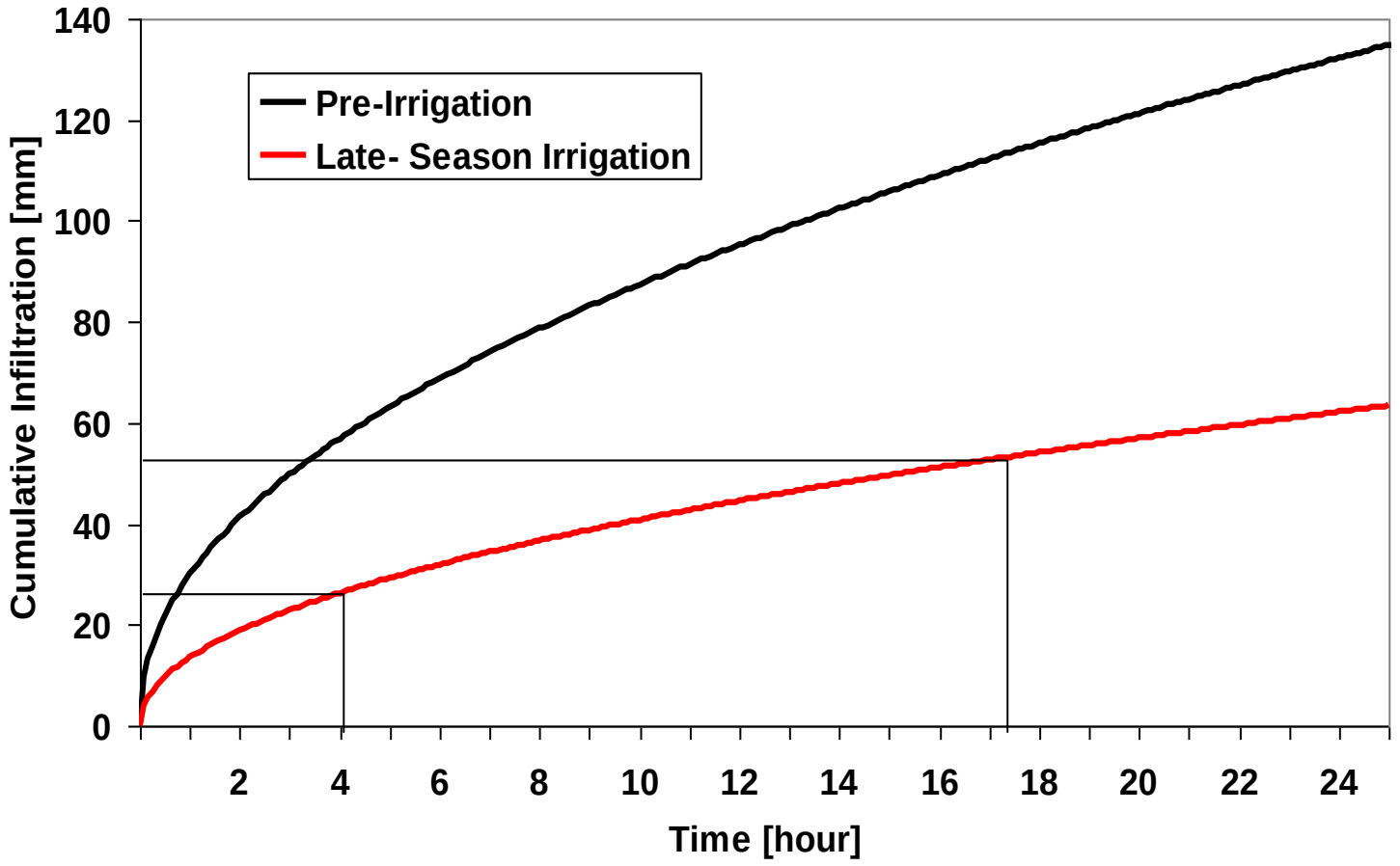
http://casoilresource.lawr.ucdavis.edu/sagbi

Soil Controlled Water Infiltration



Changing infiltration character

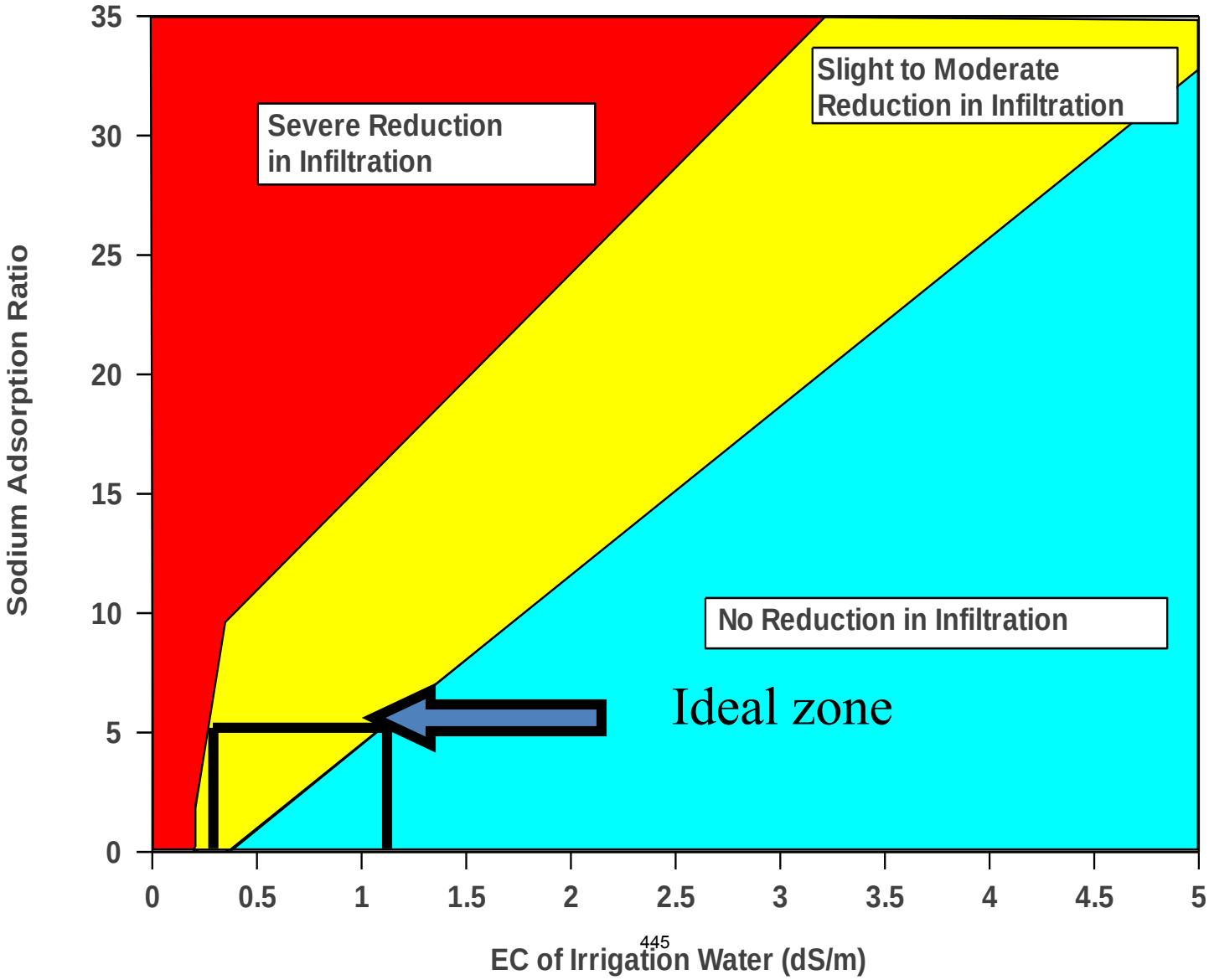
Hanford fine-sandy Loam

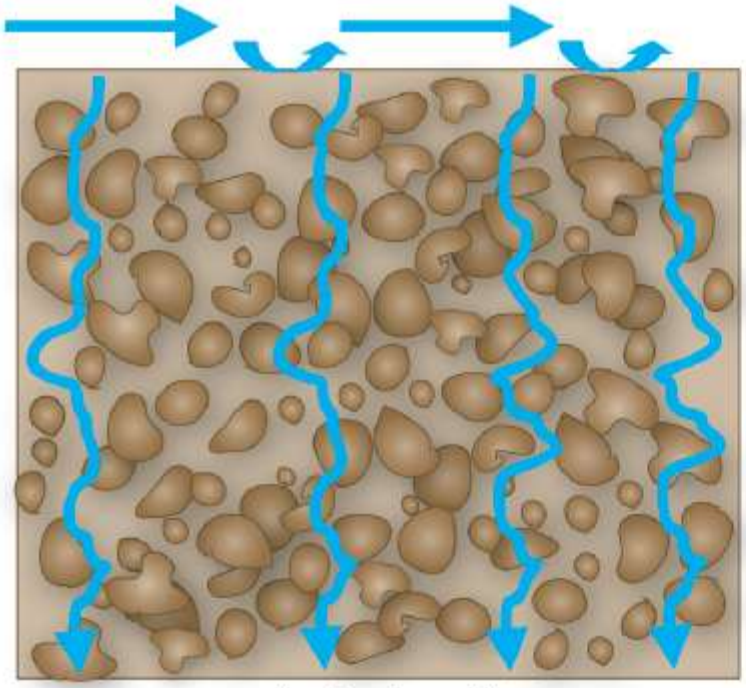


Water infiltration hazard

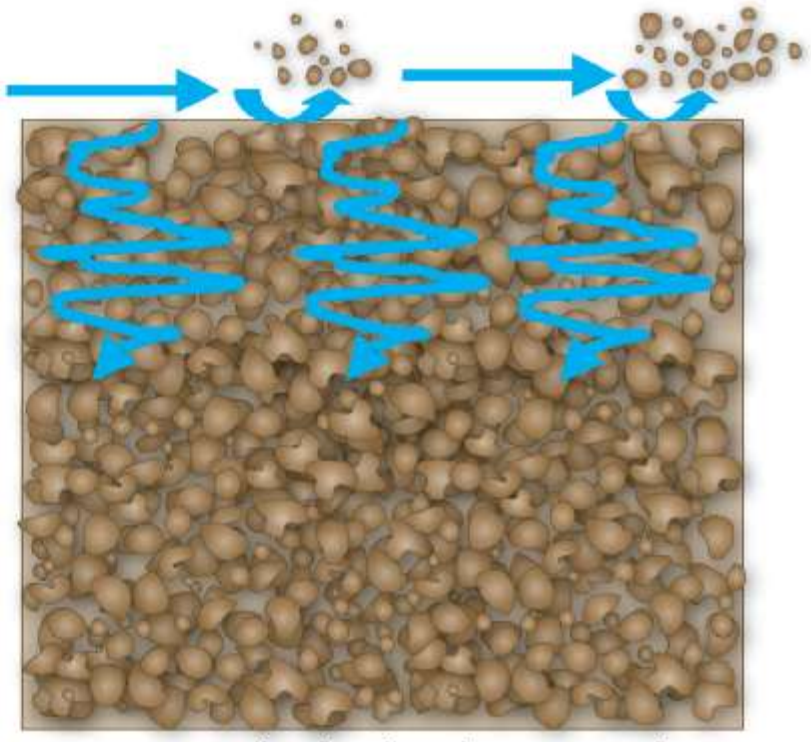


Salinity & Sodicity Impacts on Infiltration





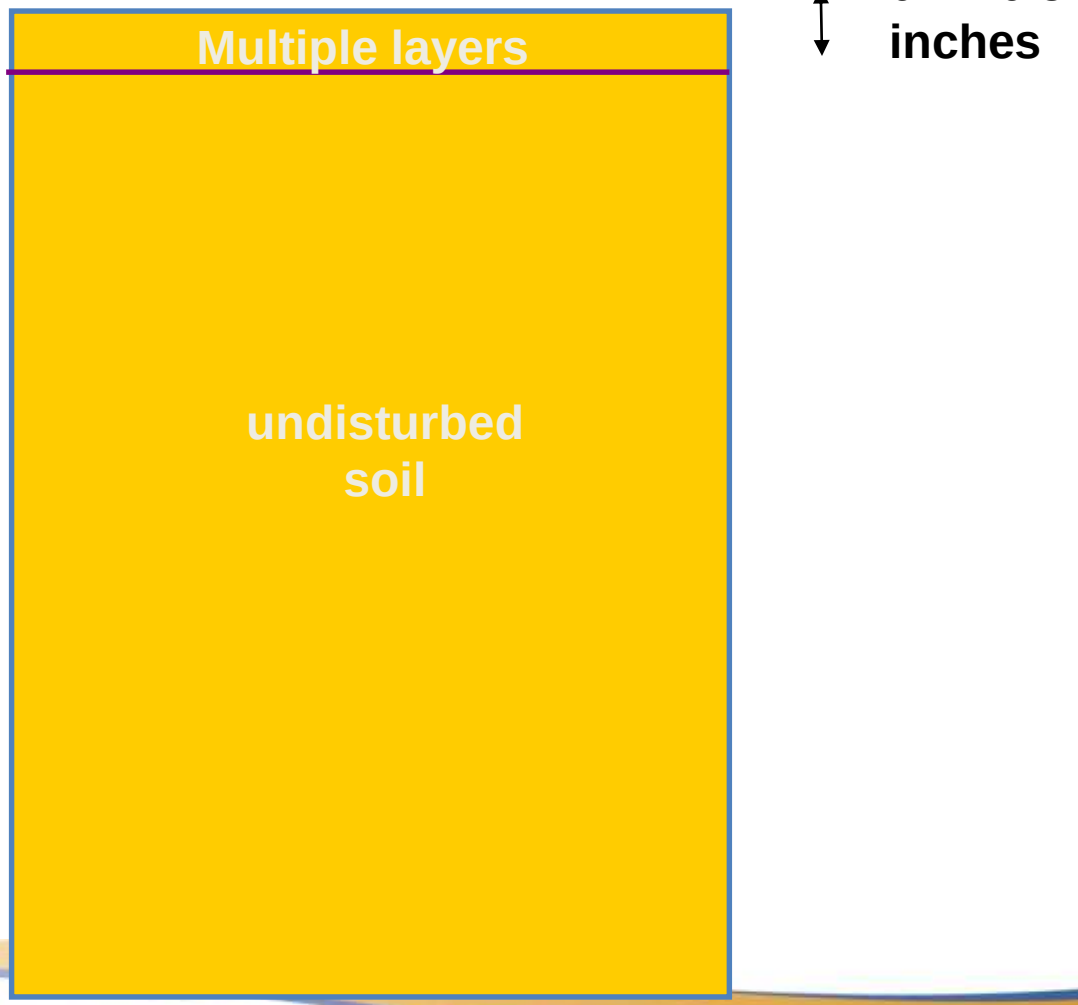
Uncompacted soil with stable aggregates



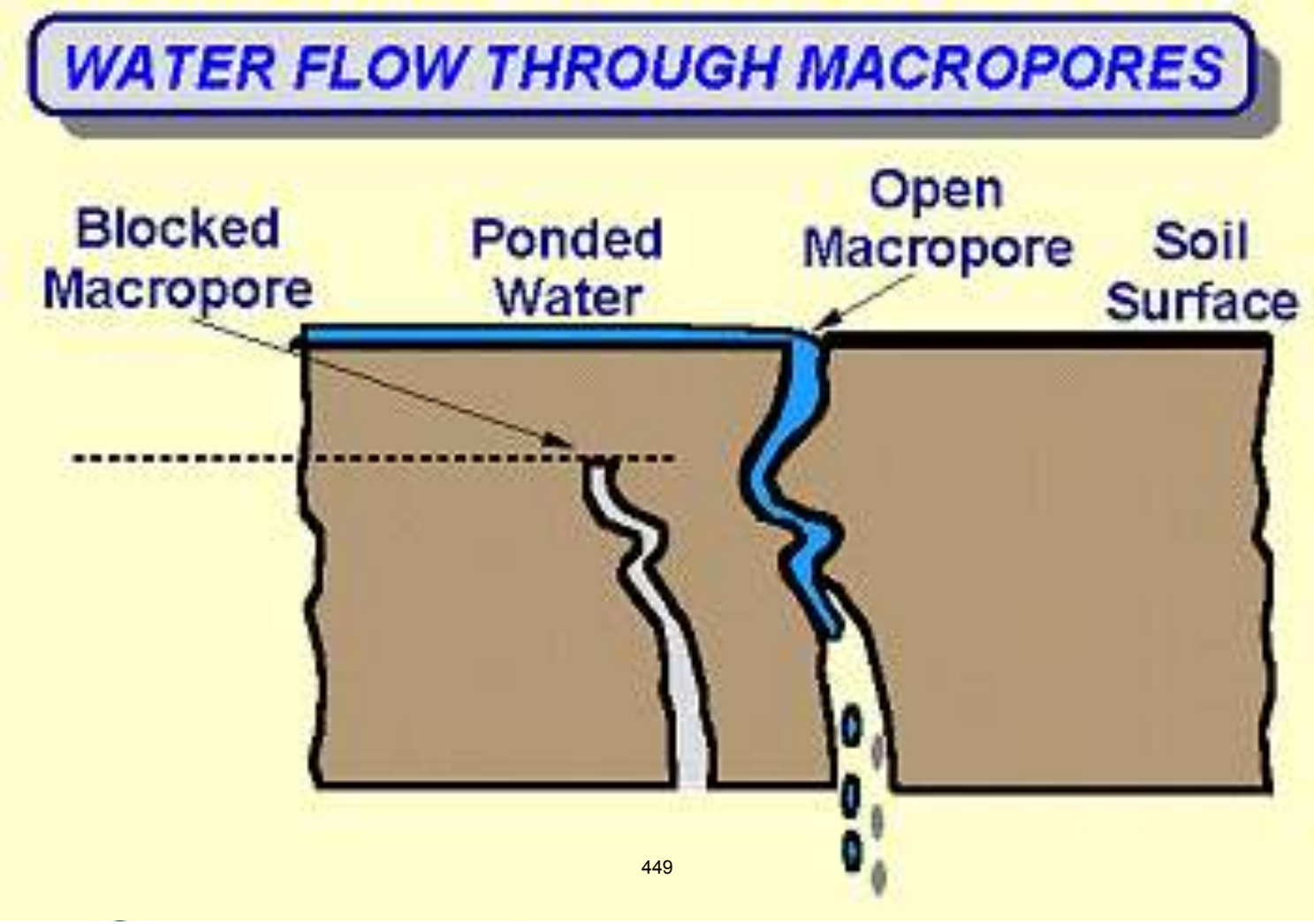
Compacted soil with surface crust and unstable aggregates


Depositional crusts
21 6'94

Depositional Crust



Soil Crusts & Access to Soil Pores

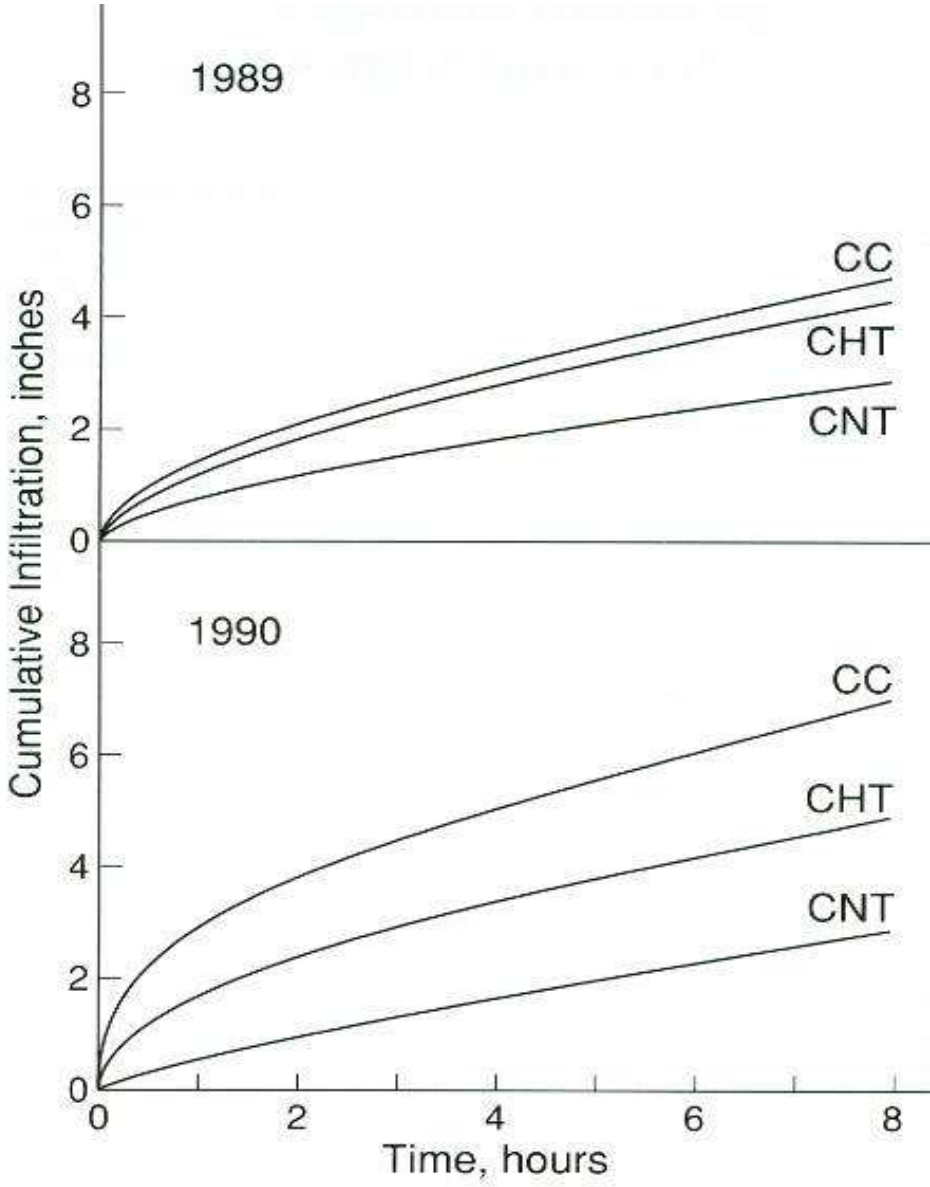


Cover Crops Impact Infiltration

- Water Penetration is strongly impacted by Surface Soil Conditions

- 2nd year effects were additive

Cover Crop: CC
Herb. treated Cover: CHT
No Cover treatment: CNT



Design and operations elements

Land management

- Cover crops
- Amendments
- Tillage (deep, scraping)
- Size and location





What Does the Future Hold for on-farm recharge?

- Continued Board presence, regulation



What Does the Future Hold for on-farm recharge?

- Continued Board presence
- Continued overdraft of GW resource



What Does the Future Hold for on-farm recharge?

- Continued Board presence
- Continued overdraft of GW resource
- SGMA



What Does the Future Hold for on-farm recharge?



presence

raft of GW

SGMA

- Unlikely increased above-ground storage



Move and Measure

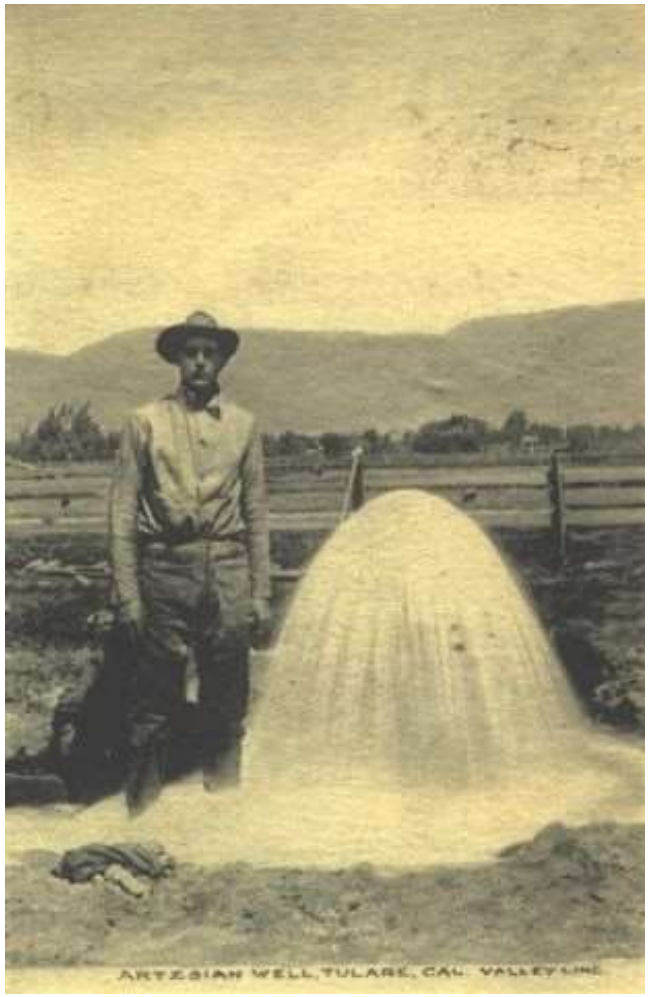











ARTESIAN WELL, TULARE, CAL. VALLEY LINE

Thanks

PRESENTATION 4

Philip Bachand, Bachand & Associates, “Local On-farm Flood Capture and Recharge Opportunities and Challenges”, Specialty Crop Nitrogen Management Workshop, 2017.

Local On-Farm Flood Capture and Recharge Opportunities and Challenges

June 14, 2017

Workshop: Capturing Excess Water for the Future
Terranova Ranch, Helm, CA

Philip A.M. Bachand, Ph.D.

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460

Contributers and Funding

- Contributers
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  - M. Ung, J. Rath and S. Roy, Tetra Tech
  - S. Carlton, Tetra Tech
  - H. Waterhouse, H. Dahlke and W. Horwath, UC Davis
  - D. Cameron, Terranova Ranch
  - C. Monreal, Provost and Pritchard
  - J. Choperena, D. Duncan and D. Mountjoy, Sustainable Conservation
  - C. Creamer, D. Merritt and E. Osterling, KRCD
  - Participating Growers

- Leveraged Funding
  - DWR Flood Corridor Program
  - Sustainable Conservation
  - CDFA Specialty Crop Block Grant
  - NRCS NIFA Program
  - Terranova Ranch

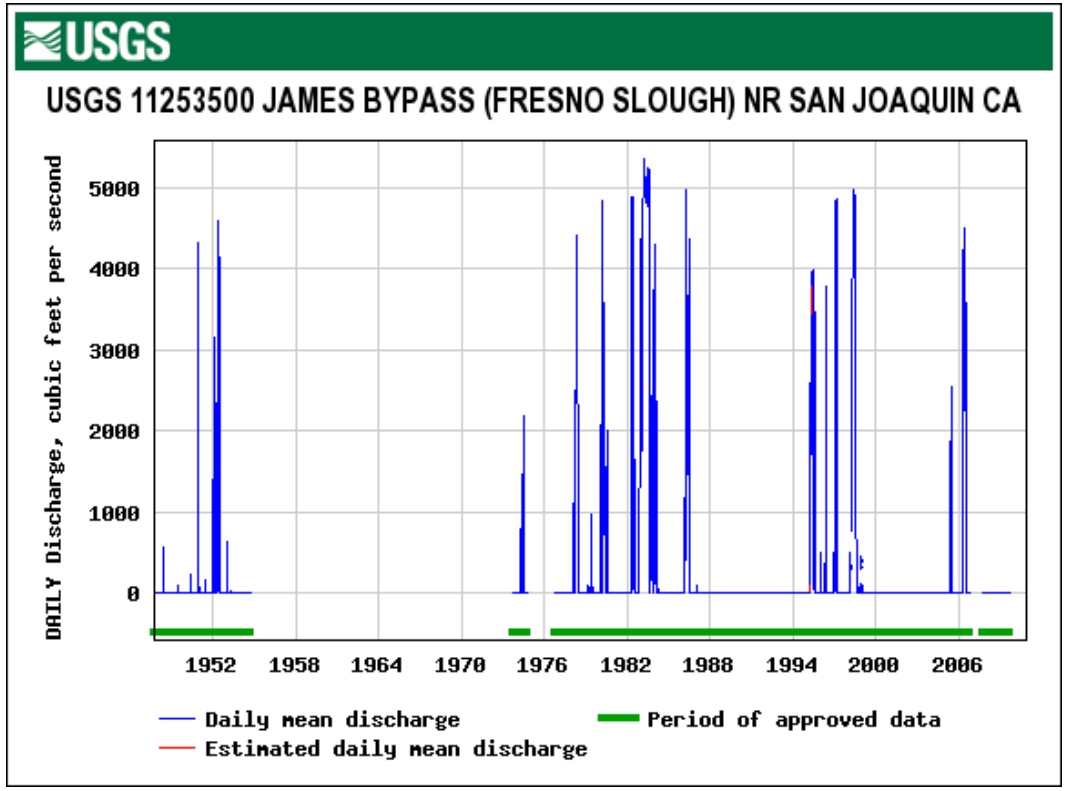
Recharge Take-aways

- What On-Farm Flood Capture and Recharge (OFFCR) Is?
- Scale of the Groundwater Problem, Statewide and Here
- The Costs for “New” Water
- The Opportunities and Constraints of Local Solutions
- Water Quality Concerns, How Much Nitrate Are We Talking About
- Next Steps in the Science and Engineering

On-Farm Flood Capture Definition and Vision

Capturing *Available* Flood Flows onto Farm Lands for Groundwater Recharge and to Mitigate Downstream Flood Risks

- *Available = Physical, Legal*
- Leveraging Private Lands
- Dual Use Farm and Flood
- Design into Farm Management
- Leveraging Community Resources





Recharge Opportunities and their Monitoring









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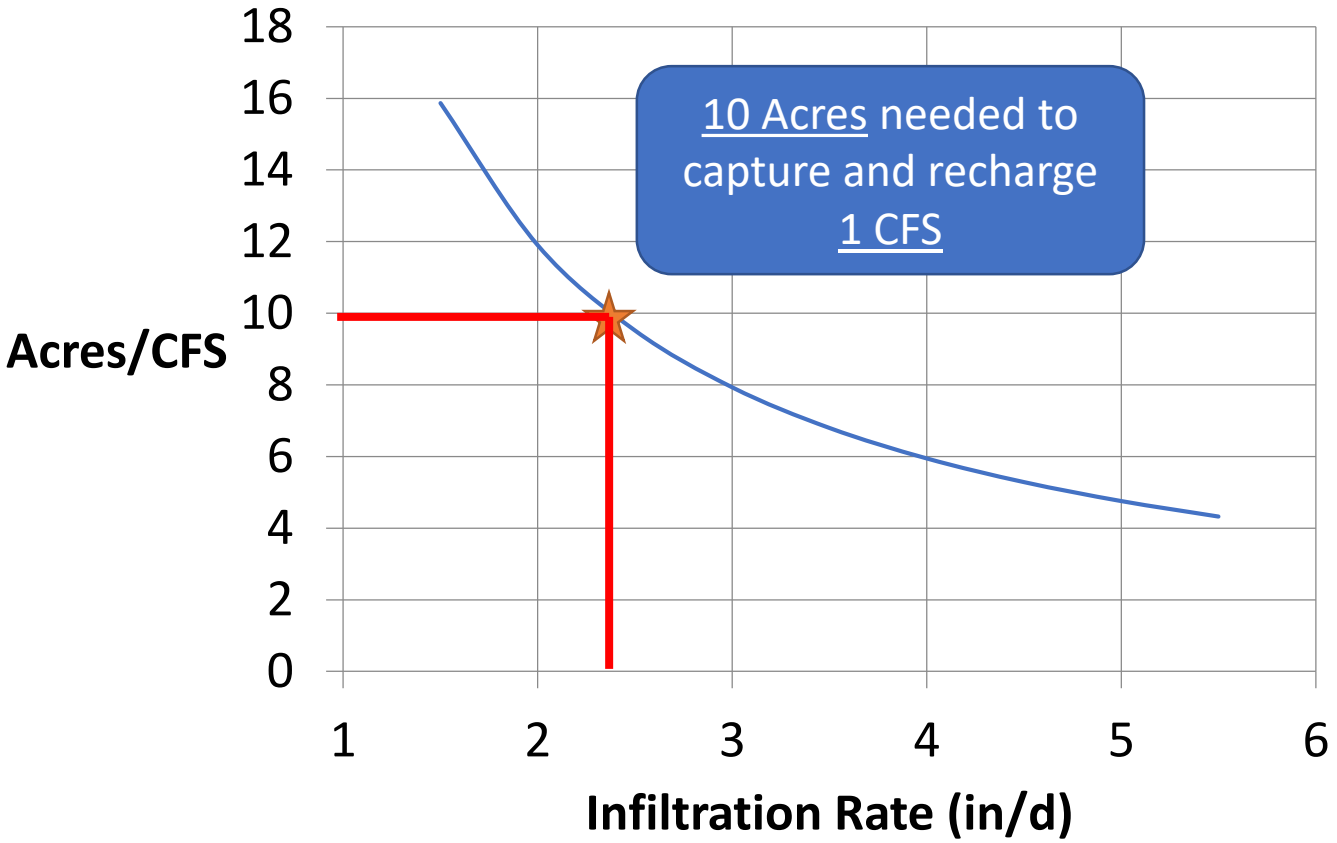
Predicting Acres/CFS ratio.



Vision

- *High infiltration rates*
- *Dual Use Farm Flood lands*
- *Mitigate Flood Risks*
- *Recharge*
- *Relatively Low Cost*

Bachand, P.A., Roy, S.B., Choperena, J., Cameron, D. and Horwath, W.R., 2014. Implications of using on-farm flood flow capture to recharge groundwater and mitigate flood risks along the Kings River, CA. *Environmental science & technology*, *48*(23), pp.13601-13609.

California Water Plan 2013
Chapter 3: California Water Today, DWR

Year	Lost GW Supply (MAF)
2001	9.7
2002	9.6
2003	8.7
2004	9.8
2005	4.1
2006	6.1
2007	11.5
2008	13.1
2009	13.1
2010	8.0
Mean	**9.4**
Median	**9.7**
Min	**4.1**
Max	**13.1**

Table 3-2 California Statewide Water Balance for 2001-2010 (in maf)

Statewide (maf)	Water Year (Percent of Normal Precipitation)									
	2001 (72%)	2002 (81%)	2003 (93%)	2004 (94%)	2005 (127%)	2006 (127%)	2007 (62%)	2008 (77%)	2009 (77%)	2010 (104%)
WATER ENTERING THE REGION										
Precipitation	139.2	160.1	184.4	186.5	251.9	251.1	123.3	152.2	151.8	205.0
Inflow from Oregon/Mexico	1.1	1.1	1.1	1.1	1.0	2.3	1.2	1.2	1.0	0.9
Inflow from Colorado River	5.2	5.4	4.5	4.8	4.2	4.6	4.7	4.9	4.6	4.7
Imports from Other Regions	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total	**145.5**	**166.6**	**190.0**	**192.4**	**257.1**	**258.0**	**129.2**	**158.3**	**157.4**	**210.6**
WATER LEAVING THE REGION										
Consumptive use of applied water[a] (Ag, M&I, Wetlands)	26.5	27.7	25.7	28.2	23.7	25.6	28.6	29.0	28.1	25.0
Outflow to Oregon/Nevada/ Mexico	0.5	0.8	1.1	0.8	1.4	2.1	0.8	0.9	1.0	1.1
Exports to other regions	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Statutory required outflow to salt sink	12.6	23.1	31.0	26.0	24.6	43.7	20.3	20.6	18.3	24.4
Additional outflow to salt sink	14.8	13.6	18.7	18.1	20.0	48.4	9.2	10.6	8.6	13.8
Evaporation, evapotranspiration of native vegetation, groundwater subsurface outflows, natural and incidental runoff, ag effective precipitation & other outflows	105.4	111.2	118.7	133.2	183.7	142.9	89.8	114.3	113.4	149.2
Total	**159.8**	**176.4**	**195.2**	**206.3**	**253.4**	**262.7**	**148.7**	**175.4**	**169.4**	**213.5**
CHANGE IN SUPPLY										
[+] Water added to storage [-] Water removed from storage										
Surface reservoirs	-4.6	0.1	3.7	-4.1	7.9	1.4	-8.0	-3.9	1.1	5.1
Groundwater[b]	-9.7	-9.6	-8.7	-9.8	-4.1	-6.1	-11.5	-13.1	-13.1	-8.0
Total	**-14.3**	**-9.5**	**-5.0**	**-13.9**	**3.8**	**-4.7**	**-19.5**	**-17.0**	**-12.0**	**-2.9**
Applied water[a] (ag, urban, wetlands) (compare with consumptive use)	43.7	46.6	43.3	47.2	41.6	44.4	48.1	47.9	46.5	42.7

Notes:

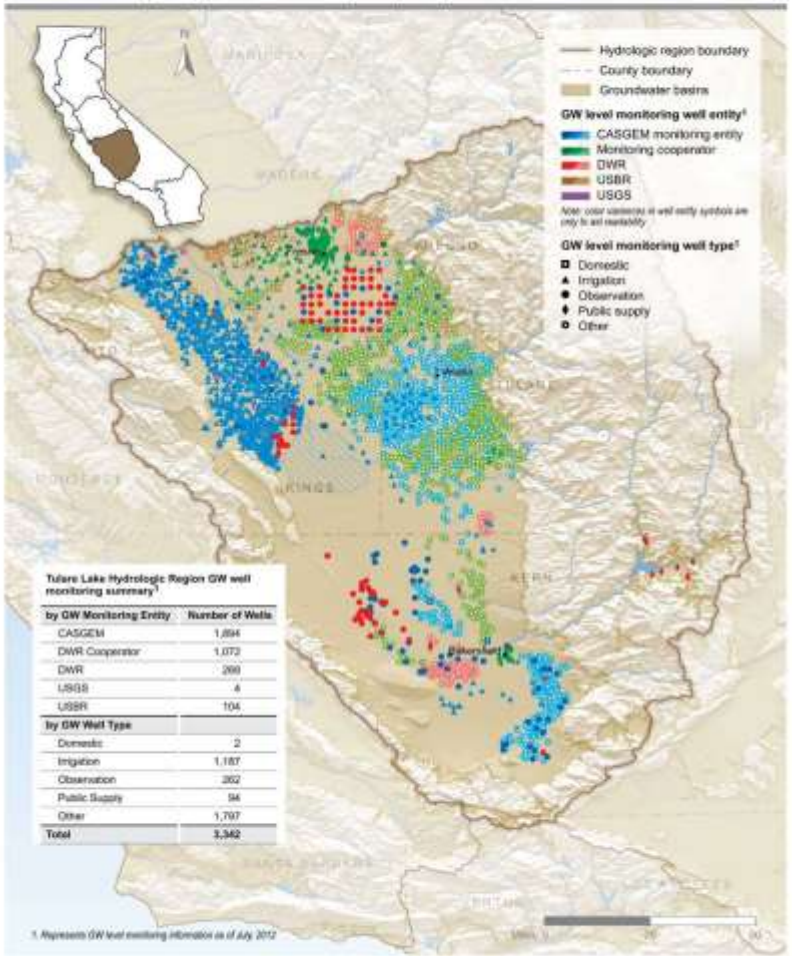
maf = million acre-feet, M&I = municipal and industrial

[a] Definition: Consumptive use is the amount of applied water used and no longer available as a source of supply. Applied water is greater than consumptive use because it includes consumptive use, reuse, and outflows.

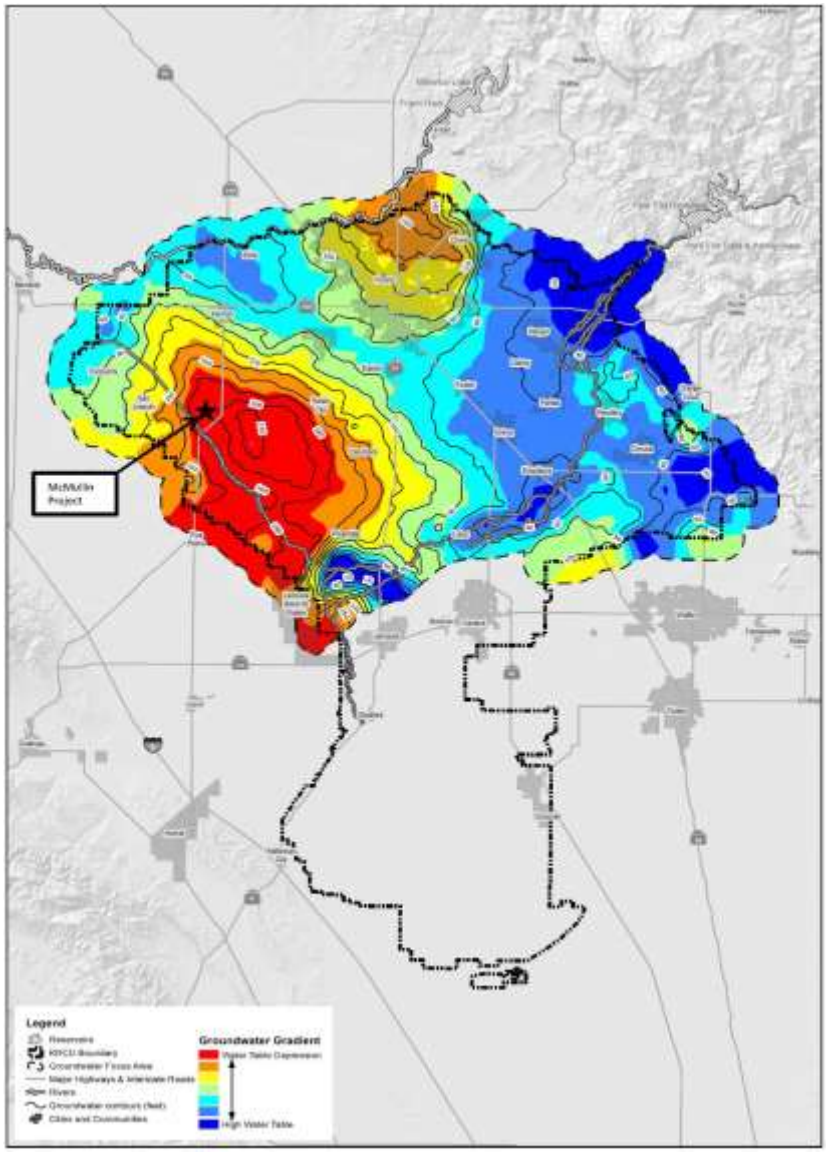
[b] Definition: Change in Supply: Groundwater – The difference between water extracted from and water recharged into groundwater basins in a region. All regions and years were calculated using the following equation: change in supply: groundwater = intentional recharge + deep percolation of applied water + conveyance deep percolation and seepage - withdrawals.

This equation does not include unknown factors such as natural recharge and subsurface inflow and outflow. For further details, refer to Volume 4, *Reference Guide*, the article "California's Groundwater Update 2013" and Volume 5, *Technical Guide*.

Figure TL-7 Monitoring Well Location by Agency, Monitoring Cooperator, and CASGEM Monitoring Entity in the Tulare Lake Hydrologic Region



by GW Monitoring Entity	Number of Wells
CASGEM	1,894
DWR Cooperator	1,072
DWR	269
USGS	4
USBR	104
by GW Well Type	
Domestic	2
Irrigation	1,187
Observation	262
Public Supply	94
Other	1,797
Total	**3,342**



California Water Plan 2013
Tulare Lake Hydrologic Region, DWR

Year	Lost GW Supply (MAF)
2001	4.1
2002	3.9
2003	3.0
2004	4.0
2005	0.1
2006	0.2
2007	4.1
2008	5.3
2009	5.5
2010	2.3
Mean	**3.2**
Median	**4.0**
Min	**0.1**
Max	**5.5**

Table TL-23 Tulare Lake Hydrologic Region Water Balance for 2001-2010 (in taf)

Tulare Lake (taf)	Water Year (Percent of Normal Precipitation)									
	2001 (87%)	2002 (71%)	2003 (88%)	2004 (85%)	2005 (120%)	2006 (123%)	2007 (50%)	2008 (77%)	2009 (71%)	2010 (116%)
WATER ENTERING THE REGION										
Precipitation	11,564	10,021	12,137	11,964	16,939	17,135	7,031	10,724	9,945	16,185
Inflow from Oregon/Mexico	0	0	0	0	0	0	0	0	0	0
Inflow from Colorado River	0	0	0	0	0	0	0	0	0	0
Imports from Other Regions	3,696	4,239	5,174	4,816	5,909	5,944	4,434	2,797	2,704	4,456
Total	**15,260**	**14,260**	**17,311**	**16,780**	**22,848**	**23,079**	**11,465**	**13,521**	**12,649**	**20,641**
WATER LEAVING THE REGION										
Consumptive use of applied water* (Ag, M&I, Wetlands)	7,986	8,124	7,667	8,221	6,953	7,376	8,214	8,592	8,684	7,668
Outflow to Oregon/Nevada/ Mexico	0	0	0	0	0	0	0	0	0	0
Exports to other regions	1,093	1,543	1,898	1,961	1,724	2,269	2,053	1,215	1,204	1,502
Statutory required outflow to salt sink	0	0	0	0	0	0	0	0	0	0
Additional outflow to salt sink	458	305	458	457	300	468	456	514	456	456
Evaporation, evapotranspiration of native vegetation, groundwater subsurface outflows, natural and incidental runoff, ag effective precipitation & other outflows	9,979	8,276	10,090	10,342	13,297	13,241	5,303	8,528	7,667	13,095
Total	**19,516**	**18,348**	**20,113**	**20,981**	**22,274**	**23,350**	**16,026**	**18,849**	**18,011**	**22,721**
CHANGE IN SUPPLY										
[+] Water added to storage [-] Water removed from storage										
Surface reservoirs	-141	-161	173	-199	680	-106	-473	-59	101	259
Groundwater*	-4,115	-3,927	-2,975	-4,002	-106	-163	-4088	-5269	-5463	-2339
Total	**-4,256**	**-4,088**	**-2,802**	**-4,201**	**574**	**-271**	**-4561**	**-5328**	**-5362**	**-2080**
Applied water* (ag, urban, wetlands) (compare with consumptive use)	11,320	11,722	11,343	11,977	10,731	11,347	12,036	12,310	12,470	11,408

Notes:
taf = thousand acre-feet, M&I = municipal and industrial
* Definition: Consumptive use is the amount of applied water used and no longer available as a source of supply. Applied water is greater than consumptive use because it includes consumptive use, reuse, and outflows.
* Definition: Change in Supply: Groundwater – The difference between water extracted from and water recharged into groundwater basins in a region. All regions and years were calculated using the following equation: change in supply: groundwater = intentional recharge + deep percolation of applied water + conveyance deep percolation and seepage - withdrawals.
This equation does not include unknown factors such as natural recharge and subsurface inflow and outflow. For further details, refer to Volume 4, *Reference Guide*, the article "California's Groundwater Update 2013" and Volume 5, *Technical Guide*.

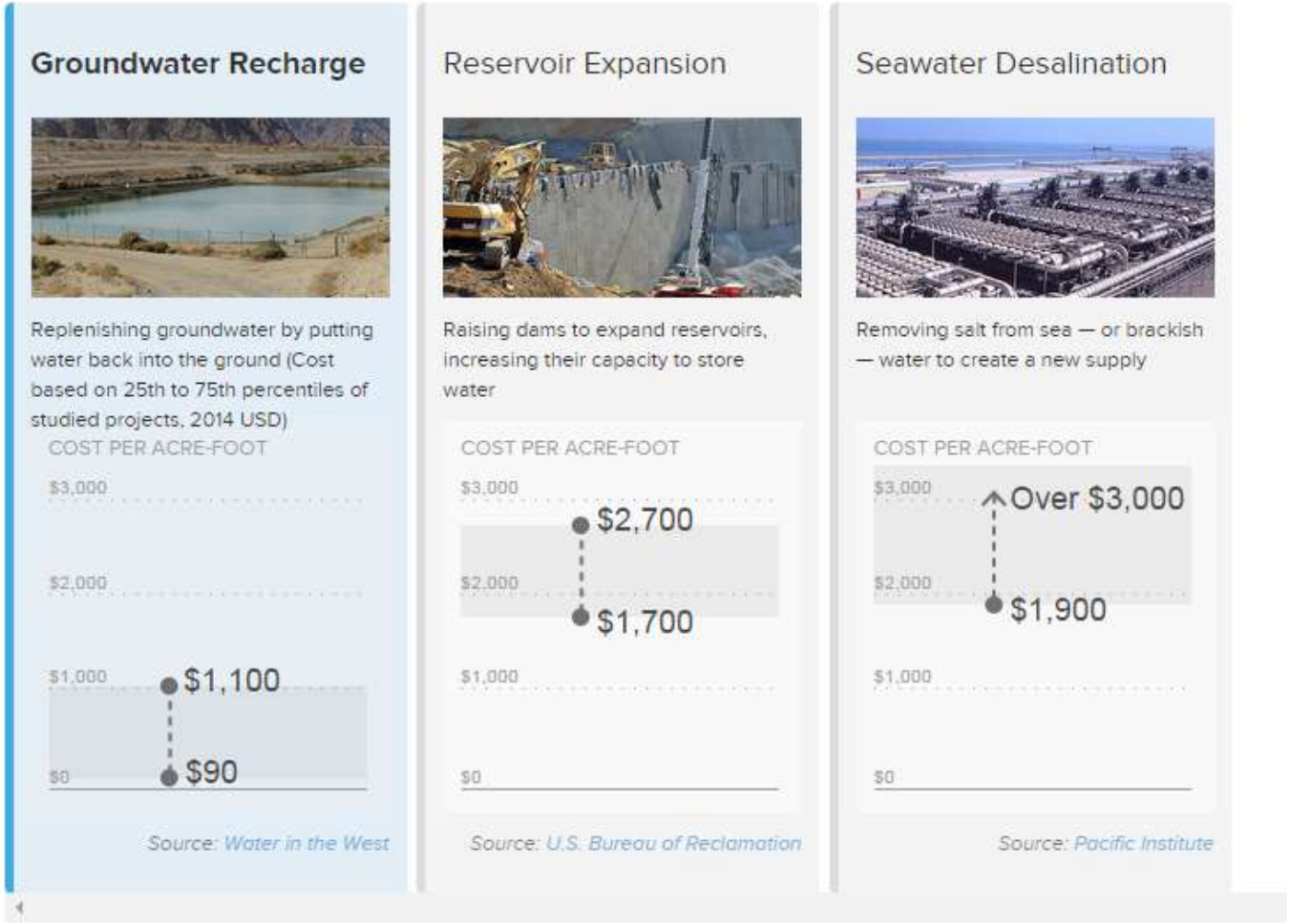
Changes in inputs and acreage from 2007 – 2012 on irrigated land (2012 USDA NASS Census Report)

Characteristics	Units	Irrigated Farms, Any land irrigated			Nonirrigated Farms		
		2012	2007	2012:2007	2012	2007	2012:2007
Land in farms	acres	16,039,761	16,231,930	99%	9,529,240	9,132,765	104%
Irrigated land	acres	7,861,964	8,016,159	98%		167,332	0%
Market value of agricultural products sold	$1,000	37,327,971	29,586,599	126%	5,299,501	4,298,465	123%
Total farm production expenses	$1,000	30,233,225	23,015,562	131%	5222442	3,947,079	132%
Fertilizer, lime, and soil conditioners purchased	$1,000	1,793,731	1,294,928	139%	12,331	19,247	64%
chemicals purchased	$1,000	2,171,784	1,347,595	161%	18,889	21,537	88%
Gasoline, fuels, and oils purchased	$1,000	1,402,954	998,021	141%	22,203	26,296	84%
Utilities	$1,000	1,571,566	1,132,624	139%	112,777	98,923	114%

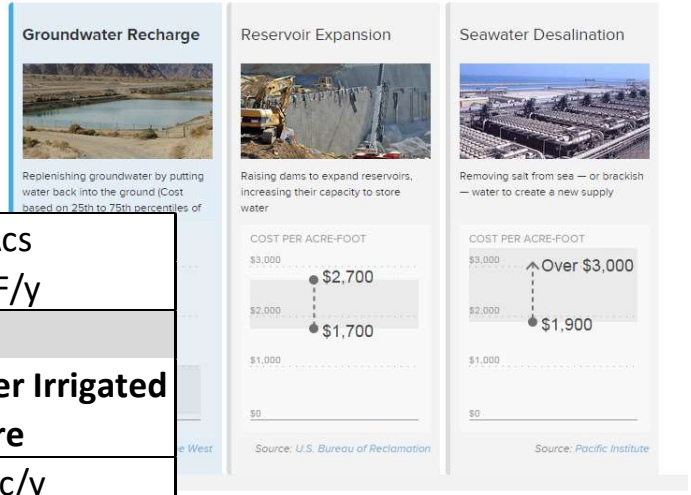
2007 – 2012

- Irrigated Land Acreage – No Change
- Production on Irr. Lands – Increase 30%
- Inputs on Irr. Lands – Increase 40 – 60%

Water Project Cost Comparison
(Recharge: Groundwater Second Act, Water in the West, 2015)



Water Project Cost Comparison Per Irrigated Acre (Recharge: Groundwater Second Act, Water in the West, 2015)



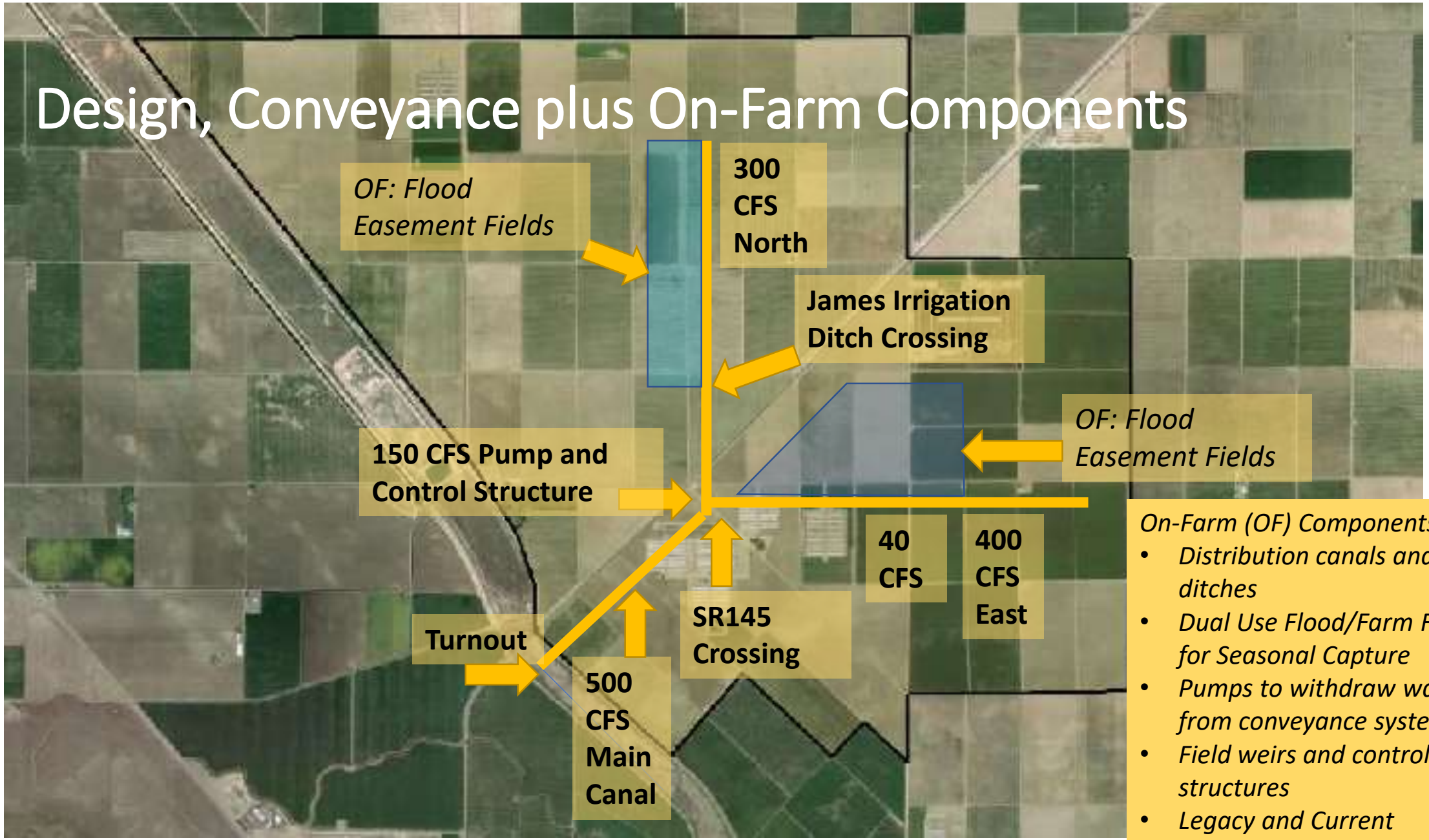
Irrigated Acres		8	MAcs
Annual CA Overdraft		10	MAF/y
Water Storage or Creation	**$/area**	**$/Year to cover annual Overdraft**	**Annual $s per Irrigated Acre**
	$s/ac-ft	M$s/y	$s/ac/y
Groundwater Recharge			
Min	90	$900	$113
Max	1,100	$11,000	$1,375
Reservoir Expansion			
Min	1,700	$17,000	$2,125
Max	2,700	$27,000	$3,375
Seawater Desalination			
Min	1,900	$19,000	$2,375
Max	3,000	$30,000	$3,750



Flood Corridor Project Expansion:

Phases 1, 2 and 3:
- Project Boundaries and
- Estimated Gross Acreage

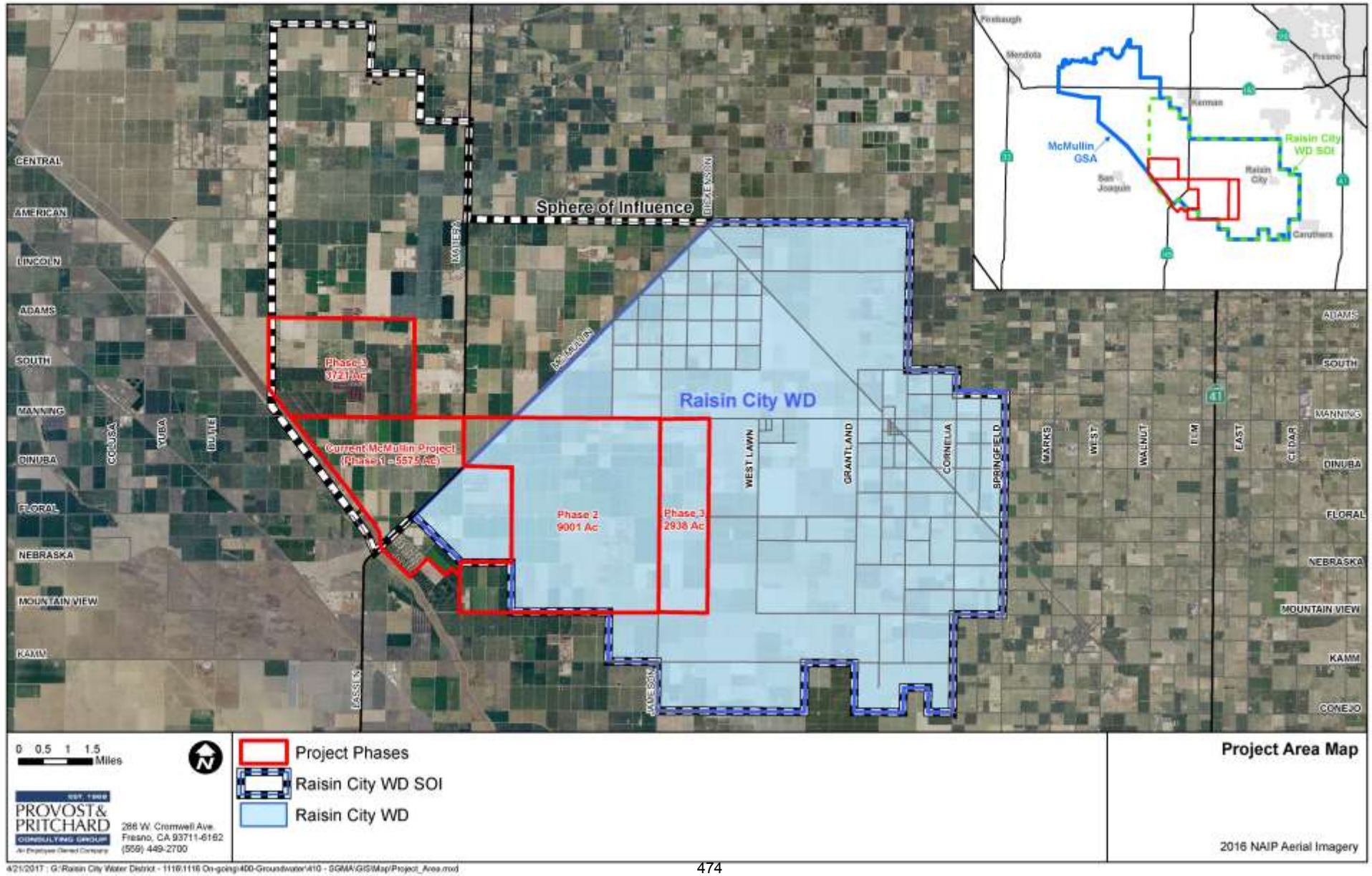
Design, Conveyance plus On-Farm Components



On-Farm (OF) Components:

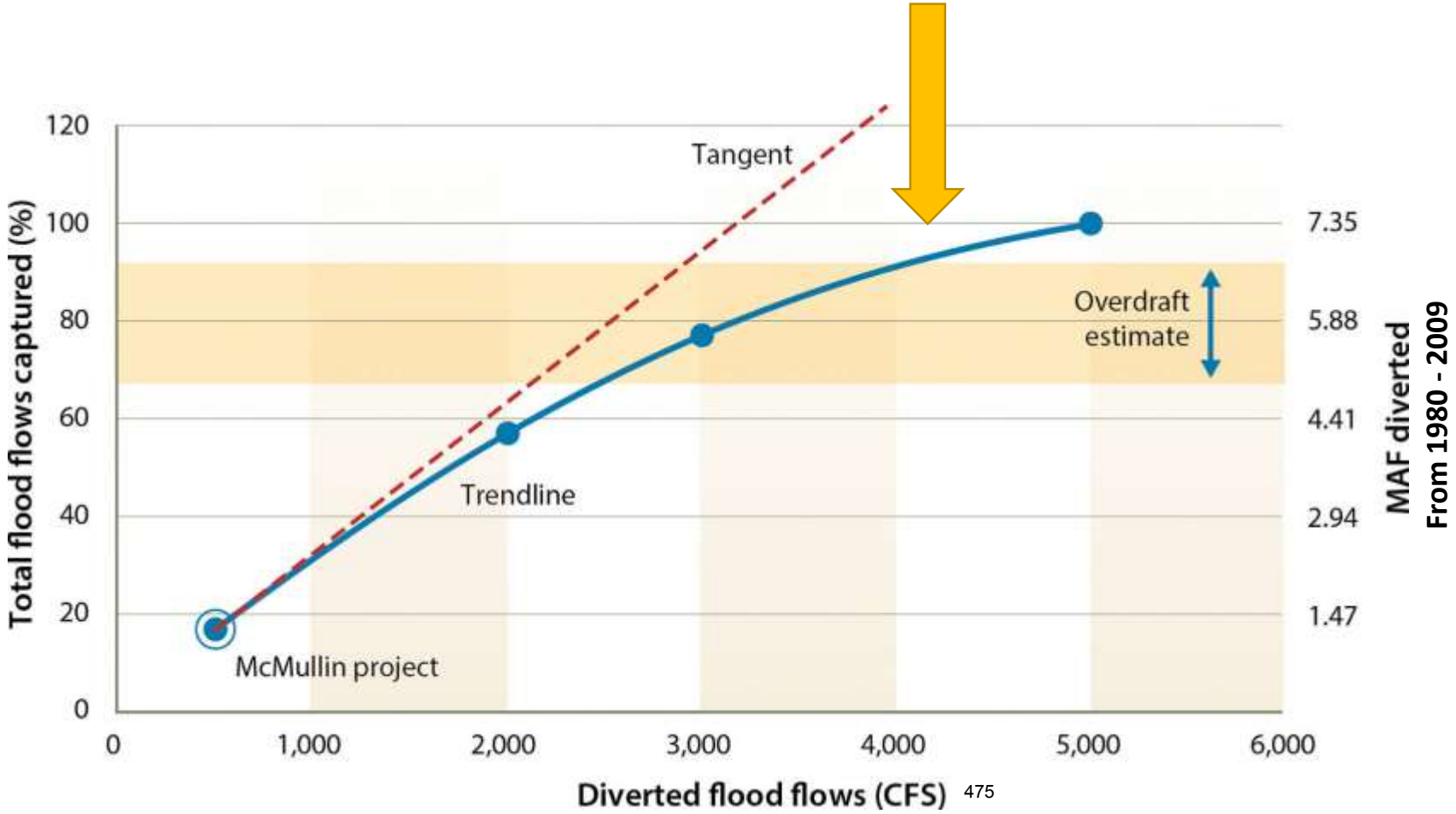
- *Distribution canals and ditches*
- *Dual Use Flood/Farm Fields for Seasonal Capture*
- *Pumps to withdraw water from conveyance system*
- *Field weirs and control structures*
- *Legacy and Current Irrigation system*

Proposed NRCS RCPP Project Expansion



Bachand, P., Roy, S., Stern, N., Choperena, J., Cameron, D. and Horwath, W., 2016. On-farm flood capture could reduce groundwater overdraft in Kings River Basin. *California Agriculture*, *70*(4), pp.200-207.

With added capacity, diminishing returns occur as fewer flood events large enough to fill the recharge system to full capacity occur.



How many McMullins are Needed in the Kings Basin to Offset GW Overdraft (annually)?

Example / Scenario	Mean	Units
Kings Basin		
Frequency of Flooding Beyond Capacity	2	1/yr
Typical Consecutive Wet Years	3	Yrs
Typical Consecutive Dry Years	3.3	Yrs
Typical Duration	3.5	Months
Annual Surplus Volume When Flood Flows Occurring	0.406	MAF/Flood Year
Period	20	years
20-year capacity	4.06	MAF/20-years
Phase 1		
Diversion Capacity When Flood Flows Available	150	CFS
	9,000	ac-ft per flood month
	315,000	ac-ft over 20 years
Design Capital Costs	7,000,000	S
	$22	$s/ac-ft over 20 year period
O&M: Pumping, Labor and Maintenance	$180	$/ac-ft
Mean Annual Diversion	15,750	annual mean ac-ft storage
	$2,835,000	$/year
Present Worth		
Net Interest Rate	1.00%	Percent
F (A/P)	18.0456	
Total	$58,159,143	Present Worth $s for 20 year period
	$185	*$/ac-ft*
Phase 2		
Diversion Capacity When Flood Flows Available	210	CFS
	12,600	ac-ft per flood month
	441,000	ac-ft over 20 years
Design Capital Costs	20,000,000	S
	$45	$s/ac-ft over 20 year period
O&M: Pumping, Labor and Maintenance	$180	$/ac-ft
Mean Annual Diversion	22,050	annual mean ac-ft storage
	$3,969,000	$/year
Present Worth		
Net Interest Rate	1.00%	Percent
F (A/P)	18.0456	
Total	$91,622,800	Present Worth $s for 20 year period
	$208	*$/ac-ft*

Assumes about $100/ac-ft in pumping and $80/ac-ft in all other Labor and Maintenance Costs

How many McMullins are Needed in the Kings Basin to Offset GW Overdraft (annually)

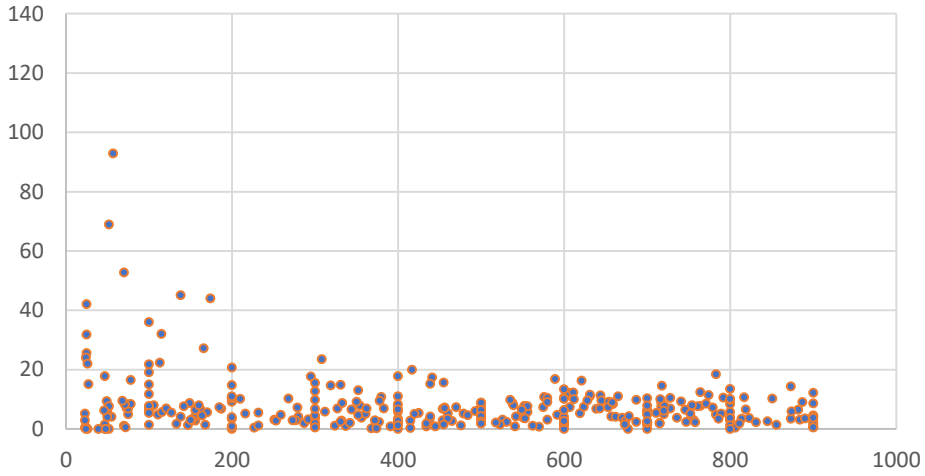
....

and what do costs begin to look like?

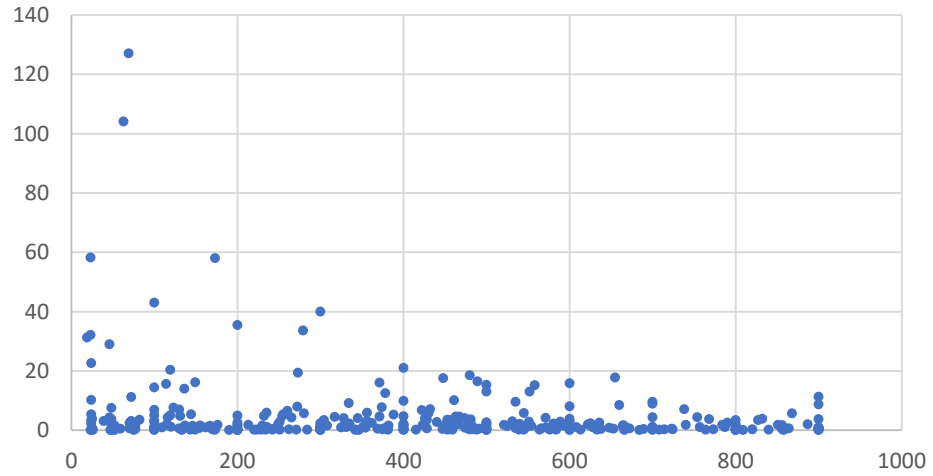
Preliminary Present Worth Analysis

Equilibrium NO3-N Profile in top 9 meters at Study Farms

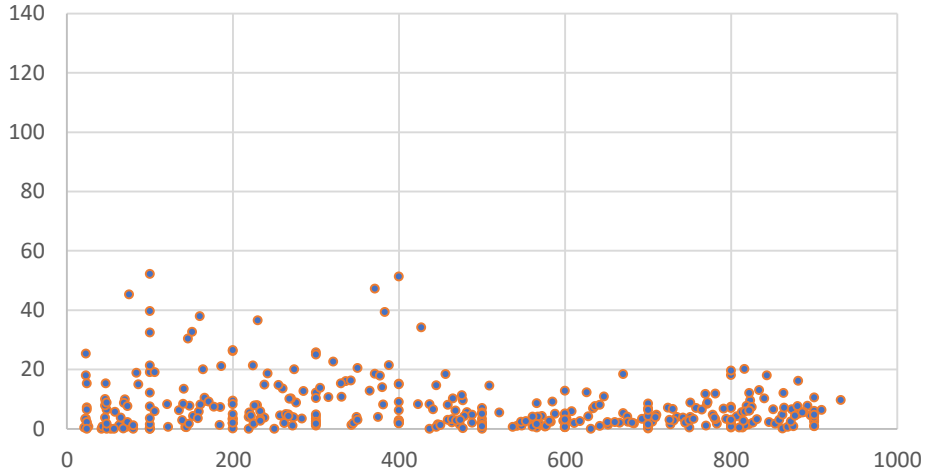
Tomatoes: NO3-N (ug/g)



Grapes: NO3-N (ug/g)

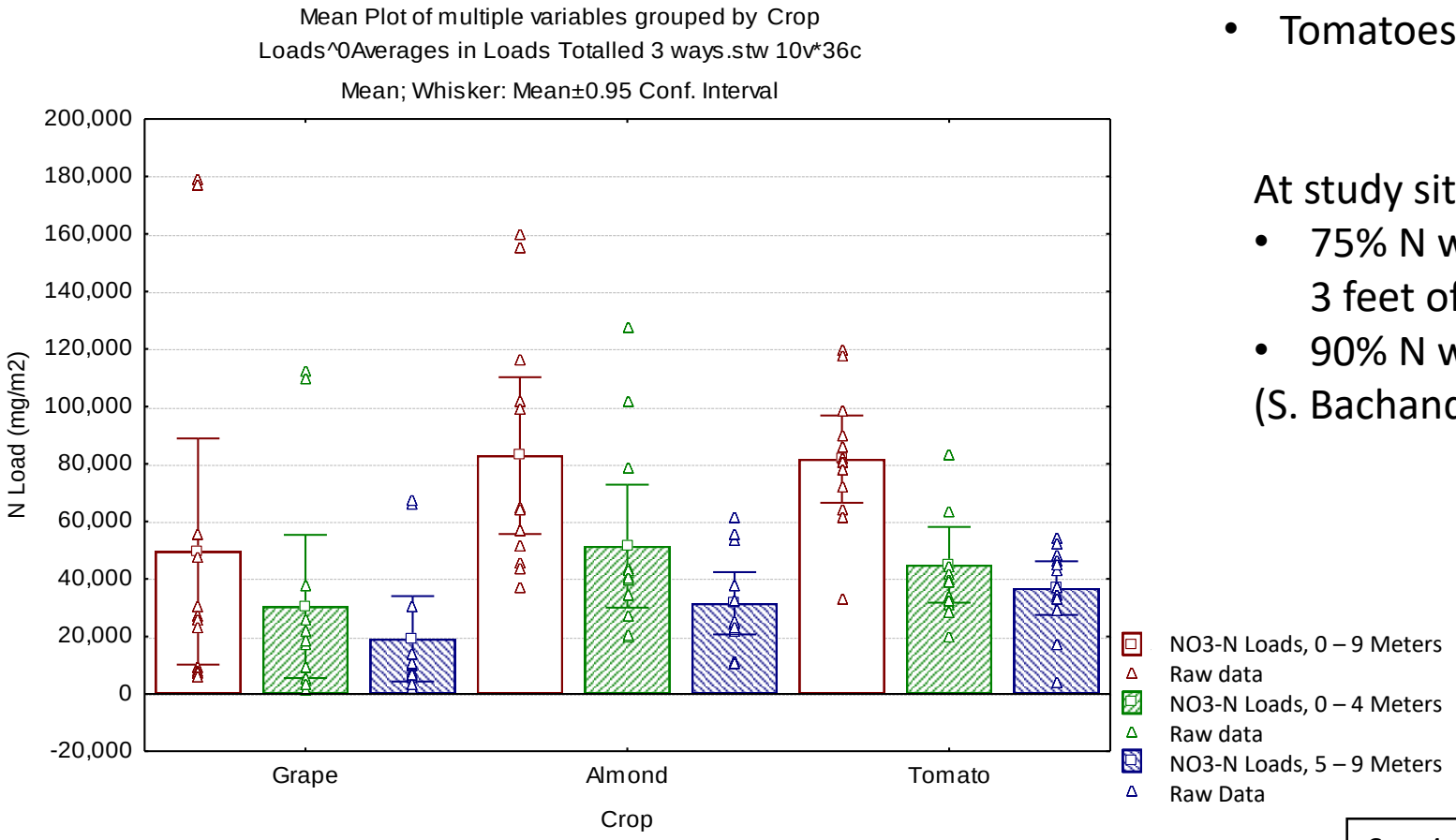


Almonds: NO3-N (ug/g)



Specialty Crop Block Grant –
Modeling Transport to Groundwater Under OFFCR
Preliminary Results

20,000 mg/m^2 ~ 200 lbs/ac



Total Loads in the Top 9 Meters:

- Loads lowest in Grapes
- Tomatoes and Almonds have similar loads

At study site:

- 75% N was flushed from upper 9 meters under 3 feet of recharge
- 90% N was flushed under 6 feet of recharge

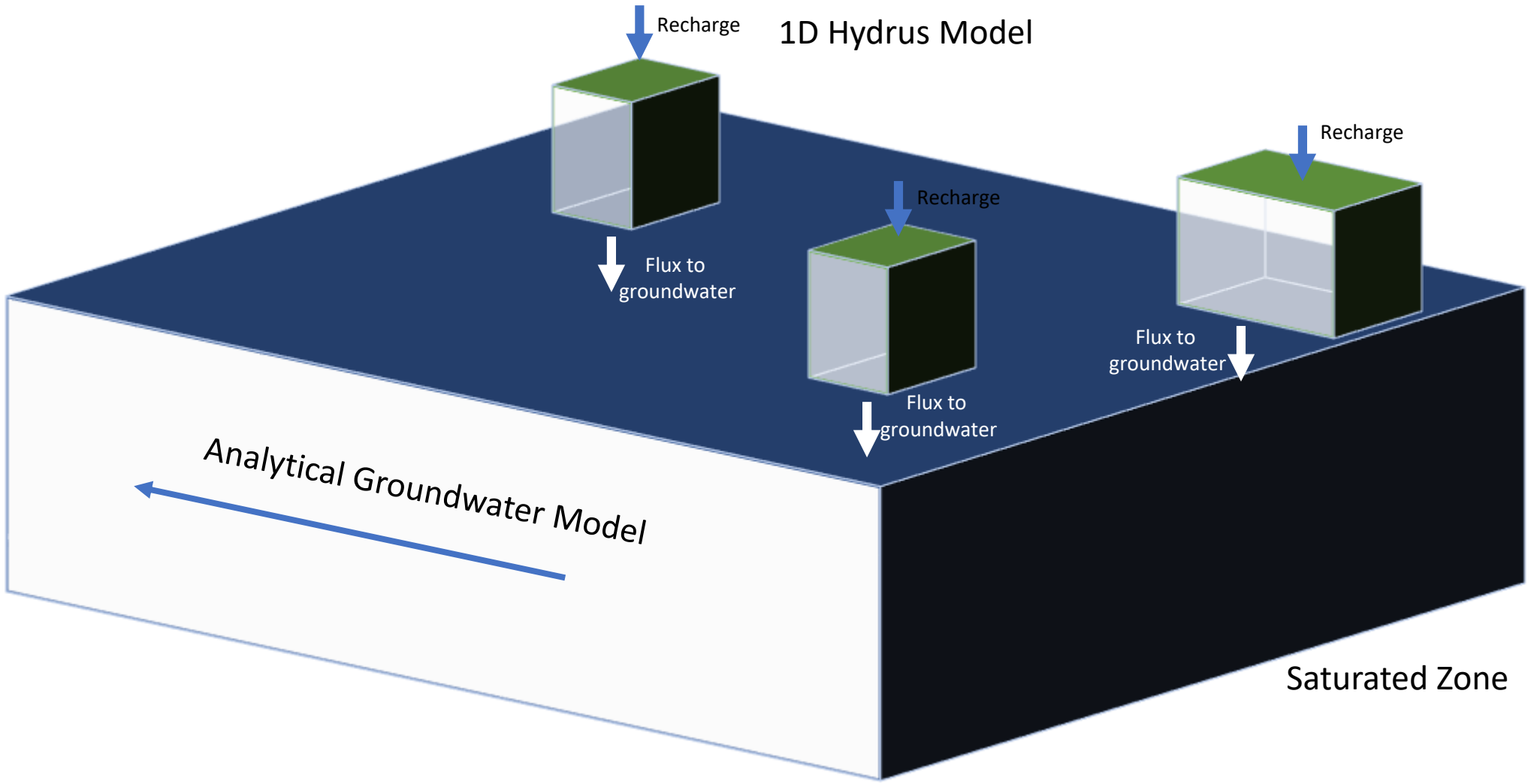
(S. Bachand, S. Carlton and P. Bachand, 2017)

Specialty Crop Block Grant –
Modeling Transport to Groundwater Under OFFCR
Preliminary Results

Nitrate Leaching Modeling Study

- 1D HYDRUS Model stacked on Analytical Groundwater Model
  - Unsaturated zone 60 m (200 ft)
  - Assume background NO3-N in vadose zone of 5 mg-N/L
- Preliminary Model Run
  - 2 and 10 feet of annual recharge per flood event year
  - Use flood event signature from last 25 years
  - Run on various crops (e.g. tomotoes, grapes, almonds)

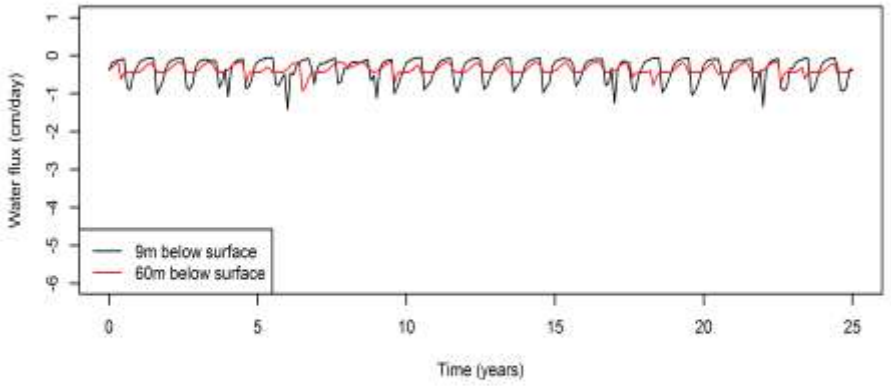
Model Framework

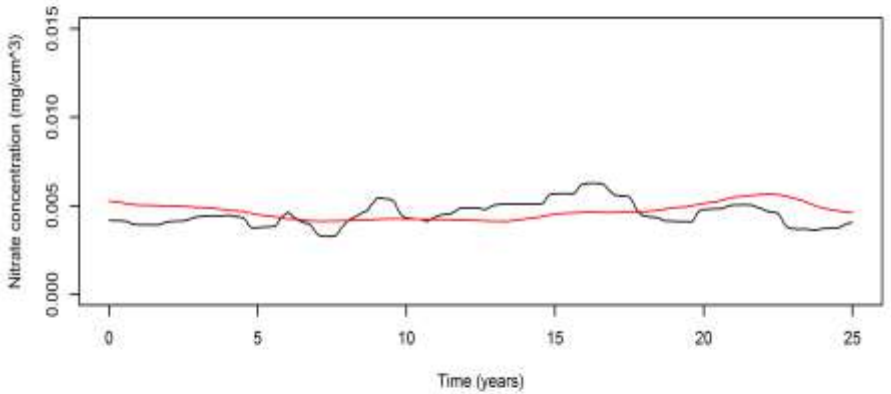


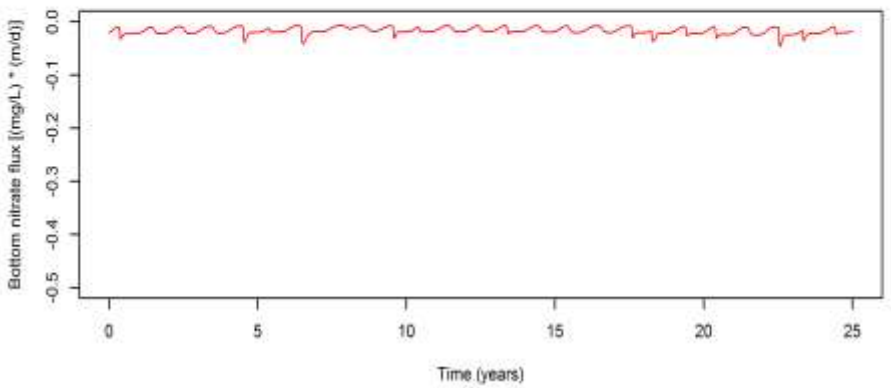
Specialty Crop Block Grant – Modeling Transport to Groundwater Under OFFCR Preliminary Results

Ung, Rath, Roy, S. Bachand and P. Bachand, 2017

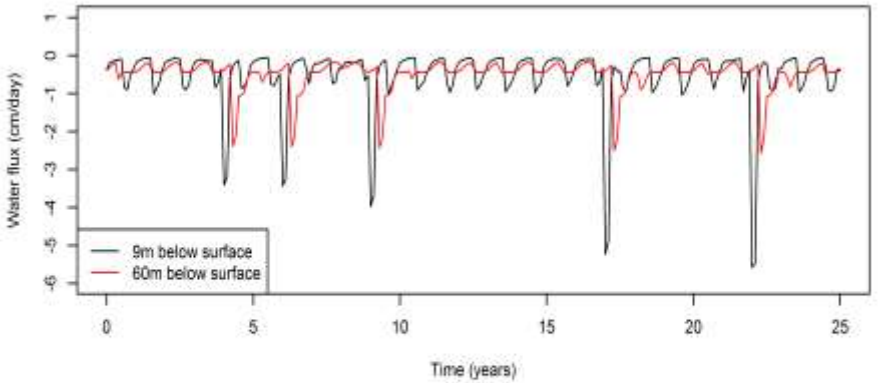
Grapes, 2 ft of recharge

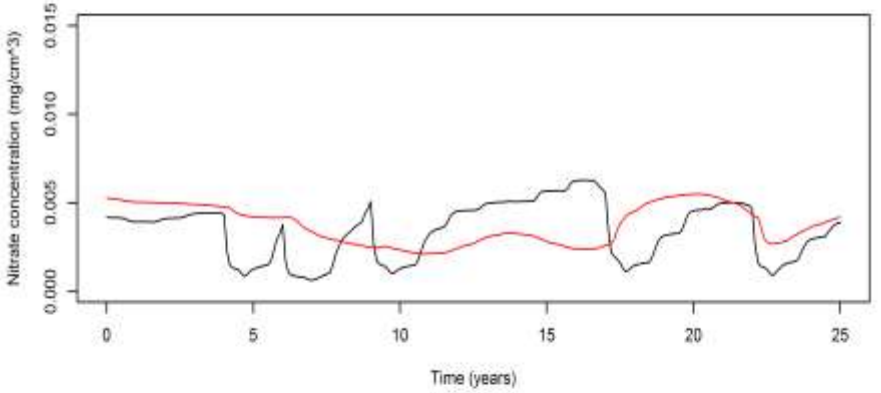


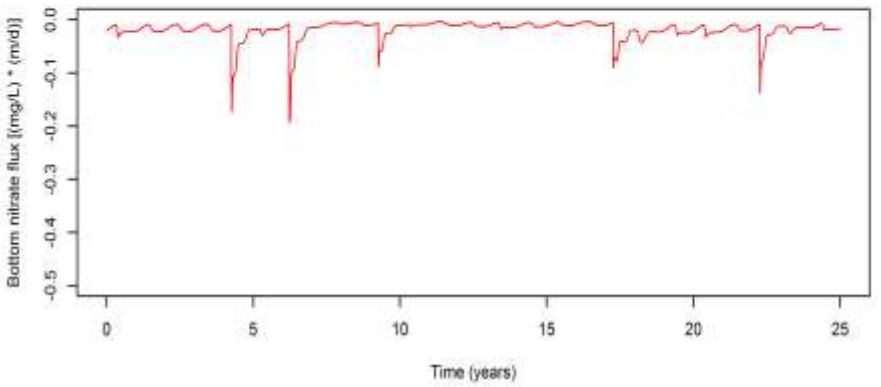




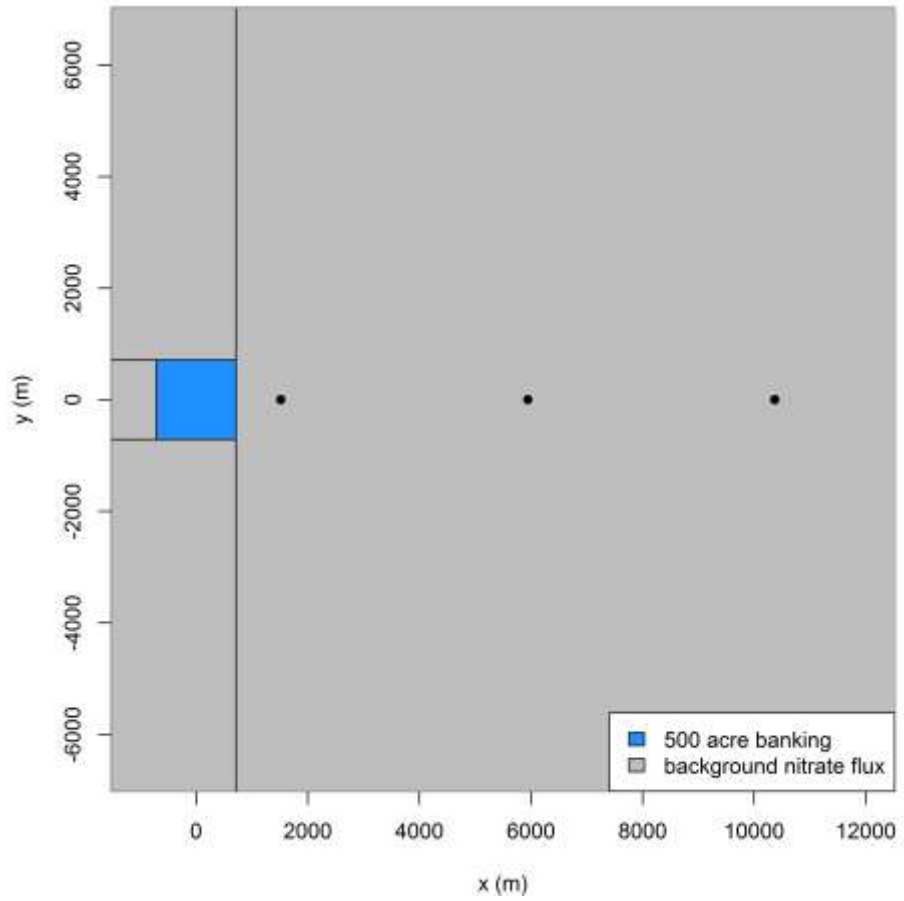
Grapes, 10 ft of recharge







Boundary condition geometry and observations points

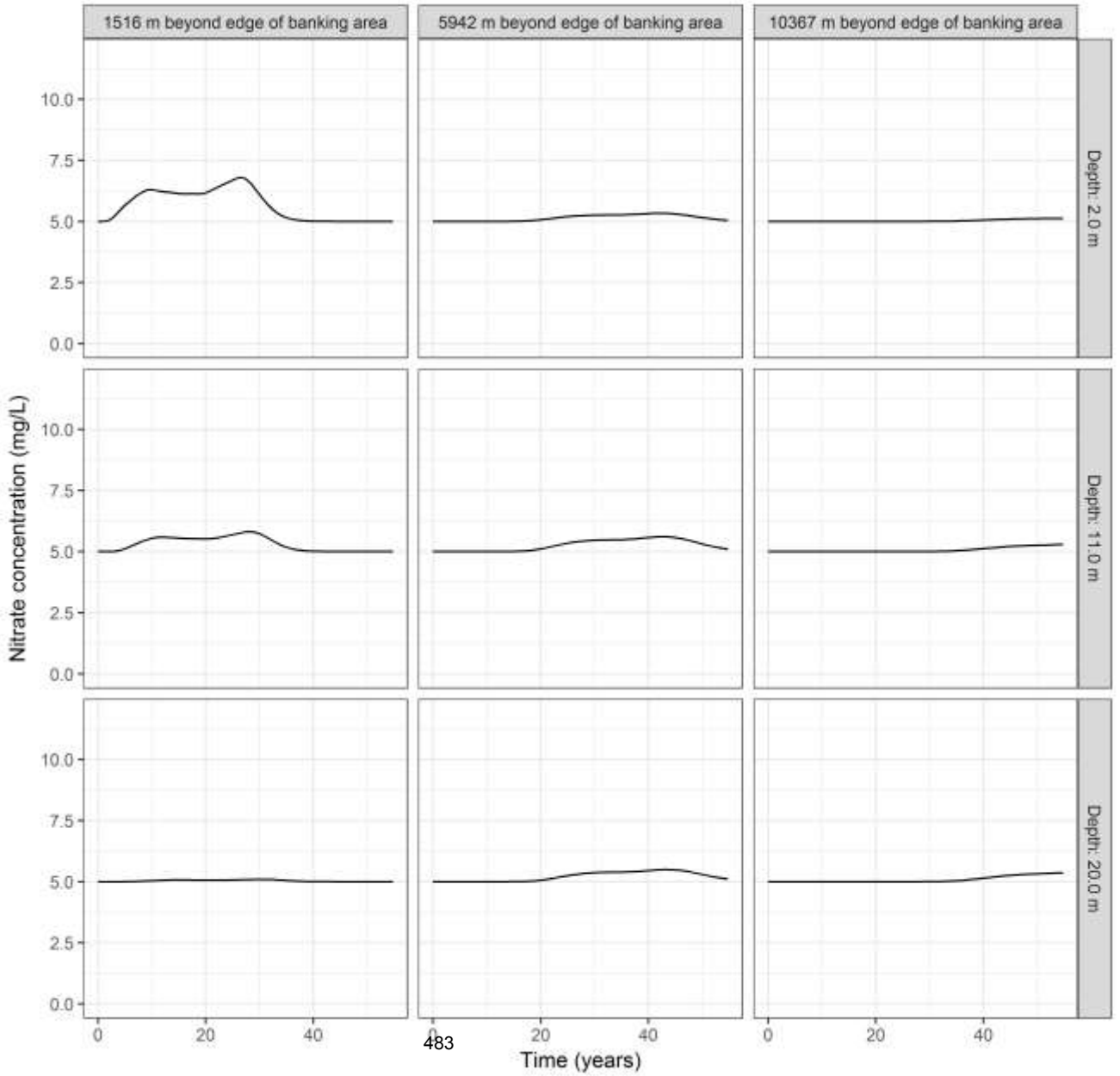


Grape Example Scenario:

- **2-ft recharge per recharge year**
- Vx = 2 ft/d
- Vz = 0.003 ft/d

Specialty Crop Block Grant – Modeling Transport to Groundwater Under OFFCR Preliminary Results

Ung, Rath, Roy, S. Bachand and P. Bachand, 2017

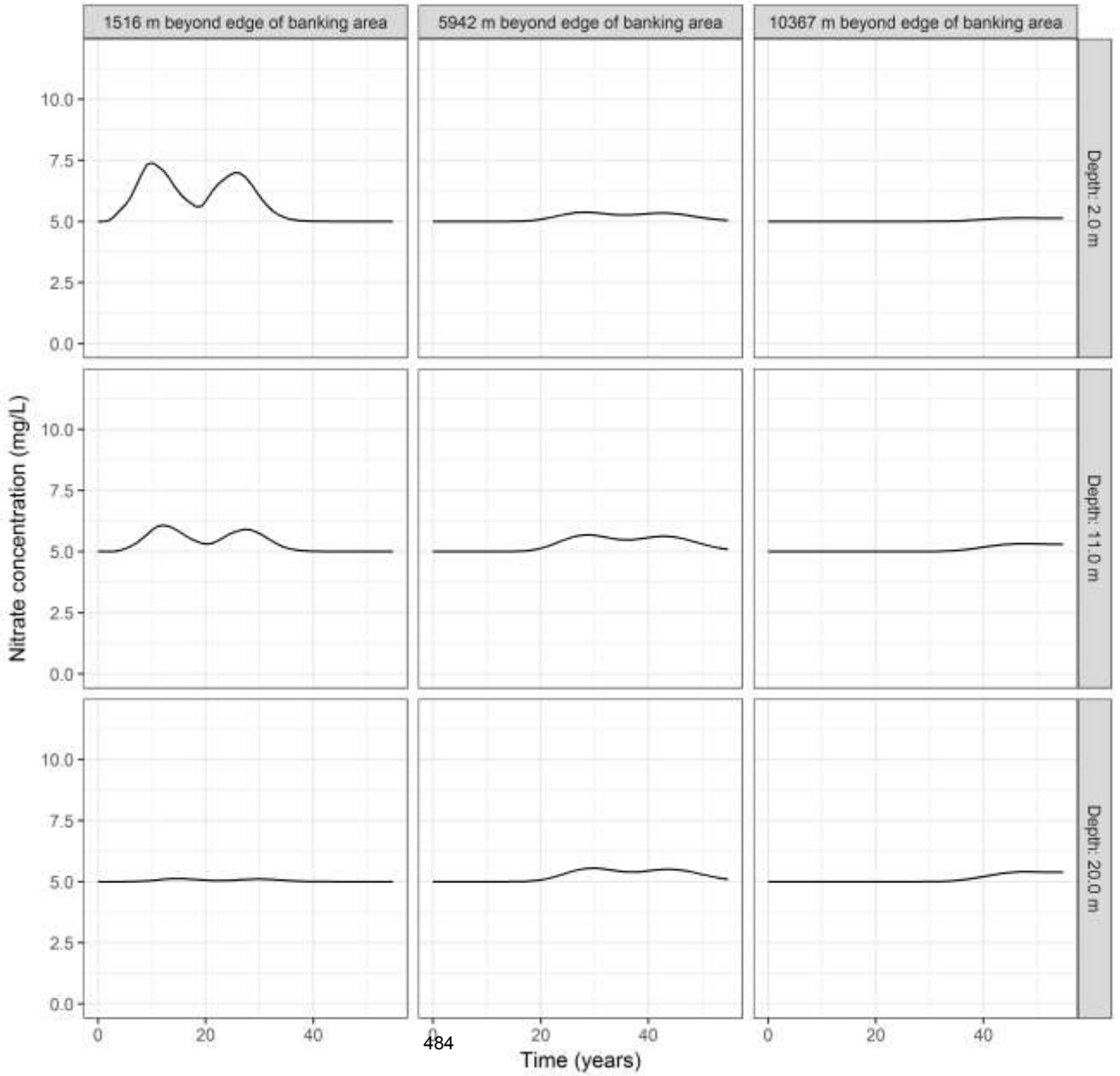


Specialty Crop Block Grant – Modeling Transport to Groundwater Under OFFCR Preliminary Results

Grape Example Scenario:

- **10-ft recharge per recharge year**
- Vx = 2 ft/d
- Vz = 0.003 ft/d

Ung, Rath, Roy, S. Bachand and P. Bachand, 2017



2017 – Next Steps in the Science and Engineering

- Testing various specialty crops: pistacios, walnuts, almonds and grapes
- Located throughout the San Joaquin Valley
- Things we are working on:
  - Root zone moisture and oxygen profile response to recharge practices
  - Grower tools (e.g. calendars, practices) to implement recharge
  - Costs and crop effects analyses
  - Achievable recharge rates
  - Groundwater hydrologic and water quality responses
  - Vadose zone transport of salts and nitrate, data and model refinement
  - Completion of McMullin Project Design, Permitting and Agreements
  - McMullin Project Construction

Recharge Take-aways

- What On-Farm Flood Capture and Recharge (OFFCR) Is?
- Scale of the Groundwater Problem, Statewide and Here
- The Costs for “New” Water
- The Opportunities and Constraints of Local Solutions
- Water Quality Concerns, How Much Nitrate Are We Talking About
- Next Steps in the Science and Engineering

Sustainable Conservation

Specialty Crop Block Grant SCB14028: Nitrate Leaching Risk from Specialty Crop Fields During On-Farm Managed Floodwater Recharge in the Kings Groundwater Basin

MEDIA CLIPPINGS

The Specialty Crop Block Project implemented by Sustainable Conservation and partners was featured in the media as follows:

Video and Article on ABC 30-TV

The video can be accessed at http://abc30.com/society/local-farmer-using-excess-water-to-flood-crops-and-improve-his-water-table/2100183/.
The article is copied below.

By Dale Yurong
Wednesday, June 14, 2017 05:59PM
FRESNO, Calif. (KFSN) --
An olive orchard at Terranova Ranch in western Fresno County is being flooded to recharge the aquifer.

"A lot of people didn't think we could do it, or we'd injure the vines or crops long-term," said

The water percolates underground where it's stored and pumped back up at a later date-- the olives still look healthy.

"We're seeing how much water we can put on, how long we can leave it on without harming the crops," said Don Cameron, Helm farmer.

Cameron is a pioneer in the process-- a flood recharge workshop on his farm drew over 70 people, including UC researchers, irrigation districts, and farmers from around the state.

"I think there's much greater attention to this concept now because water scarcity has such a direct economic threat to the viability of the Valley," said Daniel Mountjoy, Sustainable Conservation.

Grapes hold the most potential-- we were on Cameron's farm in February when he started flooding this vineyard.

"It's going to be a slow process but what that means is that our water table will probably increase in that region 35 to 40 feet."

But the technique is now catching on with olive, almond, pistachio, and walnut growers statewide. Many came to learn more about the science behind flood recharge and how to best protect their crop.

"That excess water is going to benefit us by leeching the naturally occurring salts that we're pumping through our groundwater on and getting our soil profile clean for our roots," said Matt Efird, Caruthers grower.

The technique works best in sandy soils because the floodwater has an easier time soaking through, reducing the risk of over-saturating roots. Heavy soils though pose bigger challenges.

This is the first year Cameron has tried flood recharge on his olives so he's keeping a close eye on his crop, making sure the leaves aren't turning yellow.

Field Day – Research Trial Summary

June 15, 2017

Objective: Assess the effectiveness of CropManage's water and nitrogen fertilizer recommendations for strawberry

Field details

Location: Oxnard, CA
Cultivar: Fronteras; 64" bed, two high flow tapes
Soil: Hueneme loamy sand (6% clay, 83% sand and 11% silt)
Water: EC = 1.6 dS/m
Pre-plant fertilizer (controlled release): 176 lbs N/acre
Main N fertilizer source: CN9

Treatments

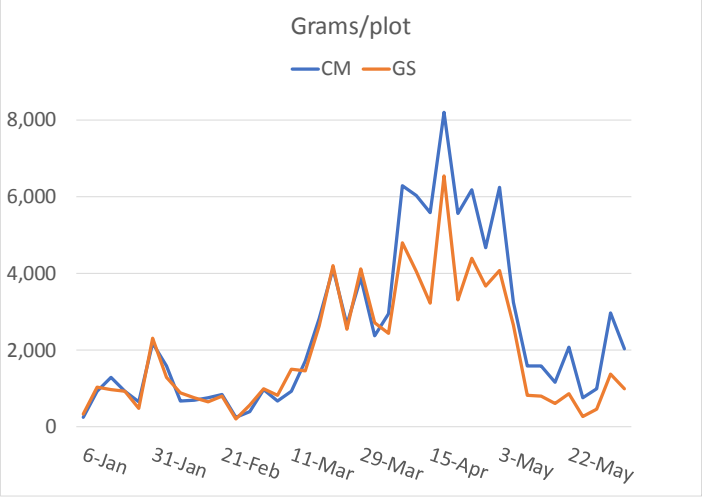
CropManage (CM): water and nitrogen fertilizer amounts created by CropManage
Grower standard (GS): water and nitrogen fertilizer managed according to ranch's standard practices

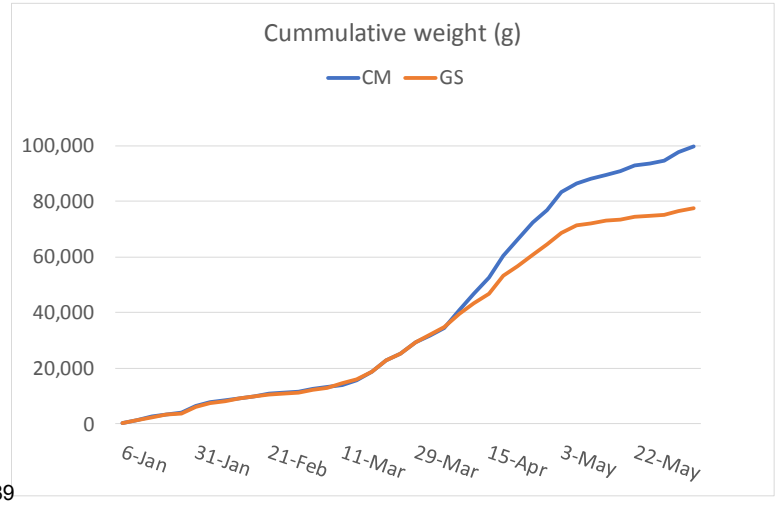
Results

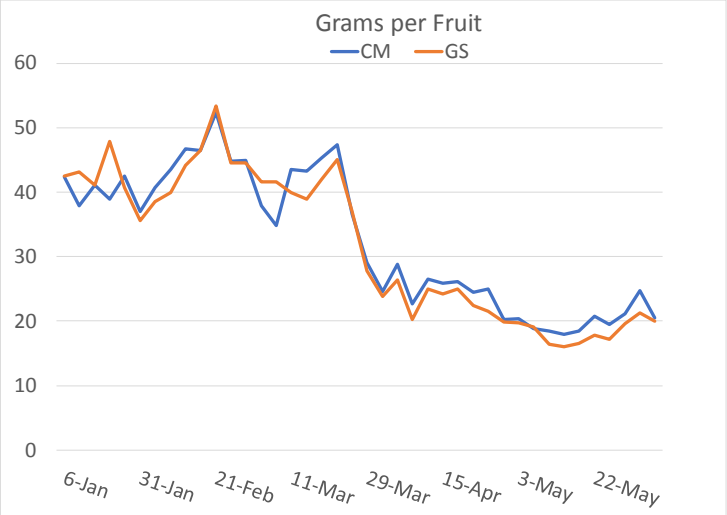
(October to end of May)

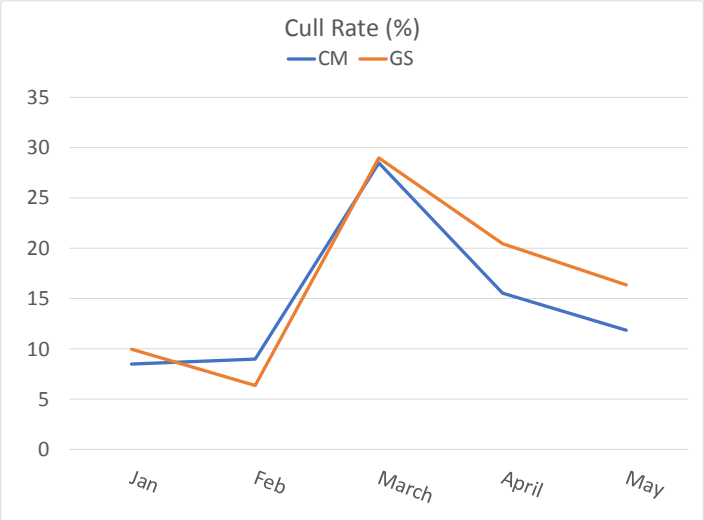
	CM	GS	CM vs GS
Water use (acre-in)	19.6	14.8	32% more
Total N fertilizer use (lbs N/acre) (Pre-plant + in-season)	269 (176 + 93)	213 (176 + 37)	26% more
Total marketable yield (fruits/plot)	3,789 (a)	2,979 (b)	27% more
Total marketable yield (grams/plot)	99,542 (a)	77,448 (b)	29% more
Cull rate (%)	17 (a)	21 (b)	4% less

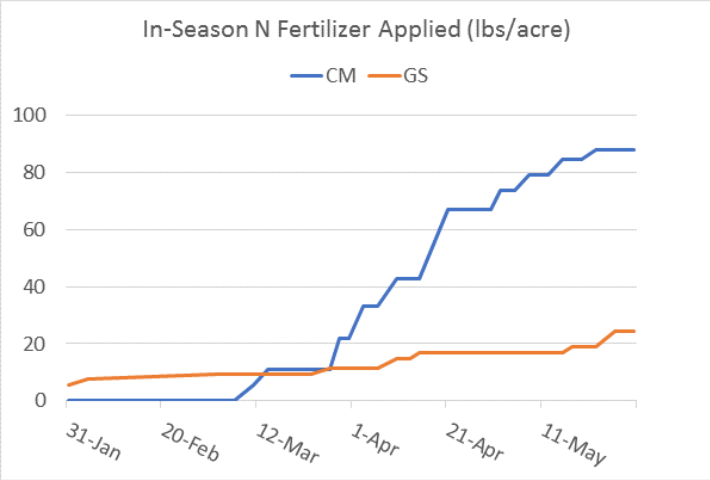
(Different letters indicate statistically significant differences between treatments)

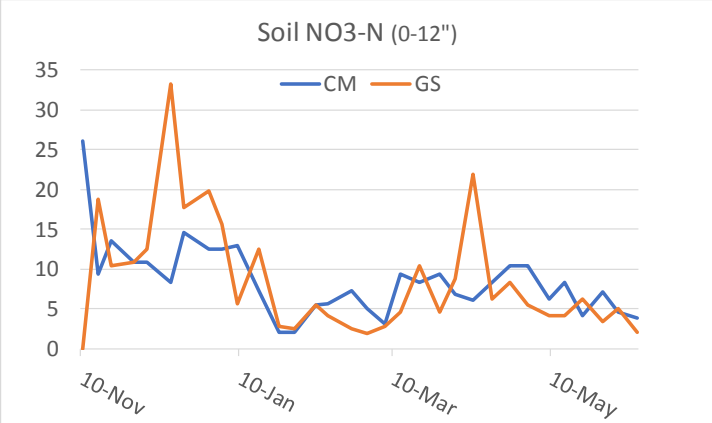


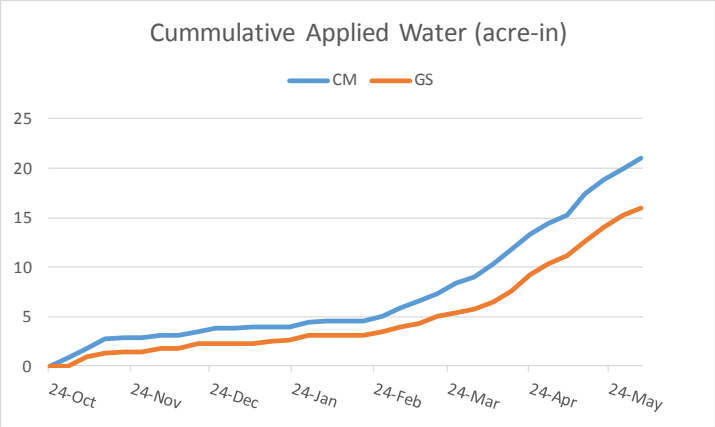


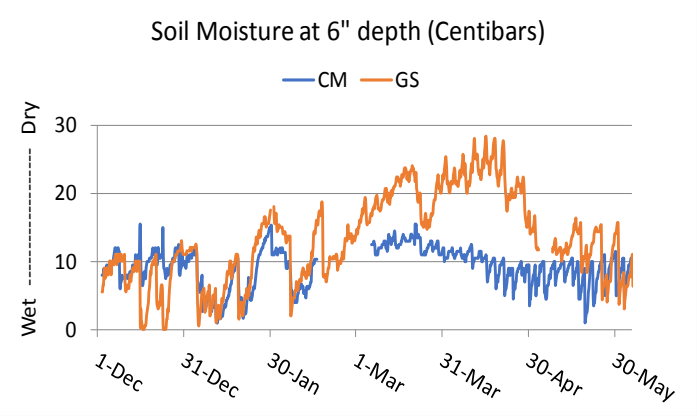












Additional details:
Each treatment was replicated four times; all other practices were equal for both treatments;
CropManage treatment used soil moisture sensors to guide irrigation;
Yield data collected by ranch staff.

Save the date: August 16, Irrigation and Nutrient Management Workshop

Thank you note: Sundance Berry Farms, Matt Conroy, Ezikiel, UCCE staff, CA Strawberry Commission

CropManage (cropmanage.ucanr.edu) is a free online software that creates water and nitrogen fertilizer recommendations on a field-by-field basis. CropManage was developed by the University of California Cooperative Extension, and it has been extended to multiple crops including celery, iceberg and romaine lettuce, spinach, broccoli, cauliflower and cabbage.

How water recommendations are calculated: the software creates water recommendations based on crop evapotranspiration (ETc) estimated since the last irrigation, which is calculated from CIMIS daily reference evapotranspiration (ETo) and crop coefficient (Kc) values for the specific stage of the crop at the time the recommendation is created. Irrigation design, irrigation efficiency and leaching fraction (soil and water salinity) are also taken into consideration for the irrigation recommendation, which provides the number of hours and amount to irrigate, as well as the frequency to irrigate.

How N fertilizer rates are calculated: fertilizer recommendations are based on the N uptake rate of the crop at various stages of development, and soil nitrate levels estimated with the quick nitrate test or laboratory analyses. Nitrogen mineralization from previous crop residue and nitrate concentration in groundwater are also factored into the recommendation. Recommended fertilizer rates are provided in lbs of N/A and also in total amounts of fertilizer.

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Adapting CropManage for Strawberry and Celery Production in Ventura County

Andre Biscaro, Michael Cahn,
Oleg Daugovish, Nathan Bradford;
University of California Cooperative Extension

Introduction

CropManage (cropmanage.ucanr.edu) is a free web-based app that uses data from multiple sources to customize recommendations of water and N fertilizer to the specific growth stage of the crops.

Data sources that drive CropManage include: plant developmental models from UC research, soil nitrate samples, expected yield, ETo data from CIMIS, irrigation system characteristics and soil properties data from the NRCS national database.

Method

Year 1

- The development of CropManage for a specific crop and region requires intensive data collection from multiple fields for at least one year in order to develop reliable plant growth models.
- Plant developmental models included N uptake, canopy cover and root depth (data not shown).

Year 2

- Two validation studies were performed in Ventura County in 2015 and 2016 in order to assess the effectiveness of CropManage's water and N fertilizer recommendations.
- The studies were conducted in randomized complete block design with four replications in a commercial field (celery) and in a research station (strawberry).
- Yield, water and N fertilizer use were compared to the grower standard practice of the field where each study took place.

Results

Strawberry

CropManage's recommendations (CM) resulted in 22% greater yields, 14% greater water use, and 34% greater N fertilizer use compared to the grower standard practices (GS).

Celery

CropManage's recommendations resulted in 5% greater yields (not statistically significant, P = 0.286), similar water use (13.8 AF), and 24% lower N fertilizer use compared to the grower standard practices.

Overall

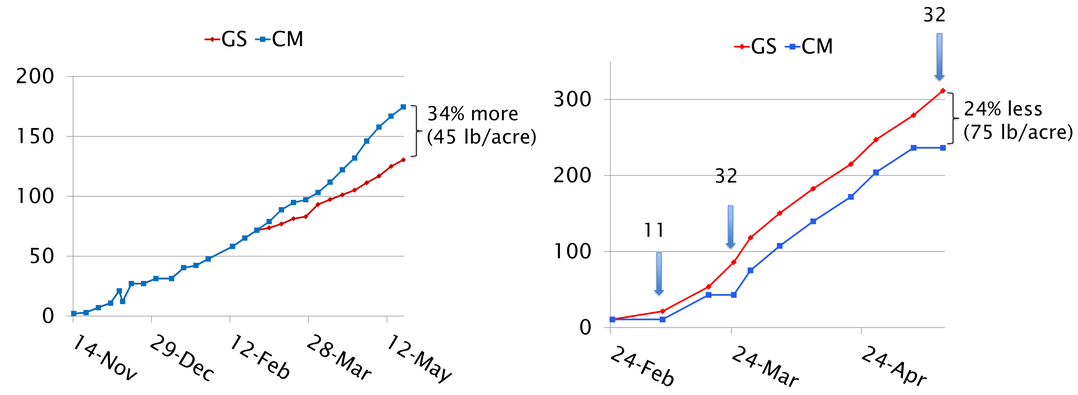
- These studies showed that recommendations from CropManage may result in greater, higher or lower use of water and fertilizer depending on the comparison management practice.
- The fact that yields were the same or greater than the grower standard demonstrated that the CropManage's recommendations do not reduce yields.

Notes

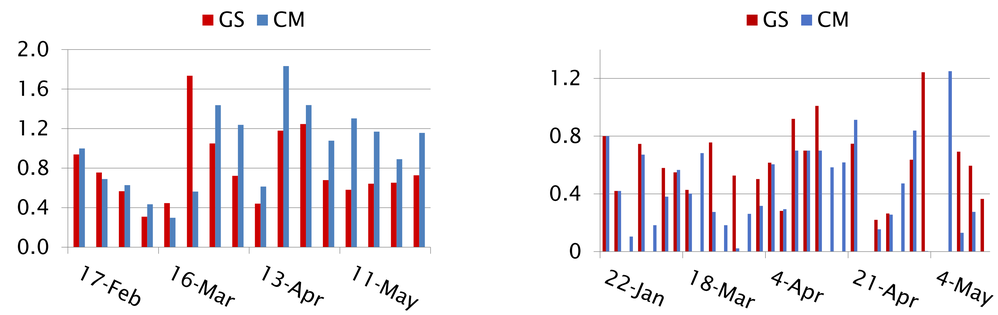
- A similar study conducted on two 14 acres strawberry fields (side-by-side comparison) resulted in 2% greater yield, similar water use and 35% lower fertilizer use for the CropManage treatment, compared to grower standard practices.
- Five other studies are currently been performed on two celery and three strawberry fields for assessing CropManage's recommendations in Ventura County.

Strawberry ***Celery***

Nitrogen Fertigated (lb/acre)



Applied Water (inches)



Summary of all data collected at the strawberry study.

	GS	CM
Total yield (lb/acre)	48,364(a)	59,171(b)
Cull (%)	28	27
Albino (%)	2	1
Water use (AF)	2.1	2.4
N fertilizer use (lb N /acre)	130	175
Veg biomass at harvest (g/plant)	542	1,047



Field Day conducted at the strawberry study site located at the Driscoll's research station, Oxnard, CA.

University of California
Agriculture and Natural Resources

Hands-on CropManage Workshop

Bringing CropManage to the Field

Date: Thursday, May 11, 2017
8:00am – 12pm

Location: UC Cooperative Extension, Ventura County
California Conference Room,
669 County Square Dr. Ste. 100 Ventura, CA 93003

- **Learn how to use CropManage to support irrigation and nutrient management decisions and record keeping**
- **Learn about the new version of CropManage (3.0)**
- **2.5 hours CCA CEU approved; VCAILG hours applied**

CropManage is a free online decision support tool for water and nutrient management of coastal crops. Even with the wet winter, water conservation will continue to be of concern in Ventura County, and water regulations will continue to be tied to efficient nutrient management. CropManage can play an important role in providing quick decision support on water and nutrient management on a field-by-field basis.

At this ***free*** workshop, we provide **hands-on** training so you can learn how to navigate and use CropManage for assisting with water and nitrogen management decisions and record-keeping. We will also cover updates to CropManage, which will making it more compatible with in-field use by farm staff.

Crops currently supported by CropManage include strawberry, head and romaine lettuce, broccoli, cauliflower, cabbage, celery, spinach, baby lettuce, cilantro, and mizuna. CropManage will soon include leaf lettuce and bell peppers.

Who should participate: Ventura County vegetable and berry growers, ranch managers, and other farm staff, and technical service providers are welcome. The workshop is for both new ***and*** current CropManage users.

What to bring: This is a hands on workshop so please bring a tablet or laptop computer so that you can follow along.

AGENDA *(subject to change)*

8:00 – 8:30	Registration and Refreshments
8:30 – 9:00	Introduction and updates on CropManage 3.0
9:00- 10:15	Getting started
10:15	BREAK
10:30 – 11:15	Strategies for using CropManage for decision support and record-keeping
11:15- 11:45	Advanced features and interfacing sensors with CropManage
11:45-12:00	Discussion of new features or changes needed

Please RSVP by Monday, May 1 to Patricia Rodriguez at 805 645-1474 or parodriguez@ucanr.edu
Space is limited.

Attachment 1: Photo Documentation of Construction and Operations of Multi-Chamber Bioreactor Research Project

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Figure 1. Initial site condition – disked field



Figure 2. Initial Grading

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Figure 3. Construction of Containment berm per county permit requirements



Figure 4. Construction of Containment berm per county permit requirements

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Figure 5. Forebay source water containment area showing input pipe and overflow



Figure 6. Initial flooding of fore bay from distribution pipe.

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Figure 7. Initial construction of sub-basin drainage and chamber boundaries



Figure 8. Layout of discharge drain pipes and fencing.

Attachment 1: Photo Documentation of Construction and Operations of Multi-Chamber Bioreactor Research Project



Figure 9. Layout of discharge drain pipes and fencing.



Figure 10. Completion of linear chamber fencing substructure

Attachment 1: Photo Documentation of Construction and Operations of Multi-Chamber Bioreactor Research Project



Figure 11. Initial lining of chambers with pond liner



Figure 12. Completion of Pond Liner

Attachment 1: Photo Documentation of Construction and Operations of Multi-Chamber Bioreactor Research Project





Figure 13 source water distribution pipes before V-notch flow devices are installed



Figure 14. Outflow pipe installation for each of the twelve treatment channels

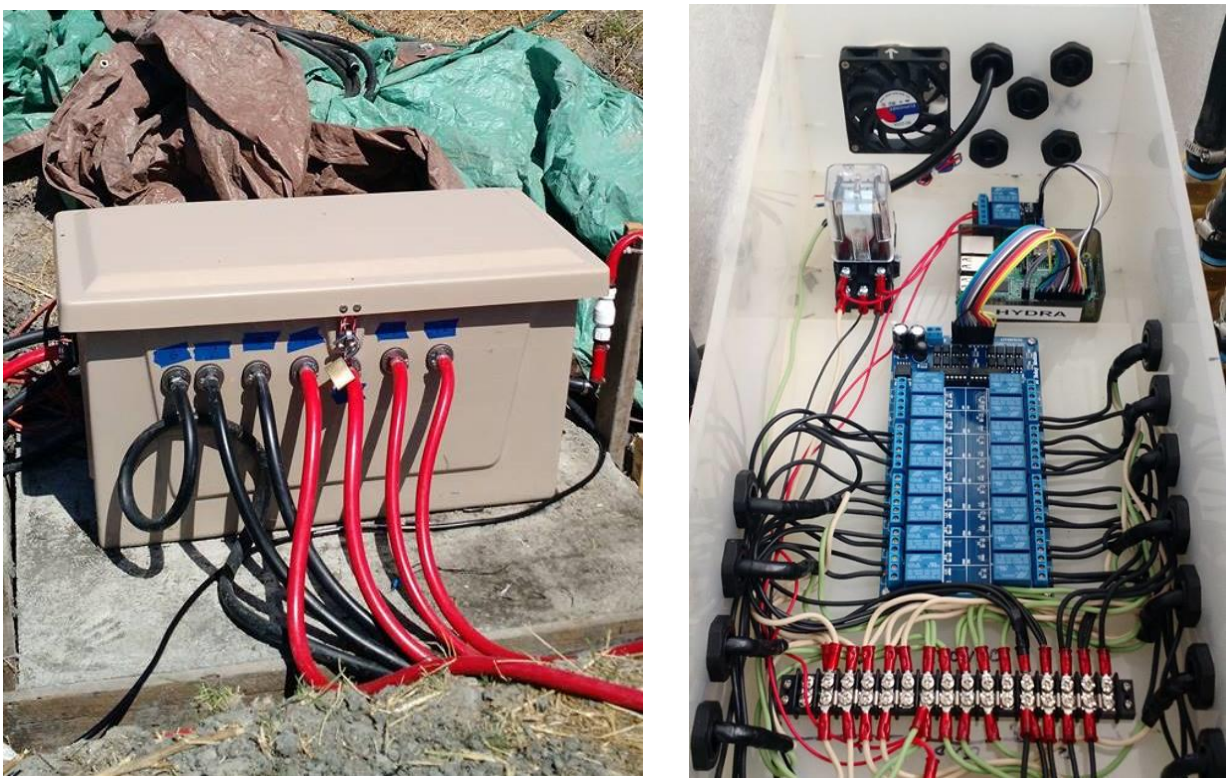


Figure 15. Installation of Hydra nutrient sampling system



Figure 16. Dye tracer flow test



Figure 17. Flow study using fluorescein dye.

Attachment 1: Photo Documentation of Construction and Operations of Multi-Chamber Bioreactor Research Project



Figure 18. Close up of discharge and screen of wood chip reactor



Figure 19. Initial flooding of treatment chambers (from left- control, heated wood chips, cool wood chips, hydrocotyle).

Attachment 1: Photo Documentation of Construction and Operations of Multi-Chamber Bioreactor Research Project



Figure 20. Treatment wetland down stream of Multi-Chamber bioreactor

Attachment 2: Project Design and Sampling Results for Multi-Chamber Bioreactor Research Project

Multi-Chamber Bioreactor Project Observations and Results

Introduction

Bioreactors provide an effective means of reducing nitrates and other non-point source pollutants from surface waters within tile drain systems. With their small footprint and relatively low costs, they provide commercial farmers with a viable method for reducing their environmental and human health impact.

The newly constructed bioreactor, located in Castroville, California under the PG&E powerline corridor, uses an experimental side-by-side comparison of three treatments, listed below, to fill data gaps regarding the performance of bioreactors on California's central coast. Our current research focus is determining the effect of initial nitrate concentration and hydraulic residence time on the rate of nitrate load reductions.

The goals of our project are: 1) to provide local growers with the best available data needed to determine what type of bioreactor is appropriate for their farm, and 2) to share design and construction findings with others interested in constructing bioreactors.

The current design includes 12 linear flow-through chambers comprised of three treatment systems (wood chip bioreactor, heated wood chip bioreactor, aquatic plant growth) replicated three times each. The remaining chambers are used as a control, replicating flow through a similarly sized agricultural ditch. The temperature in the heated wood chip chambers was increased passively using greenhouse tarp materials and varied slightly with daily climate conditions. Year-round data collection is required to fully assess the effectiveness of the greenhouse tarp materials for heating woodchips. In the future, multiple repeated heating experiments will be completed using different temperature ranges and heating methods to generate the data set needed to develop more complete nutrient reduction curves.

Enhanced Water Quality Sensor System

The original nutrient sampling design included collection of nutrient grab samples from the detention basin source water and from the discharge of each of the treatment chambers during 15 sampling events. Each sample reports nutrient level, temperature, dissolved oxygen, pH, and specific conductivity. A one-day lag between sampling of the source water and the discharge water was specified to account for the residence

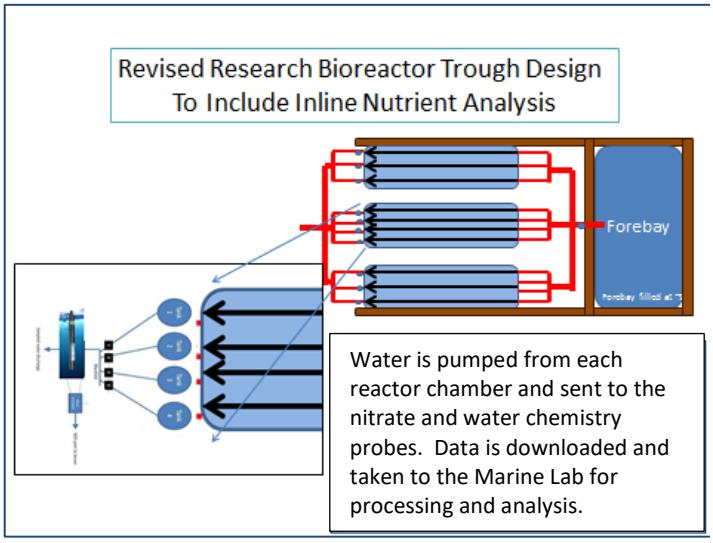


Figure 1. Bioreactor Design and Hydra-Nutrient Analyst sampling.

time of water within the treatment chambers. With separate funding from Anthropocene Institute, we were able to improve the monitoring capacity of the facility to include a multi-channel water sampling system that enables each of the 13 chambers (source water and 12 chamber discharges) to be automatically monitored in series. The revised design (Fig.1) will increase the data collection capacity of this system from 15 grab samples events to multiple samples collected daily for weeks at a time between calibration events. We collected grab samples to calibrate the water probes and provide quality assurance throughout the research project.

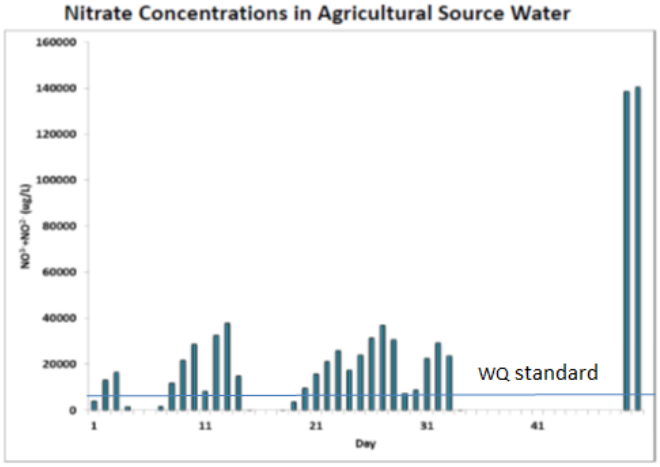


Figure 2. Nitrate Concentrations (NO2-NO3) are represented as daily average concentration over a month in summer 2015. Concentrations fluctuate from below detection limits to 140 mg/l.

Source Water Analysis

One of the benefits of constructing this research project within a working agriculture landscape is that nutrient concentrations within the source water represent ambient conditions and fluctuate in relation to adjacent farm practices (irrigation, crop rotation, etc.). The source water nutrient concentration study documented daily nutrient concentrations in the source water destined for the bioreactor system (Fig.2). Concentrations within the source water ranged from zero (detection limit 0.5 mg/l N) to 140 mg/l (140000 ug/l). The horizontal line in the figure denotes the 4 mg/l water quality objective set by the Central Coast Regional Water Board. These data demonstrate the range of concentrations that occur in this system and the temporal fluctuations in those concentrations. The multi-chamber bioreactor system will help document the efficacy of new designs within a field setting with highly variable nutrient concentrations.

Additional source water characterization was completed using nitrate concentration data of source water collected in June 2017. Daily concentrations of total dissolved inorganic nitrogen (DIN) collected during this summer growing season were within a smaller range of 24 to 48 mg/l. Two possible reasons for the lower (but still significant) range in nitrate concentrations may be due to seasonal differences in fertilizer and irrigation schedules, or due to a change in the reporting of nitrates from NO3-NO2 mg/l to total DIN mg/l.

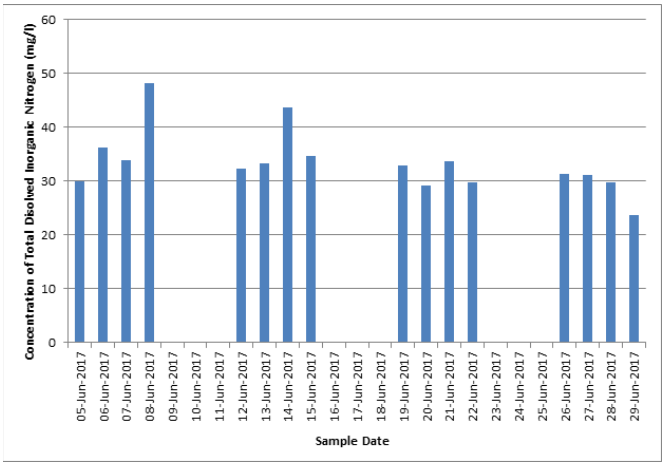


Figure 3. Source water nitrate concentrations (DIN) during field experiments.

Development of Load Reduction Curves for three Bioreactors and control (Ag ditch) systems

Nutrient reductions from each treatment chamber were estimated using data collected over a 25 day period in June 2017. Discrete water samples were collected from the source water and from discharges of each treatment chamber four times each week. Source water was collected one day before associated discharge water was sampled to account for the 24-hour residence time within each treatment chamber. Daily reductions in nutrient concentrations were then estimated for each chamber using a two-day average to account for any variation in residence time (Fig. 4). Each treatment was also calculated as an average of its three treatment chambers to mute individual variability.

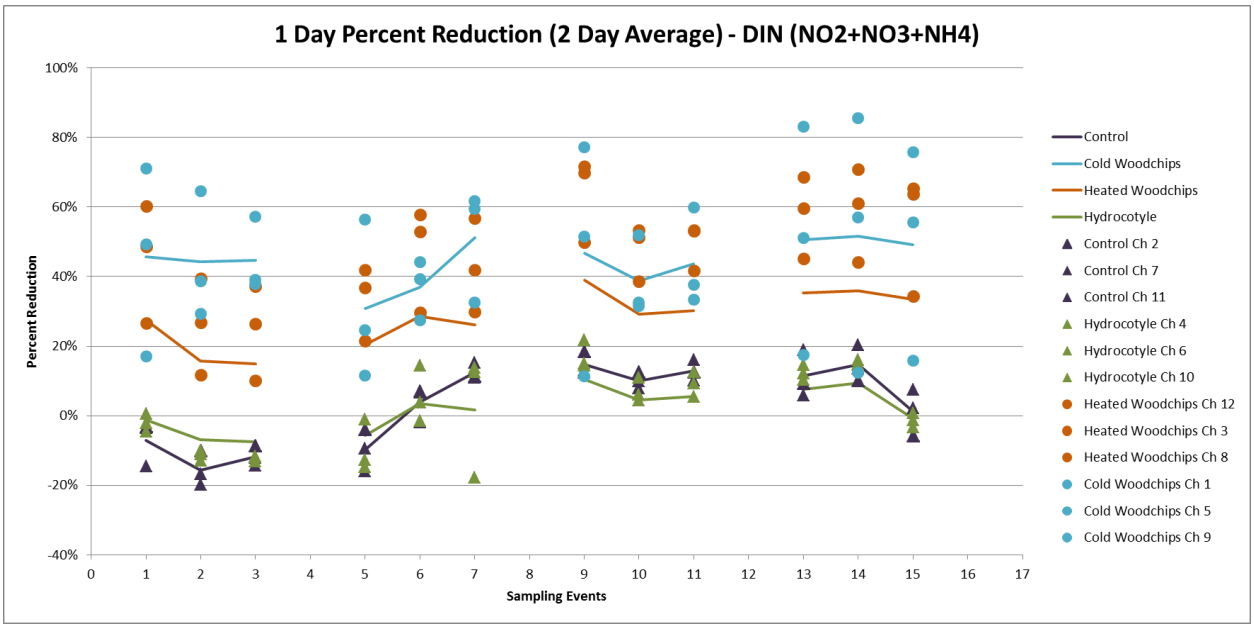


Figure 4. One-day total DIN percent reduction by treatment using a two-day average to account for water mixing within chambers. 16 samples were collected over a four-week period, and indicate that both the woodchip and heated woodchip treatments have the greatest reduction of treatments considered.

Woodchips and other treatment media cause some mixing of water and thus discharge water concentrations were assumed to be a mixture of treated water from within a small time window. We were able to estimate that water mixing occurs for approximately one day after water enters each treatment chamber using dye tracer tests and load calculations within control chambers. Water sampled at the discharge point was found to be a mix of water that entered the chamber between 48 and 24 hours earlier.

To account for this mixing, daily nutrient concentration reductions were estimated as two-average concentrations originating one day earlier from the fore bay than the treatment chamber discharge: [input concentration (average T0&T1) – discharge concentration (average discharge T1&T2)].

Average flow and nitrate concentration data were used to estimate key data for each treatment and to establish load reduction curves. Data variables measured include flow rate (adjusted by chamber to achieve a 24 hour residence time), hydraulic residence time (HRT), surface area, and

volume. These variables were used to estimate average nitrate reductions as percent reduction, concentration reduction (mg/l), and load reductions (total DIN g/day). Load reductions were standardized as grams of total DIN reduction per 1000 sq. feet per day (Table 1).

Table 1. Average reduction in nitrate concentration (mg/l DIN) and load reductions (g/day) within each treatment over 16 sampling events.

Treatment	Average dischage concentration	Flow Rate (g/m)	HRT	area (sq ft)	Volume (cubic feet)
Ag Ditch	32.47	4.64	21.96	400	1000
Hydrocotyle	32.85	4.39	21.16	400	1000
Cool woodchips	13.51	2.78	20.65	400	500
Heated woodchips	18.23	2.64	22.12	400	500
Treatment wetland	3.27	43.35	84.00	465,000	558000

Treatment	Percent Reduction	mg/L Reduction	Load Reduction g/day	Load Reduction (grams/day) per 1000 sq ft of treatment	Concentration (mg/l) Reduction per 1000 sq ft
Ag Ditch	3%	0.90	22.68	56.70	2.24
Hydrocotyle	2%	0.46	11.08	27.69	1.16
Cool woodchips	45%	14.87	225.44	563.61	37.19
Heated woodchips	28%	9.21	132.72	331.79	23.03
Treatment wetland	89%	20.99	6,176.63	13.28	0.05

Denitrification rates of bacterial reduction processes are dependent on numerous environmental factors. Because denitrification rates are based on initial concentration, denitrification rates change with residence time and source water concentrations. Specific factors accounted for when establishing nitrate reduction rates include, 1) initial nitrate concentrations in source water (if a zero order nitrogen reduction reaction is assumed appropriate), and 2) ambient water temperature within the treatments. Reduction duration was standardized by regulating the residence time to 24 hours within all treatments.

Lessons Learned and Design Considerations for Your Bioreactor

Heated Woodchip Bioreactor

The effectiveness of woodchip bioreactors decreases as temperature declines (Miller 2014). This is particularly problematic along the central coast where the need for nitrate reduction persists into the winter months, but the ambient water temperatures decrease below optimal levels. To address this, we covered our heated woodchip chambers with a polyethylene greenhouse fabric that is anti-condensate and lets both UV and IR radiation through.

The temperature within the heated bioreactors increased on sunny afternoons by as much as 11°C within the upper portion of the chambers, but the temperature in lower portions of the chamber was lower than source water. This suggests that thermal stratification is an important factor in the design and operations of a greenhouse heated bioreactor. This stratification may also limit mixing and reduce the volume of wood chips providing nutrient reduction value. This observation led CSUMB researchers to assume that water below the thermocline was isolated from flow and therefore residence time within heated wood chip chambers was lessened to a half-day. The research team has installed solar thermal panels and heat pumps to increase temperature within the lower portion of these chambers to reduce stratification and increase residence time. This infrastructure will be used once initial experiments are complete.

Pennywort Bioreactor

Pennywort (*Hydrocotyle ranunculoides*) is a native perennial aquatic plant that forms large dense vegetation mats and can grow either floating in-channel or rooted in sediment. This species of Pennywort is associated with reducing nitrates, phosphates and turbidity in sewage water (Basilico 2017). In the Salinas Valley it has also been shown to reduce more hydrophobic pesticides, organochlorine and pyrethroid, when used in conjunction with a sediment settling basin (Anderson 2011). In future research we will work with Department of Pesticide Regulation to determine if pesticide loads are reduced within these chambers.

General Design Considerations When Building a Bioreactor

1. Choose dimensions.
    - The width and length of a bioreactor will depend on the desired amount of water to be treated. There is little consensus regarding optimal dimensions, but it is our goal to use our denitrification rate data to build a model that will estimate required bioreactor size based on the desired number of acres to be treated and the peak flow from that land.
2. To line or not to line?
    - Using a polyethelene pond liner ensures all water entering the chamber is treated and leaves via the outlet, as opposed to some unknown amount of water contributing to groundwater recharge. While this makes quantifying the total amount of water treated easier, there are drawbacks to using a liner when it comes to maintenance and construction. In our experience, making the lining leak free at the outlet is difficult, and any liner above the water-line makes great habitat for rats to nest in. Though there are ways to mitigate these problems, an alternative option in predominantly clay soil, as is present in the Lower Salinas Valley region, is to have an unlined chamber.
3. Choose source material for woodchips (if applicable).
    - While there is little evidence to suggest a significant difference between source material for woodchips, pressure treated wood and eucalyptus should be completely avoided because of their undesirable chemical composition. For our facility we are using woodchips sourced from Randazzo Salvage which gets wood from local construction and landscaping projects.
4. Filling the bioreactor.
    - **Wood chips**. A woodchip bioreactor can be filled by using a tractor to dump woodchips in or near the site, and using pitchforks to manually spread the woodchips. However, if the chamber is very large in size or inaccessible by tractor, contracting with a blown woodchip delivery service, like JetMulch Inc., is a great alternative.
    - **Pennywort**. Pennywort is a very hearty plant that can easily be transplanted. For our project, we tore large sections of the plant from the Castroville Slough and transported it in containers to the chamber without much detriment to the plants.
    - **Note:** If using pond liner, do a leak test by filling the chamber with only water before filling it with a treatment media. All repairs become more difficult when navigating around woodchips or plants.

5. Maintenance
    - Leaving a treatment-free space around both the inlet and outlet of the chamber allows for easy access for maintenance and repairs. Our woodchip chambers contain barriers that allow water to pass through but hold the woodchips in place. Nevertheless routine maintenance will still be required to prevent clogging and biofouling.

Integration of Experimental results into water quality regulatory compliance.

Farmers are being asked to adopt practices that demonstrate progress towards achieving water quality objectives. Currently, most actions have been focused on reducing runoff of pollutants from farms. Moving forward, treatment will become a standard practice. Farmers will need guidance on how and where to construct treatment systems and understand the potential construction and operating costs. State regulators are interested in compiling data on the effectiveness of these measures to aid industry negotiations. Our data demonstrate the load reduction potential of wood chip bioreactors and compile construction and operating "lessons learned" that will help industry use of these techniques.

Moving forward, load reduction data from treatment systems will be used to document environmental success and help demonstrate regulatory compliance for farmers up stream of treatment systems. Figure 5 depicts farms within a defined watershed that have already participated in treatment systems and additional farms where treatment systems can be constructed. Demonstrating water quality improvements from pilot areas and from industry monitoring should benefit future regulatory compliance for specialty crop growers.

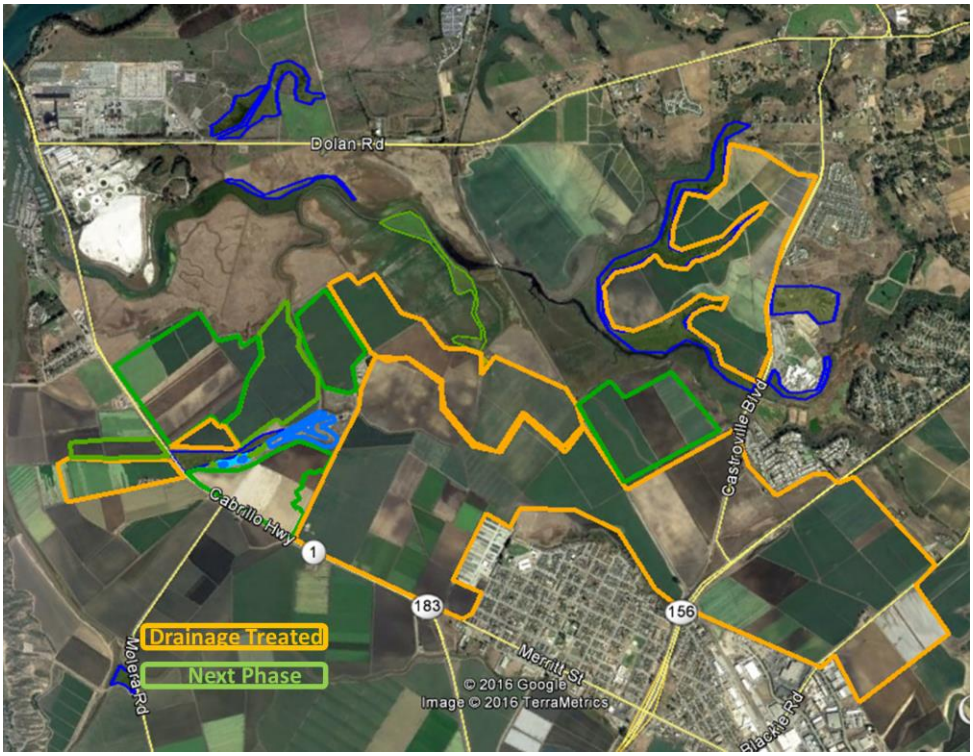


Figure 5. Example of watershed based water quality management. Yellow areas are farms currently being treated by off farm practices and green areas will be treated once newly designed practices are installed.

References

Miller, G. "Limitations on Nitrogen Removal by Treatment Wetlands Under Maritime Climatic Conditions" (2014). *Capstone Projects and Theses*. 588. http://digitalcommons.csumb.edu/caps_thes/588

Basilico, G., A. Magdaleno, M. Paz, J. Moretton, A. Faggi, L. deCabo. “Sewage pollution: genotoxicity assessment and phytoremediation of nutrients excess with Hydrocotyle ranunculoides” (2017) Environ Monit Assess 189:182.

Anderson, B., B. Phillips, J. Hunt, B. Largay, R. Shihadeh, R. Tjeerdema. “Pesticide and toxicity reduction using an integrated vegetated treatment system” (2011). Environmental Toxicology and Chemistry 30:5.

Attachment 3: List of presentations and partners who have received information on intended nutrient reduction rate estimates of the project during 2016-2017

2017 Meetings:

- Agriculture Water Quality Alliance (AQWA) Meeting: 6/14
- Meeting with Moon Glow Dairy: 6/2
- NRCS Conservation Innovation Grant (CIG)- Nutrient management team meeting: 6/2
- Salinas water quality monitoring/modeling TNC-MLML grant wrap up meeting: 5/25
- Headwaters 2 Oceans Conference, Irvine, CA: 5/23
- Big Sur Land Trust coordination meeting: 5/8
- Meeting with Professor Doug Smith (CSUMB faculty) and new intern for Bio-Reactor Project: May 2017
- Blanco Drain land owner meeting (Farm Nutrient Coop partners): Spring 2017.
- Multiple meetings with Emma Hiolski, Ph.D. Science Communication Program, University of California, Santa Cruz regarding new article and podcast on bioreactors: Spring 2017

  Podcast: https://soundcloud.com/scicom-slugs/deterring-pesky-geese
  video: https://vimeo.com/222961280

- Meeting with regulatory compliance manager Ocean Mist Farms: 4/18
- Professor John Silva's CSUMB class field trip -Molera Treatment Wetland and Multi-Chamber Bio-Reactor: 3/3
- Greater Monterey County IRWMP, Regional Water Management Group meeting: 2/15
- Ventana teen environmental group tour of Bio-Reactor: 2/14
- Meeting with Monterey County Supervisor, John Phillips: 2/13
- Sea Mist Farms sustainability meeting: 2/10
- SWRCB Irrigation Nutrient Management Grant, final presentation to Regional Water Quality Control Board: 2/6
- Sea Mist Farms initial info meeting: 2/8
- Elkhorn Slough National Estuarine Research Reserve Science Symposium: 1/24
- Nature Conservancy Donor tour of Multi-Chamber Bio-Reactor: 1/17
- NRCS CIG Nutrient management team meeting: 1/12
- State Coastal Conservancy Healthy Watersheds meeting: 1/4

2016 Meetings:

- Monterey Bay Farm Nutrient Coop Partners, Steering Committee meeting: 12/28
- Meeting with Sea Mist Farms compliance manager regarding watershed approach to water quality solutions: 10/28
- NRCS CIG, grower outreach meeting: 10/27
- Ag Order development presentation at AQWA meeting: 2/3

Lower Salinas Valley Water Quality Cooperative

Addressing Nutrients within Irrigated Lands

Initial Pilot Program

For the Moro Cojo Watershed

DRAFT PROPOSAL FOR DISCUSSION

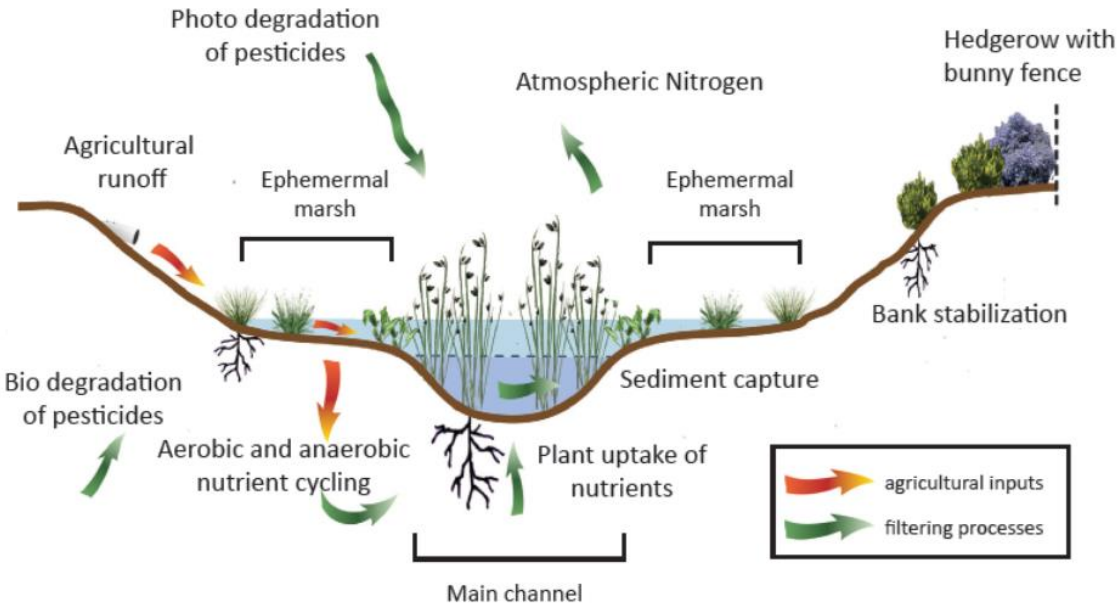
January 2016

Ross Clark CCWG @ MLML

Jennifer Biringer, TNC

Paul Robins, RCDMC

DRAFT



The physical, chemical, and biolgical processes that occur in wetlands help filter out pollutants

Nutrient Management Practices

On-Farm practices consist of actions and technologies that lead to a reduction in the application and/or release of nutrients within a farm field. Many practices aim to increase the efficiency of current farming practices in order to reduce over watering and over application of fertilizers (i.e. PICA). Such efficiencies often require technical experts to provide sub farm soil and crop data so that farmers can apply nutrients more precisely. Such practices aim to reduce nutrient application and thus unintended loading to waterways.

Edge-of-Farm practices consist of infrastructure (detention basins, grassed drainages, bio-reactors) that collect, filter and treat farm drainage (surface or tile drain) prior to those waters being released to public drainages. Many practices aim to remove nitrates through biological activity, releasing nutrients as Nitrogen gas. Such practices help to reduce nutrient loading prior to discharge into public waters.

Off-Farm treatment systems are designed to collect, filter and treat water within common drainages, both agriculture ditches and local creeks. Such systems have been documented to effectively remove Nutrients, sediments, pesticides and pathogens from waterways, resulting in lower concentrations in downstream receiving waters. Such systems include natural restored wetlands, treatment wetlands (designed to facilitate load reductions), bio-reactors and vegetated detention systems and drainage channels.

Cellulose wood chip bioreactors are a relatively new technique to treat irrigated agriculture tail water specifically to reduce nitrate concentrations (Figure 2). Water is directed from fields or drainage channels to the input location for a bio-reactor. Water flows through the bioreactor and is then discharged back into the drainage channel or receiving water. Benefits of a bio-reactor include its compact size, relative quick time to full function (wetlands take several years to

mature to full function) and limited food safety concerns. Limitations include concerns with sediments leading to clogging, bacterial respiration reduced at lower temperatures, limited ability to decrease other pollutant concentrations, and no added environmental value to adjacent water bodies (i.e. habitat and buffer value).
The cumulative effect of bio-reactors strategically placed adjacent to farm drainages and treatment wetlands placed at the lower end of sub-drainages have been demonstrated to provide, in concert with on farm practices, superior nitrate load reduction potential (Watson 2007).

Other technologies are being developed to filter and treat agriculture discharge waters to remove nutrients. Resin polymers are being investigated that extract nitrate from water as are investigations to the effectiveness of culturing algae that uses the nutrients in discharge water and sell the algae as a secondary product. Such innovative approaches will need to be tested to evaluate their efficacy similar to recent work documenting the treatment capacity of wetlands and bioreactors.

Tracking and Monitoring Program

The effectiveness of the Lower Salinas Valley Cooperative at reducing surface water quality (nutrient concentrations and loading) will be quantified through several measured metrics. Specifically the Cooperative will collect necessary data as specified in an adopted *Surface Receiving Water Quality Sampling and Analysis Plan* to quantify and report the status of several variables;

1) Surface water quality trends of sub-drainage discharges before the confluence with receiving waters.
2) Treatment system effectiveness monitoring.
    a. Concentration changes achieved through system
    b. Instantaneous and seasonal load reductions achieved through system
3) Correlative analysis of cooperative nutrient reduction trends and ambient data collected by CCAMP and Preservation Inc.
4) On-farm management efforts of Cooperative members

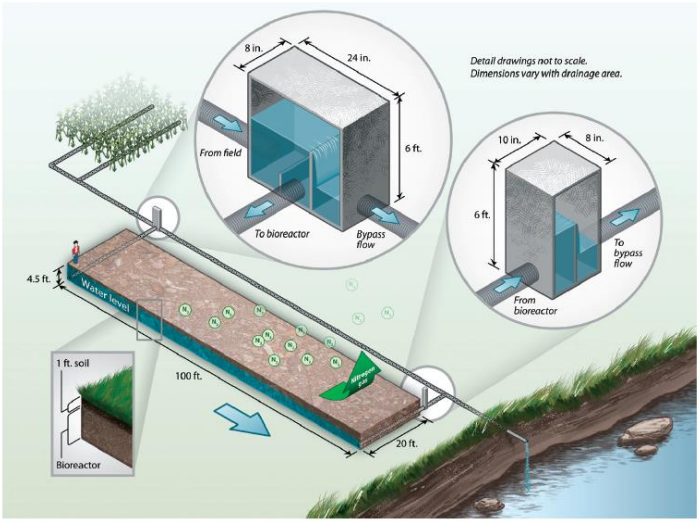


Figure 3: Descriptive illustration of a woodchip bioreactor (image by John Petersen, www.petersenart.com)

Monitoring strategy:

1) Monthly monitoring of total nitrogen at locations selected specifically to track sub-watershed nutrient reduction trends

2) Sampling to quantify load and concentration reductions of total nitrogen of all treatment systems
3) Source tracking and sub-watershed evaluation measures as needed based on monthly monitoring results

Estimated Costs of Monitoring within the Moro Cojo Watershed pilot area:

1) Monthly sampling of 7 drainage sites = $12,000 annually
2) Annual intensification monitoring at treatment systems = $18,000 annually
3) Source Tracking =$ 12,000 Annually

Reporting

The Cooperative will report the cumulative level of effort taken by members to reduce nutrient loading within the defined watersheds. In an effort to demonstrate continuous progress towards water quality improvement, the cooperative will report:

1) Agricultural lands participating in the cooperative; acres of land within each sub-watershed (total and participating members), percentage of various crops in production for those drainages, total nutrients applied and average per acre allocation within each drainage area, percent of lands within each drainage implementing some type of water and nutrient management strategy (necessary to determine nitrate loading risk factor).
2) Location, size, status and effectiveness of cooperative treatment systems
3) Cumulative load reductions achieved within sub-watershed due to the combine effect of treatment systems and on-farm practices.
4) Additional actions that will be employed to ensure "continuous improvement and sufficient progress towards water quality improvement"
5) Load and concentration trends of waters flowing from sub-watersheds to receiving waters.

Membership

Growers that own lands within a Nutrient Management Cooperative are invited to become members. If negotiations with Regional Board Staff are successful reporting and monitoring requirements will be assigned to the cooperative, and thus, greatly reduce Order administrative costs for individual growers.

The Cooperative will take responsibility for reporting to the State the combined efforts of members to comply with the Order.

Cost sharing of Cooperative Members

1) Costs for program implementation will be allocated annually among members as a membership fee and as a per acre charge.
2) Credits will be apportioned to landowners that support expansion of the cooperative by providing access to lands where additional cooperative treatment systems will be

installed or where private treatment systems are implemented that benefit the success of the cooperative.

3) Additional charges/costs may be allocated to members who fail to meet minimum implementation of on-farm practices and where site specific discharges place an undue burden on the cooperative.
4) An agreed upon annual budget share that will be allocated to support ongoing monitoring and expansion of treatment systems within the sub-watershed.

Nutrient Load Reduction Credit System

A credit trading system will be investigated as a mechanism to allow co-op members to contribute to compliance in proportion to their impact. Co-op members will ultimately determine how credits should be allocated, but potentially creditable actions include:

- Co-operative funding of a wetland restoration or construction project;
- Placement of on-farm interventions on own lands;
- Funding of on-farm interventions on another member's lands;
- Documented reduction in instantaneous N-loads;
- Contribution to research on innovative nutrient reduction strategies.

Co-op members may decide to make credits available for sale to co-op members who are unable or unwilling to take any creditable action. Cooperative Program members will also work with State grant programs to secure matching funding to support treatment system construction.

DRAFT

PG&E Bioreactor Model-based Analysis

F. Watson et al. 27 Jul 2017

Please DO NOT DISTRIBUTE YET beyond Watson, Clark, O'Connor, Adelaars, Leandro, Morris with checking first with Watson.

Model description

We assumed that underlying governing equation for nutrient reduction was a temperature-modulated first-order process:

$$\frac{\partial N}{\partial t} = \alpha_N \, N \, f(T)$$

where N is nutrient concentration (e.g. nitrate+nitrate as N in mg/L), *t* is time (days), α_N is an rate parameter, *T* is temperature (°C), and *f*(*T*) is a temperature modulation function.

Temperature is arguably the primary limiting factor for denitrifying wetland or bioreactor function along California's Central Coast (Miller et al., in prep). This region differs from most of the USA in having a maritime climate with temperatures that are sufficient for year-round crop growth, but too cool for rapid microbial function in the winter.

The temperature function represents the expectation that nutrient removal – like many processes in environmental biology – will be maximized at a temperature somewhere above 20°C, and minimized at temperatures near 0° and 40°C. The desired function should thus should be unimodal with a maximum value of 1 at the mode, and minima of 0 either side of the mode (or possibly -1 in some future analysis that recognizes the possibility of nutrient **increases** at sub-optimal temperatures).

For the temperature modulation function we used a standard beta distribution function (Yan & Hunt 1999). The beta distribution function typically has two shape parameters (*a* and *b*) that yield an upward modal function when both parameters have values greater than 1.

$$f(T) = Beta(T, a, b)$$

We re-expressed the function to have one parameter ($\alpha_{T,opt}$) representing the optimum temperature, leaving the other ($\alpha_{T,shape}$) to represent the shape. Values of $\alpha_{T,shape}$ near one lead to a broad mode, and large values lead to a narrow mode. Thus:

$$f(T) = \mathrm{Beta}(T, a, b) = \mathrm{Betamod}\left(T, \alpha_{T,shape}, \alpha_{T,opt}\right)$$

$$a = \alpha_{T,shape}$$

$$b = (a - 1)/\alpha_{T,opt} + 2 - a$$

(the latter function is just a re-arrangement of the standard formula for the mode of a beta distribution)

Solving the governing equation yields:

$$N = N_0 \exp(\alpha_N \, f(T) \, t)$$

where N_0 is the initial nutrient concentration.

Translating this equation to a flow-through reactor context yields:

$$\mu_{N,out} = N_{in} \exp(\alpha_N \, f(T) \, t_{res})$$

where N_{in} is the inlet concentration, $\mu_{N,out}$ is the mean outlet concentration, and t_{res} is the mean residence time (days).

The above equation estimates a mean condition, about which random variation is expected to occur. An appropriate statistical model for the random variation is a Tobit-normal distribution, which is like a normal (Gaussian) probability distribution, but truncated below impossible (e.g. negative) values:

$$Y_{N,out} \sim \text{Tobit-normal}\left(\mu_{N,out}, \sigma, \lambda, \infty\right)$$

where $Y_{N,out}$ is a random variable representing observed outlet concentrations, σ is the standard deviation of the Tobit-normal distribution (mg/L), λ is a laboratory detection limit (e.g. 0.1 mg/L).

The final, complete statistical model was thus:

$$Y_{N,out} \sim \text{Tobit-normal}\left(\mu_{N,out}, \sigma, \lambda, \infty\right)$$

$$\mu_{N,out} = N_{in} \exp\left(\alpha_N \text{ Betamod}\left(T, \alpha_{T,shape}, \alpha_{T,opt}\right) t_{res}\right)$$

with fitted parameters σ, α_N, $\alpha_{T,shape}$, and $\alpha_{T,opt}$, and measured input variables N_{in}, T, and t_{res}.

Model fitting

We estimated inlet concentration from measurements taken at the inlet trough, linearly interpolated over time, and then lagged by the estimated mean residence time. This could be improved in future using a weighted average of lag times based on the full temporal distribution of residence times.

We estimated channel temperature as the average of outlet temperature and inlet temperature (interpolated and lagged).

We prescribed the flow rates of each channel in order to achieve a nominal 1-day mean residence time, based on measurements of channel geometry and initial assumptions about the porosity and hydraulic efficiency.

We then estimated the actual mean residence time using dye tracer tests (using Rhodamine WT dye). The tests met with various complications, resulting in substantial 'noise' in the data. Enough 'signal' was present in the data to suggest that thermal stratification in the woodchip channels led to multiple flow paths and non-nominal mean residence times. In particular, the warmed woodchip channels appeared to experience a faster-than-nominal mean residence time. Given this, for the initial modeling presented here, we assumed mean residence times of 16.1 hours for the three warmed woodchip channels, and 35.7 hrs for the remaining nine channels. These residence times were achieved at a mean flow rate of approximately 2.5 gpm per channel.

Early data were discarded (prior to 13 Jul 2017) because they were more indicative of a reactor start-up process (e.g. adsorption of nitrate to woodchip particles) than of longer-term intended reactor function (denitrification).

Formal statistical analysis remains incomplete until we formally compare the full model (described above) to various simplified models that exclude one or both effects (initial concentration & temperature).

We fitted the model separately to each channel. This provides a useful comparison of within-treatment variation versus between-treatment variation. In future, a single mixed-effects model could be fitted to all data, considering treatment as a fixed effect, and channel number as a random effect. This would yield a more quantitative comparison of with-treatment and between-treatment effects.

Model results

All results are preliminary until more data are obtained, especially during the cool season.

The model results indicated that all three channels with a given treatment behaved similarly to each other, and differently to channels with a different treatment. All channels experience nutrient reduction to varying degrees (Table 1 and Figs 1 to 6). The woodchip channels experienced much greater reduction than the control and surface-vegetated channels (Fig. 1). The cool woodchip channels experienced slightly more reduction than the warmed channels, probably due to the shorter residence times apparent in the warmed woodchip channels. There was no apparent difference in the instantaneous rate of reduction between the cool and warmed woodchip channels (Figs 4 and 5). These results were obtained in mid-summer; we would expect a different result in

winter, when the temperature difference between the cool and warmed channels is expected to be much greater. Warmer temperatures were indicated to have a positive effect on reduction in all channels (Figs 4 to 6).

While the nature of the results is consistent with a denitrification process (the intended outcome), we cannot yet rule out that the reduction is due to other processes, such as adsorption or conversion to other nitrogen species. All that we have observed is reduction in the concentration of certain aqueous inorganic nitrogen species. This is typical of many bioreactor studies.

Model application

Initial model-based estimates of reduction rates for each treatment are shown in Table 2, notwithstanding the shortness of the data set, and the lack of winter data. Based on the data collected to date, and assuming a near-optimal (i.e. summer) temperature of 20°C, the nutrient reductions in woodchip reactors of the kind we installed could be expected to be around 4.0-5.3% per hour, or 62-71% per day. Assuming a typical 40 mg/L inlet concentration, this equates to a 25-29 mg/L reduction over one day.

A goal for growers may be to attain concentrations below the typical regulatory standard of 10 mg/L, this would require residence times of 1.13-1.52 days, given the existing geometry of the reactors. Achieving these residence times would require either 13% slower flow rates, or a 13% larger reactor.

The farm block area treatable in this way by one of the bioreactors is estimated to be 2.98 acres. This assumes 2 mm runoff per irrigation events, with irrigation events spaced 2-days apart (Watson et al. 2003; Harris et al. 2007). Larger farm blocks would require larger reactors, or improved reactor function, which may come to pass as the microbial communities develop further.

Table 1. Fitted model parameters.

Treatment	Channel number	Sample size	AIC	Model parameters							
				σ	mean	α_N	mean	$\alpha_{T,opt}$	mean	$\alpha_{T,shape}$	mean
Control	2	12	73.151	3.654		-0.220		22.0		40.0	
Control	7	12	78.528	4.571	4.29	-0.161	-0.21	22.0	22.0	40.0	40.0
Control	11	12	78.945	4.651		-0.261		22.0		40.0	
Cool woodchips	1	12	68.809	3.049		-1.540		22.0		29.5	
Cool woodchips	5	12	73.192	3.660	4.18	-1.621	-1.29	22.0	21.7	39.1	36.2
Cool woodchips	9	12	84.350	5.826		-0.695		21.0		40.0	
Warm woodchips	3	12	69.439	3.130		-1.713		22.0		16.7	
Warm woodchips	8	12	60.112	2.122	2.73	-1.070	-1.50	22.0	22.0	20.0	17.7
Warm woodchips	12	12	67.924	2.939		-1.728		22.0		16.2	
Floating vegetation	4	12	74.612	3.883		-0.264		22.0		40.0	
Floating vegetation	6	12	80.431	4.948	4.48	-0.287	-0.25	22.0	22.0	40.0	40.0
Floating vegetation	10	12	78.774	4.618		-0.198		22.0		40.0	

Table 2. Reduction rates estimated from fitted model.

Treatment	Channel number	First-order reduction coefficient (at 20C)		Relative reduction (%) per hour (at 20 C)		Relative reduction (%) per day (at 20 C)		Absolute one-day reduction (mg/L), assuming 40 mg/L initial (at 20C)		Days to reach 10 mg/L from 40 mg/L initial (at 20 C)	
		by channel	mean	by channel	mean	by channel	mean	by channel	mean	by channel	mean
Control	2	0.154		0.6%		14%		5.7		8.98	
Control	7	0.113	0.15	0.5%	0.6%	11%	14%	4.3	5.6	12.26	9.61
Control	11	0.183		0.8%		17%		6.7		7.59	
Cool woodchips	1	1.188		4.8%		70%		27.8		1.17	
Cool woodchips	5	1.146	0.99	4.7%	4.0%	68%	62%	27.3	24.6	1.21	1.52
Cool woodchips	9	0.633		2.6%		47%		18.8		2.19	
Warm woodchips	3	1.484		6.0%		77%		30.9		0.93	
Warm woodchips	8	0.900	1.30	3.7%	5.3%	59%	71%	23.7	28.6	1.54	1.13
Warm woodchips	12	1.504		6.1%		78%		31.1		0.92	
Floating vegetation	4	0.185		0.8%		17%		6.8		7.49	
Floating vegetation	6	0.201	0.18	0.8%	0.7%	18%	16%	7.3	6.4	6.89	8.12
Floating vegetation	10	0.139		0.6%		13%		5.2		9.99	

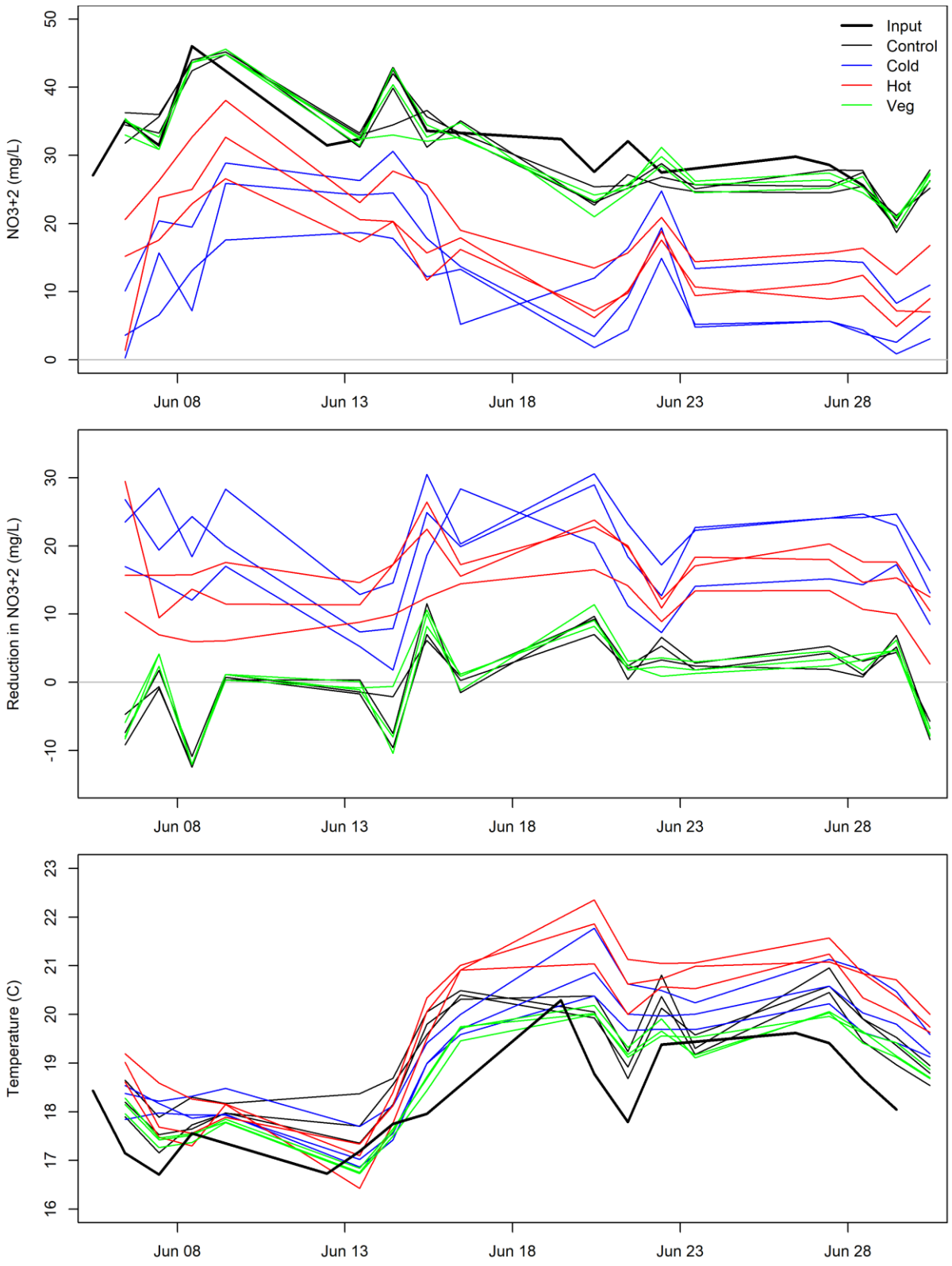


Figure 1. Raw time series of nitrate+nitrite and temperature in 12 bioreactors and the inlet trough.

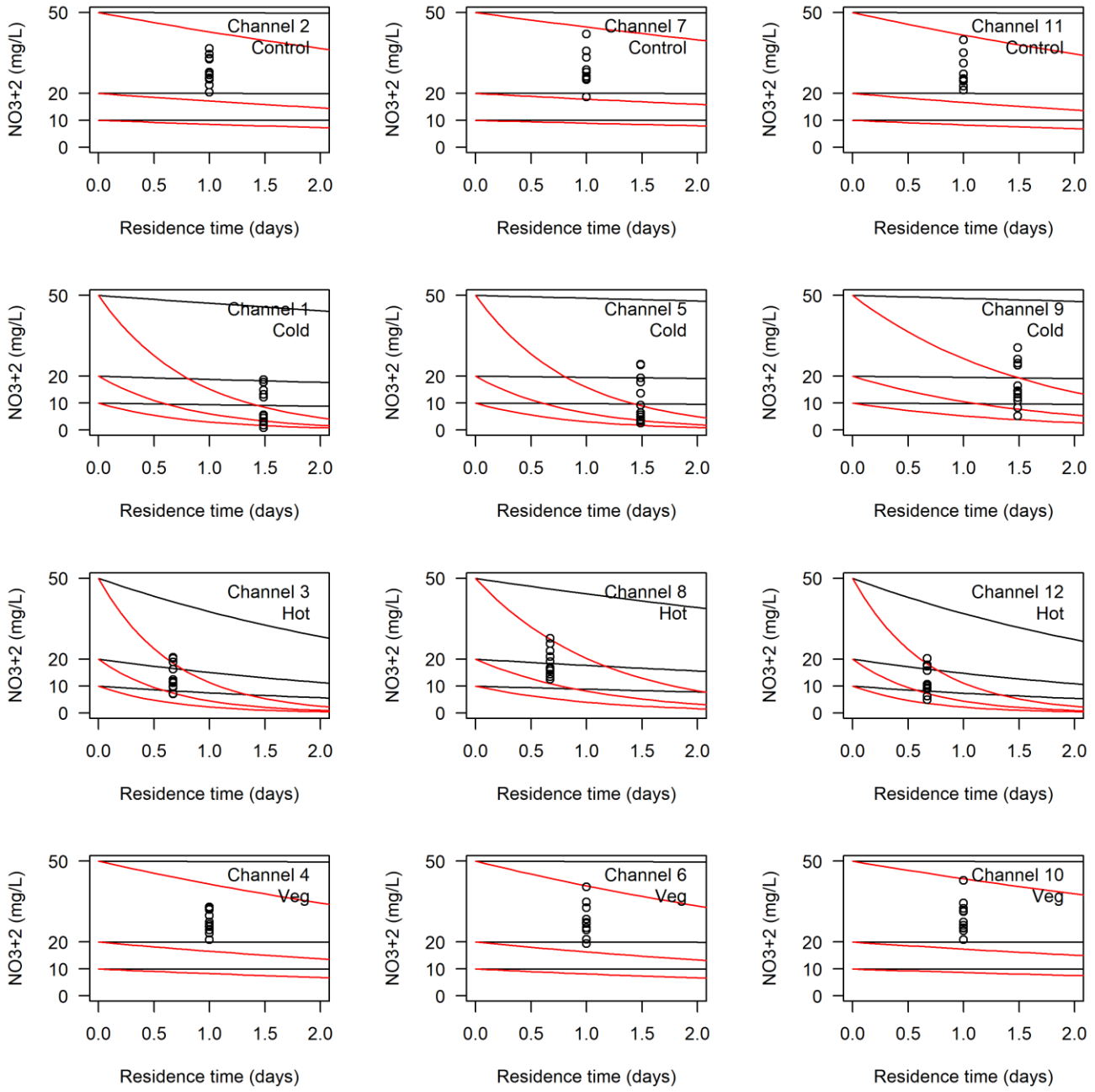


*Figure 2. Fitted nutrient reduction models, plotted with respect to **residence time**. Black and red lines are for cooler and warmer conditions (15 ℃ and 20 ℃) respectively. Circles are raw data, **not** differentiated by controlling variables (input concentration and temperature).*

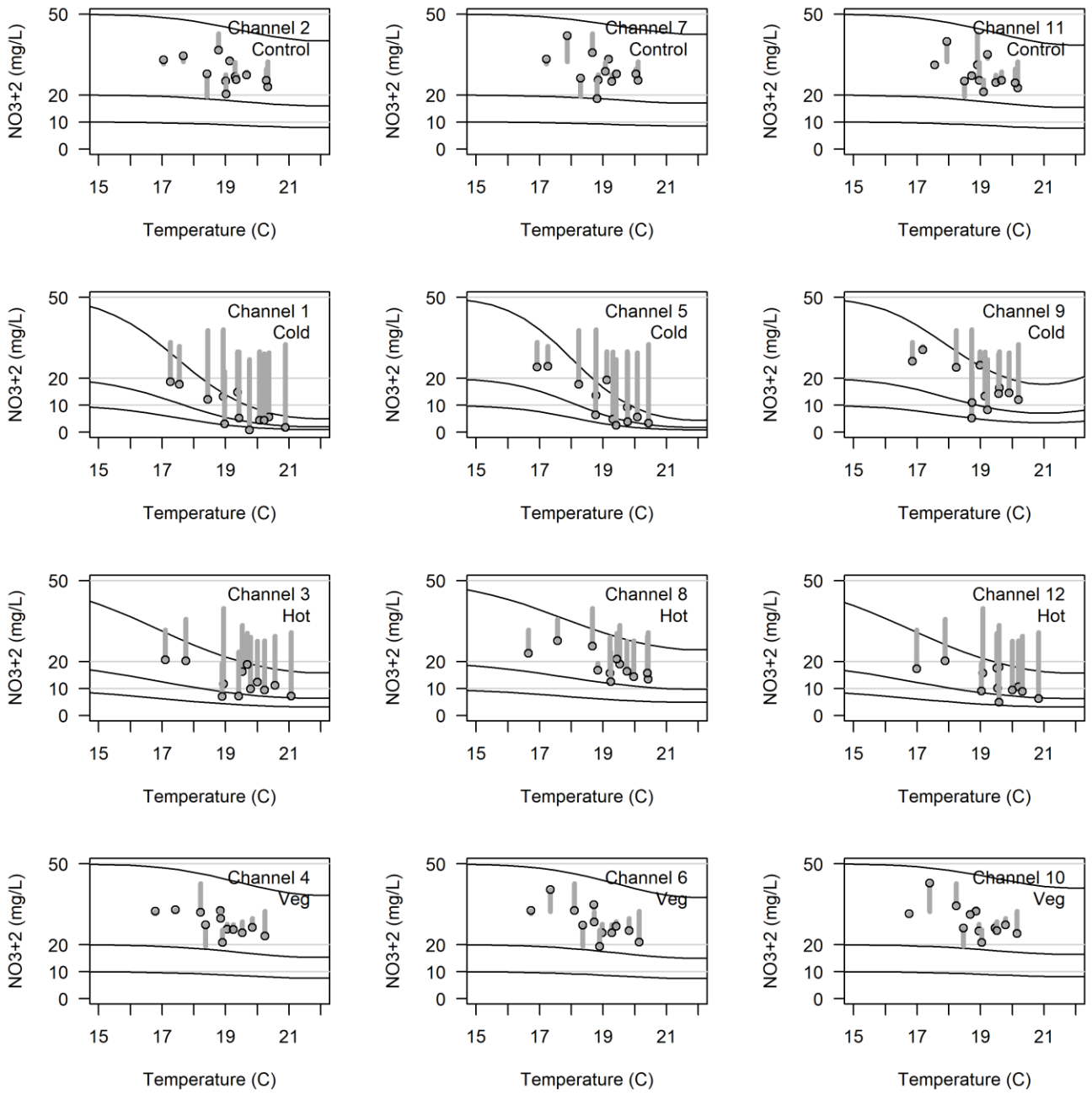


*Figure 3. Fitted nutrient reduction models (black lines), plotted with respect to **temperature**. Circles indicate raw data (final concentration), with gray tails pointing to initial concentration.*

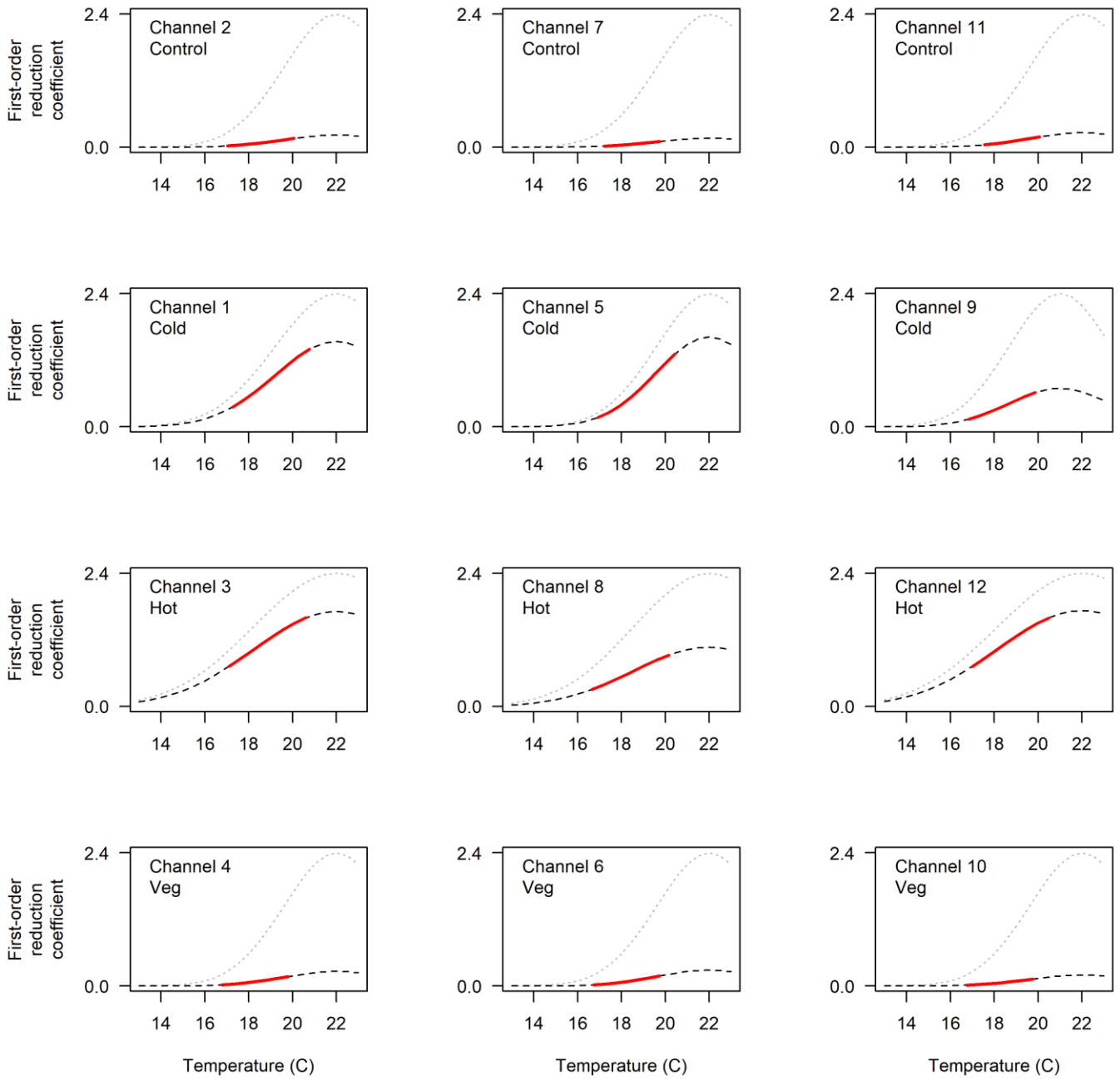


Figure 4. Modeled first-order reduction rate coefficients, over the range of temperatures observed to date (red).

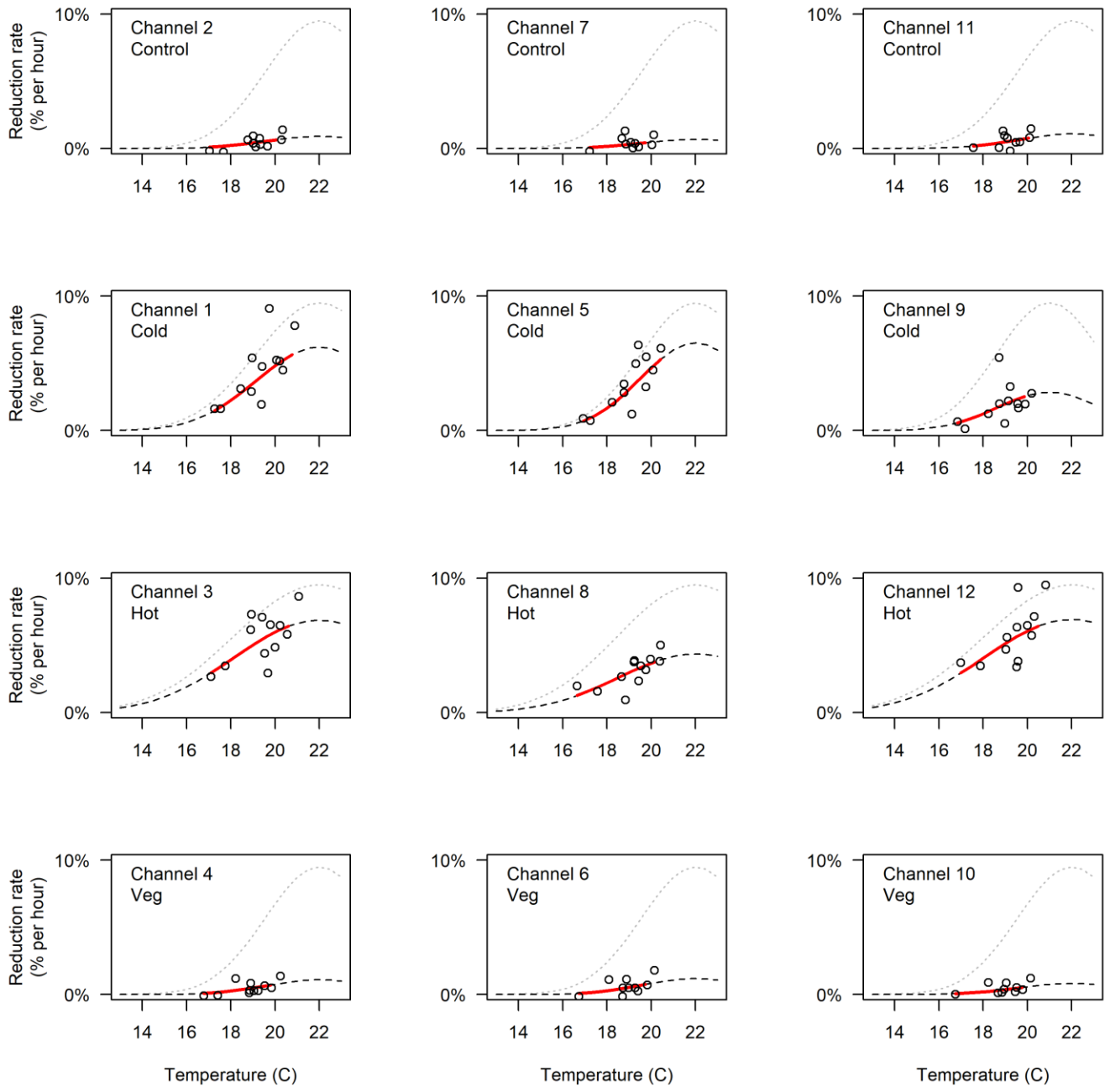


Figure 5. Modeled nutrient reduction rates (nitrate+nitrite), per hour. Circles indicate reduction rate computed directly from raw observations, ***not*** *differentiated by variation in inlet concentration.*

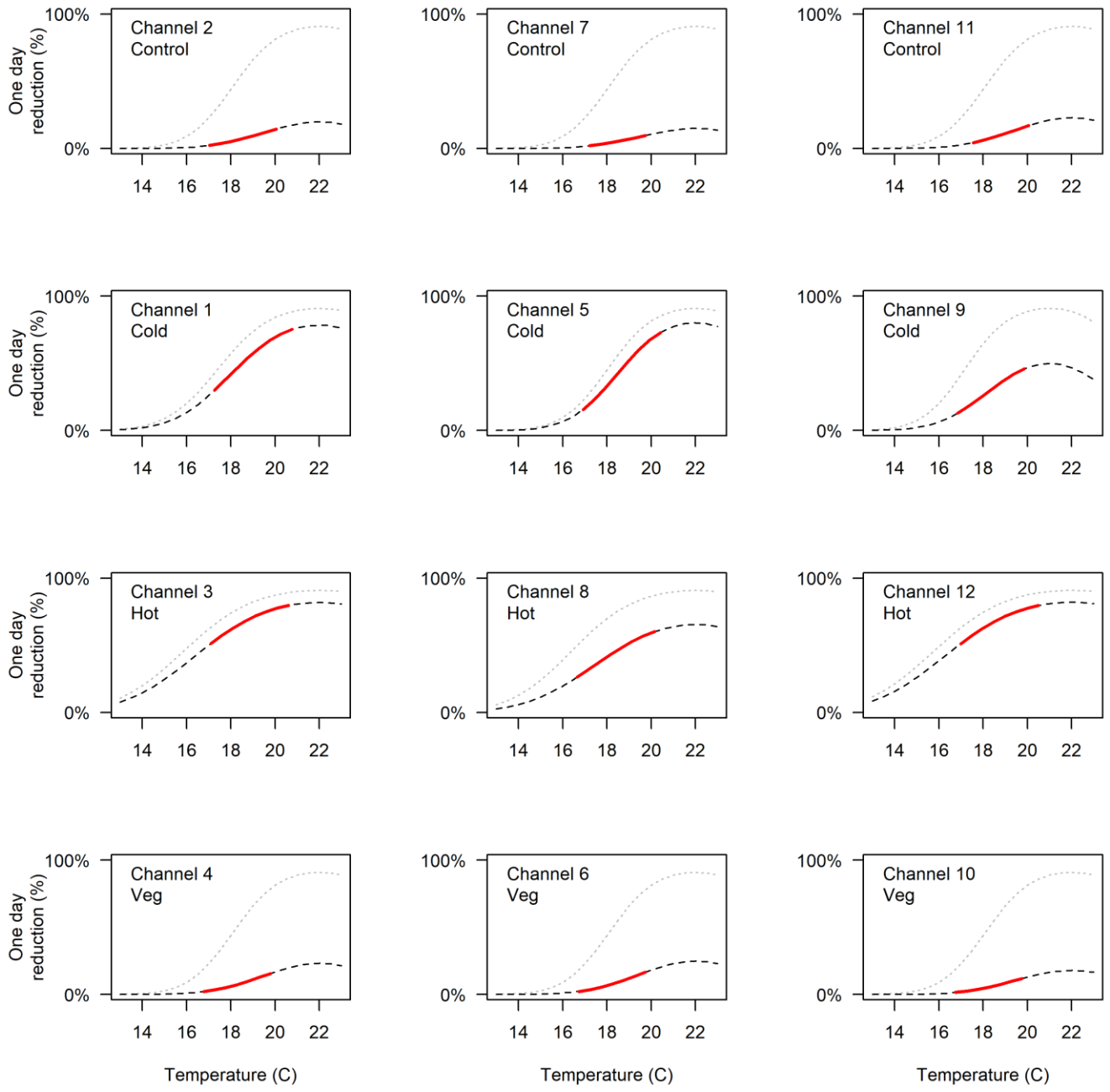


Figure 6. Modeled nutrient reduction rates (nitrate+nitrite), as a percentage over a one-day interval.

Bioreactor Design and Performance

Based on Results of Experimental PG&E Bioreactor

Introduction

Bioreactors provide an effective means of reducing nitrates and other non-point source pollutants from surface waters within tile drain systems. With their small footprint and low costs, they provide commercial farmers with a viable method for reducing their environmental and human health impacts.



Our Project

The newly constructed PG&E bioreactor located in Castroville, CA uses an experimental side by side comparison of three treatments, listed below, to fill data gaps regarding the performance of bioreactors on California's central coast.Our current research focus is determining the effect of initial nitrate concentration and hydraulic residence time on the rate of nitrate load reductions. With the ultimate goal of: 1) providing local growers with the best available data needed to determine what type of bioreactor is appropriate for their farm, and 2) sharing our lessons learned regarding their design and construction.

Treatments

Non-heated Woodchips

Due to their low costs and favorable hydraulic properties, woodchips are the most common media for bioreactors. Woodchips act as a substrate and carbon source for denitrifying bacteria which convert environmentally harmful nitrate into an inert gaseous form.

Our preliminary results show this treatment to be the most effective. However, this data is from spring/summer. Heated woodchips may prove more effective in winter months.

Estimated cost*
Materials—$2,200
Maintenance—$500/year

Heated Woodchips

The effectiveness of woodchip bioreactors decreases as temperature declines (1). This is particularly problematic along the central coast where the need for nitrate reduction persists into the winter months, but ambient water temperatures decrease below optimal levels. To address this, we covered our heated woodchip chambers with a polyethylene greenhouse fabric.

Estimated cost*
Materials—$1,900
Maintenance—$500/year

Pennywort

Pennywort (*Hydrocotyle ranunculoides*) is a native perennial aquatic plant that forms large dense vegetation mats and can grow either floating or rooted in sediment. This species of Pennywort is associated with reducing nitrates, phosphates and turbidity in sewage water (2). Locally, it has been shown to reduce hydrophobic pesticides, when used in conjunction with a sediment settling basin (3).

Estimated cost*
Materials—$600 **
Maintenance— $0.00

* Cost estimates based off of 1000 ft^2 of treatment , ** Cost of pondliner, Pennywort locally sourced from ag ditch for free

Treatment	Avg. Discharge Conc.	Flow Rate (g/m)	Hydraulic Residence Time	% Reduction	Load Reduction (g/day)	Load Reduction (g/day) per 1000 ft^2 of treatment
Ag. Ditch	32.47	4.64	21.96	3%	22.68	56.70
Pennywort	32.85	4.39	21.16	2%	11.08	27.69
Non-heated Woodchips	13.51	2.78	20.65	45%	225.44	563.61
Heated Woodchips	18.23	2.64	22.12	28%	132.72	331.79

General Design Considerations When Building a Bioreactor

Choose dimensions

The width and length of a bioreactor will depend on the desired amount of water to be treated. There is little consensus regarding optimal dimensions, but it is our goal to use our denitrification rate data to build a model that will estimate required bioreactor size based on the desired number of acres to be treated and the peak flow from that land.

To line or not to line?

Using a polyethelene pond liner ensures all water entering the chamber is treated and leaves via the outlet, as opposed to some unknown amount of water contributing to groundwater recharge. While this makes quantifying the total amount of water treated easier, there are drawbacks to using a liner when it comes to maintenance and construction. In our experience, making the lining leak free at the outlet is difficult, and any liner above the water-line makes great habitat for rats to nest in. Though there are ways to mitigate these problems. An alternative option in very clayey soil, such as we have in the Monterey Bay region, is to have an unlined chamber.

Choose source material for woodchips (if applicable).

While there is little evidence to suggest a significant difference between source material for woodchips, pressure treated wood and eucalyptus should be completely avoided. For our facility we are using woodchips sourced from Randazzo Salvage which gets wood from local construction and landscaping projects.

Filling the bioreactor.

Woodchips. The bioreactor can be filled using a tractor to dump the woodchips, then spreading them manually with pitchforks. However, if the chamber is very large in size or unaccessible for a tractor, contracting with a blown woodchip delivery service, like JetMulch Inc., is a great alternative.

Pennywort. Pennywort is a very hearty plant and can easily be transplanted. For our project, we tore large sections of the plant from the Castroville Slough and transported it in containers to the chamber.

Note: If using pond liner, do a leak test by filling the chamber with only water before filling it with a treatment. All repairs become more difficult when navigating around woodchips or plants.

Maintenance

Leaving a treatment-free space around both the inlet and outlet of the chamber allows for easy access for maintenance and repairs. Our woodchip chambers contain barriers that allow water to pass through but hold the woodchips in place. Nevertheless routine maintenance will still be required to prevent clogging and biofouling.

FOR MORE INFORMATION

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SCB14031 Attachment 7

Development of an Agriculture Water Quality Enhancement Cooperative

An Alternate Approach to Water Quality Compliance

1. **What is the problem?** Growers within the Salinas Valley have partnered with non-government organizations and the Resource Conservation District of Monterey County to implement treatment wetlands, bioreactors, and other on farm practices to improve water quality. Researchers have compiled regional data demonstrating the efficacy of these practices and used these findings to improve and expand treatment projects, leading to greater water quality improvements (see Appendix B). Our results show that the outputs of these water quality projects in the Moro Cojo watershed (Figure 1) treat water from over 1,000 acres, and achieved the nitrate water quality standard for warm and cold water habitat in that drainage basin of 1 mg/L between 2005-2016 more than 80% percent of the time and the drinking water standard of 10 mg/L 100% of the time, demonstrating significant accomplishment of nitrate water quality targets compared to other areas in the region. Without assurances by the Regional Board that there's an interest in looking at watershed based approaches and providing defensible regulatory incentives for these types of approaches, additional grower/landowner participation will be challenging to attain. Barriers to increasing the adoption of such practices include regulatory uncertainty, the cost burden of cleaning water from upstream sources, and a lack of recognition of the benefits of these projects in regulatory compliance reporting. Recognition in the form of regulatory incentives such as a change to a lower tier, reduced reporting requirements, higher regulatory certainty, and/or anonymity in reporting, compiled on a watershed basis, could provide incentive for broader participation and signal empowerment of self-directed efforts that lead to water quality improvements on a watershed scale.

   Farmers have voiced interest in having greater autonomy in selecting the best practices for local conditions within their drainage. As such, the establishment of the Moro Cojo ag cooperative is intended as an example of self-directed problem solving within a defined drainage and not an example of specific management actions that should be applied/required universally.

2. **How can we help?** One approach, currently being explored by The Nature Conservancy, Resource Conservation District of Monterey County, Grower-Shipper Association of Central California, Monterey Bay National Marine Sanctuary and Central Coast Wetlands Group is the development of a multi-farmer cooperative in which landowners/growers in a defined drainage work together to address water quality as a group. This approach directs the responsibility and accountability for making water quality improvements to include both the individual farmers and a group of growers working cooperatively with increased opportunities and methods to address water quality problems at a watershed scale. Cooperative success can be documented at the downstream receiving water and participating farmers would be recognized for accomplishing water quality objectives.

   The Moro Cojo Slough has documented success toward water quality improvements at the watershed scale as described in Appendix A. Statistically significant improvements in

concentrations of un-ionized ammonia, dissolved oxygen, pH and total nitrogen have been achieved at the base of the watershed (309MOR) between 2005-2016, brought about by combined and coordinated efforts of growers, researchers and nonprofit agencies through a compendium of projects and management practices described in Appendix B.

The cooperative approach has taken time to develop; meanwhile growers who are willing to attempt alternative water quality improvement strategies are left unengaged. To take advantage of landowner willingness to support additional site-specific measures that benefit water quality, farmers need to be recognized for their efforts. It is also of interest to the landowners and growers that an alternative regulatory pathway be defined where actions taken by a cooperative (that document progress towards meeting water quality standards) can be recognized and valued.

3. **What is the cost of not helping?** Farmers throughout the Central Coast have already participated in measures to improve water quality. Furthermore, evaluations of the water quality benefits of off-farm treatment systems have demonstrated the value of farmers and non-regulatory stakeholders working together to identify options to address specific water quality challenges. Several projects in the Moro Cojo Slough watershed have reports, models and monitoring data that quantify concentration and load reductions of practices treating individual farms as well as an entire 1,000 acre drainage (Table 1).

Table 1. Nitrate reductions measured within bio-reactors and a new treatment wetland filtering runoff from 1000 acres of lower Salinas Valley row crops. Reductions within the treatment wetland represent initial reductions (summer input concentrations but with minimum plant establishment in the wetland) and established reductions (1 year on during winter background nutrient concentrations). Descriptions of each treatment are provided within the supplementary technical bulletin.

Treatment	Average source water nitrate concentration (mg/l)	Average dischage concentration	Flow Rate (g/m)	HRT	Volume (cubic feet)
Cool Wood Chips	32.50	13.51	2.78	20.65	500
Heated Wood Chips	32.50	18.23	2.64	22.12	500
Treatment Wetland (6 month old, summer grow season concentrations)	32.50	3.27	43.35	84.00	558000
Treatment Wetland (1 year old, winter baseline nitrate concentrations)	8.95	0.08	30.00	58.13	558000

Treatment	Percent Reduction	mg/L Reduction	Load Reduction g/day	Load Reduction (grams/day) per 1000 sq ft of treatment	Concentration (mg/l) Reduction per 1000 sq ft
Cool Wood Chips	45%	14.87	225.44	563.61	37.19
Heated Wood Chips	28%	9.21	132.72	331.79	23.03
Treatment Wetland (6 month old, summer grow season concentrations)	89%	20.99	6176.63	13.28	0.05
Treatment Wetland (1 year old, winter baseline nitrate concentrations)	99%	8.85	382.32	0.00	0.02

We expect widespread interest in these types of cooperative approaches, provided we can build in appropriate incentives, including streamlining regulatory reporting and compliance for sub-watersheds engaging in strategic self-directed projects and management practices that are likely to bring about water quality benefits. Additionally, we would like to incentivize innovation and experimentation with projects that we reasonably believe will deliver improved water quality. By creating a regulatory option for interested operators that allows them to experiment, gather

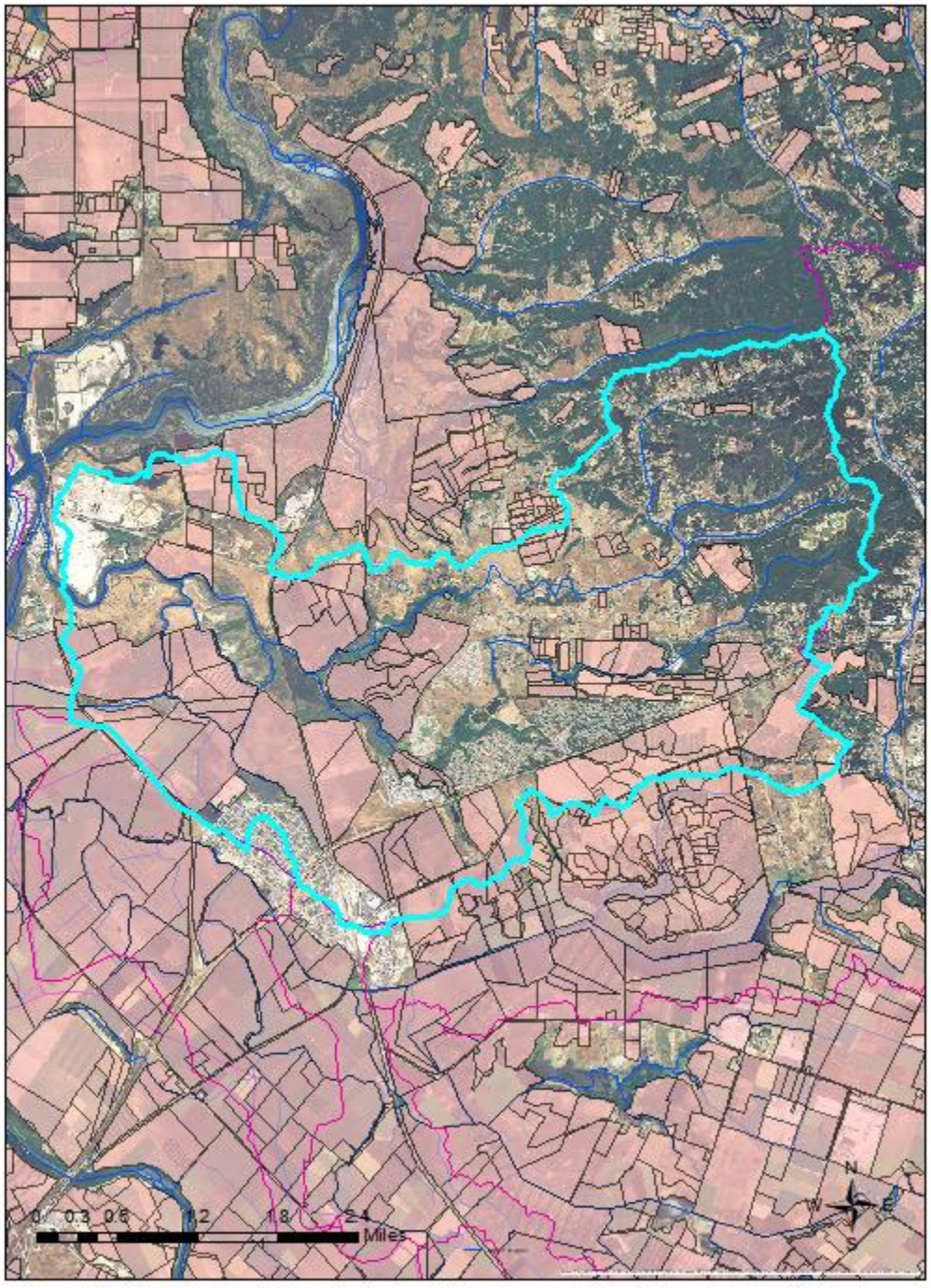
data, and report findings as part of an ongoing investigation into the benefits of these types of systems in the lower Salinas. Watershed cooperatives free to select practices and projects appropriate for their situation would be more likely to form if their actions are recognized within the regulatory program and "credit" can be gained by the farmers who adopt these cooperative approaches. Cooperative partners are eager to implement additional water quality improvements and several projects have already been identified and designed.

Why Now?

Putting in place a regulatory agreement or form of recognition to support a cooperative effort in the Moro Cojo watershed could mark a win-win for farmers, owners, and the Regional Board at a time when planning for Ag Order 4.0 is about to begin. A focus on incentive-based watershed programs to improve water quality should be given serious consideration in that order's development. There could be benefit in testing this regulatory approach on a small scale in the Moro Cojo watershed, which could potentially be refined and adapted to other watersheds. This regulatory structure would reward grower involvement and encourage active engagement of growers in solving water quality problems in their local watershed where they can make a difference. The regulatory nature of the cooperative approach would need to be seen as a benefit that would increase regulatory certainty and reduce liability.

Another reason for developing a cooperative approach now is that the group of partners working on the USDA NRCS Conservation Innovation Grant have the funding and motivation to work with growers, landowners and the Regional Board to try to structure something that could work for all parties and that would bring about water quality improvements.

Figure 1. Map showing the Moro Cojo watershed with the Monterey County Ranch map as a back drop.



SCB14033 Attachment 1

Optimization of Flat Plate Drying of Carrot Pomace

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Introduction

Processing of specialty crops into fresh-cut, canned, or frozen form yields a low-value, nutritionally dense co-product such as purees and pomaces. These products are high in moisture, which makes them suitable candidates for drum drying. Currently, drum drying requires high-pressure steam obtained from non-renewable energy sources such as burning natural gas. Thus, integration of solar thermal technology to provide the heat required for drum drying will inform the development of a processor-friendly solar thermal drum dryer that can be used to quickly dry specialty crop products such as apple, pear, berry, and vegetable purees as well as pomaces from tomato, grapes, olives, and carrots.

Objectives

The overarching goal of ARS's program in this area is to develop solar or solar-assisted drum dryer designs optimized for a given specialty crop and location. Based on the challenges identified in the agricultural industry, it is critical that special attention is paid to the design and configuration of solar drum dryers as well as the quality attributes of the added-value product. Thus, the objectives of this study are to:

- Identify optimal processing and formulation conditions for solar drum drying of specialty crops *e.g.* carrot (*Daucus carota* var. *sativus*) pomace [reported here]
- Assess quality attributes of the added-value dried products [reported by Dr. Rebecca Milczarek at 2016 IFT Conference in Chicago, IL]
- Evaluate the efficiency of solar drum drying with respect to current operations [reported by Mr. Jonathan Ferry at 2016 ASABE Conference]

Materials and Methods

To test the solar-thermally heated drum dryer design concept, an oil-heated flat plate dryer was employed. Based on a split plot response surface design, various feed blends of pomace, maltodextrin (carrier), and water were dried on the flat plate at varying plate surface temperatures for varying lengths of time. Surface temperature and drying time were based on typical drum drying conditions. Carrot pomace was collected from the Arvin, California Grimmway Farms plant.

Flat Plate Dryer



Specialty Crop



Flat Plate-Dried Products



Experimental Parameters

Pomace: Water (1:x)	Maltodextrin (%)	Inlet Temperature (°C)	Drying Time (minutes)
0	0	92	2
1	10	112	3
2	20	132	4

Data Acquisition

Moisture content (M.C.) and water activity (a_w) measurements were recorded for all dried products and regression equations were generated. A target water activity of 0.6 was chosen to ensure no growth of yeast and mold in the dried product. Statistical software JMP (version 9.0.1, SAS Institute Inc., Cary, NC, USA) was used for statistical analysis.

Results

The significance of the various formulation and process variable terms, as well as their square and interaction terms, indicate that water activity and moisture content are sensitive to maltodextrin, time, and temperature. Although M.C. is not sensitive to interaction and square terms, a_w is sensitive to the interaction of maltodextrin and temperature. Terms that were not statistically significant, based on measured response variables, have been excluded.

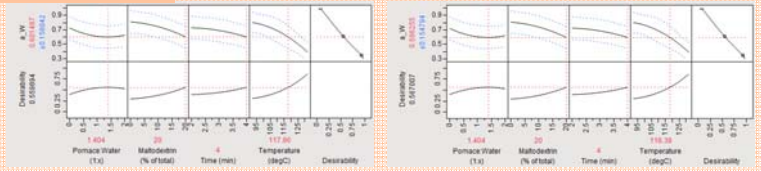
Prediction profiles reveal that to achieve the highest desirability value and a_w less than 0.6, an optimum amount of water and a minimum surface temperature of 118°C is needed. Contour plots for the a_w and M.C. response variables confirmed that the maximum maltodextrin and heating time are essential to meet the desired water activity.

Significance

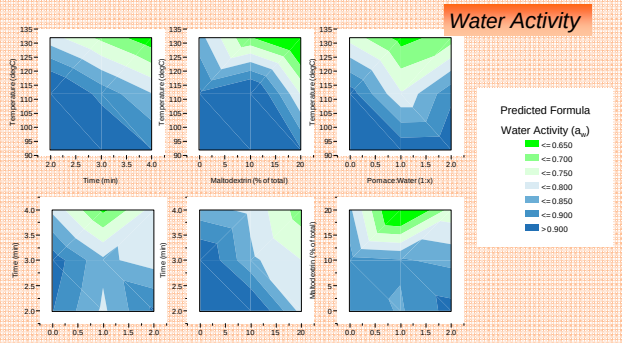
Model Components	Measured Response Variables	
Model Term	**a_w**	**Moisture Content**
(Pomace:Water [1:x])		
(Maltodextrin [% of total]	***	***
(Time [min])	**	***
(Temperature [°C])	**	***
(Maltodextrin) x (Temperature)	*	

*= significant with $p < 0.05$; ** = significant with $p < 0.01$; *** = significant with $p < 0.001$

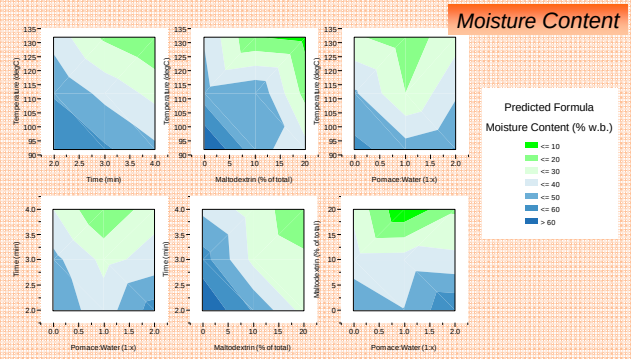
Prediction Profile



Water Activity



Moisture Content



Conclusions

Moisture content and water activity were sensitive to the maltodextrin content, dwell time, and plate surface temperature, yet insensitive to amount of added water. Based on a target water activity of 0.6, results have revealed that even with an optimum amount of added water, maximum amount of maltodextrin, and maximum heating time, a minimum surface temperature of 118°C is needed. Thus, this work has demonstrated that carrot pomace can be effectively dried and stabilized on a flat plate heater under a variety of feeding process conditions provided that a minimum plate surface temperature of 118°C is utilized. Results of this work will inform the design of a solar drum dryer for use in drying purees and pomaces.

Acknowledgements

The authors thank Grimmway Farms, (Arvin, California, USA) for supplying the carrot pomace for this study. This project is supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

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SCB14033 Attachment 2

Process and Formulation Effects on the Quality of Flat Plate Dried Pomace

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Abstract

Pomace is a co-product of the fruit and vegetable processing industry; it has potential applications as a source of food ingredients but is currently underutilized. Drum drying is one method that could be used to dry and stabilize pomace. However, the quality effects of the dryer surface temperature, product dwell time, content of carrier, and content of added water (to aid in application of the pomace to the dryer surface), have not yet been explored. In this work, a flat plate heater was used to simulate the surface of a drum dryer. Industrially-produced carrot pomace of initial moisture content of 80.3% (wet basis) was used as the starting material. Based on a split-plot response surface design, various feed blends of pomace, maltodextrin (carrier), and water were dried on the flat plate at varying surface temperatures for varying lengths of time. The plate surface temperature (92°C to 132°C) and drying time (2 min to 4 min, plus a 1 min heat-up time) represented conditions that would be achievable on a typical drum dryer. Regression equations were generated for the L* (lightness), a* (greenness/redness), and b* (blueness/yellowness) color values of the dried material, as well as for the overall color change (ΔE) and hue. The R^2 values for the fits of these quality metrics were 83.1%, 90.6%, 89.0%, 83.3%, and 86.4%, respectively. The significance of the various formulation and process variable terms, as well as that of their square and interaction terms, was determined. All the measured color parameters were significantly ($p < 0.05$) affected by the drying time and the plate surface temperature. In addition, L*, a*, and b* were significantly affected by the maltodextrin content; a* and b* were additionally significantly affected by the added water content. Some factor interaction terms were also found to have a significant influence on L*, a*, and b*; notably, the interaction between added water and maltodextrin had a strong effect on b*. To minimize the color change between the wet feed and dried material, dryer surface temperature and dwell time should be minimized, content of added water should be maximized, and maltodextrin content should be 18% (while still using conditions that produce a fully-dried product). The results of this work will inform the design of a solar thermal-powered drum dryer that can produce high-quality dried specialty crop purees and pomaces.

Rationale

Pomace is a co-product of the fruit and vegetable processing industry; it has potential applications as a source of food ingredients but is currently underutilized. Drum drying is one method that could be used to dry and stabilize pomace. However, the effects of the dryer surface temperature, product dwell time, content of carrier, and content of added water on the color of the dried product, have not yet been explored.

Materials and Methods

Materials

Carrot (*Daucus carota* subsp. *sativus*) pomace was obtained from a commercial carrot juice processing facility (Grimmway Farms, Arvin, CA, USA) in May 2015, frozen, and stored at at -20˚C. The frozen pomace was thawed overnight at 4˚C the day before sample mixture preparation. Maltodextrin (dextrose equivalent 18) was purchased from Grain Processing Corp. (Muscatine, IA, USA). Deionized water was used for making the pomace mixtures.

Flat Plate Dryer Design

A custom-built flat plate dryer was commissioned to simulate the surface of an oil-heated drum dryer. The dryer had dimensions of 12" x 12" (300 mm x 300 mm) for the drying surface and 1" (25 mm) thickness. For ease of cleaning and food compatibility, the surface was constructed of stainless steel. The hollow interior of the plate was filled with heat transfer fluid (mineral oil) that was circulated at 100 g/s in a closed loop through an electrical heater. The inlet oil temperature was measured with an in-line thermocouple; initial trials revealed that the average plate surface temperature was 10°C lower than the inlet oil temperature for the range of inlet temperatures used in this experiment. Figure 1 shows a schematic drawing and photo of the flat plate dryer.

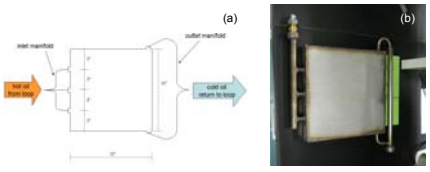

Figure 1: (a) Schematic drawing and (b) photo of flat plate dryer

Experiment Design

Two formulation variables (added water content and maltodextrin content) and two process variables (plate surface temperature and mixture dwell time) were explored via a split-plot experiment designed with the statistics software package JMP (Version 9, SAS Institute, Cary, NC, USA). The high and low values of the 4 independent variables are shown in Table 1. A total of 48 runs were completed, comprised of 12 whole plots (plate surface temperature) with 4 subplots each.

Materials and Methods (continued)

Variable	Low Level	High Level
Dwell Time [minutes]	2	4
Plate Surface Temperature [°C]	92	132
Pomace:Water Ratio [1:x]	0	2
Maltodextrin [% of total weight]	0	20

Table 1: High and low limits for variables in split-plot experiment



Figure 2: Scraping dried carrot pomace off dryer surface

Sample Preparation and Quality Measurement

Thawed carrot pomace was blended with water and/or maltodextrin (according to the experimental design) at low speed in a stand mixer to create the 48 sample mixtures. The sample mixtures (approximately 30 g each, in individual containers) were then refrozen and thawed overnight before testing.

The pomace mixtures were applied to the flate plate once the plate had been preheated to the setpoint temperature for at least 10 minutes. A 1-minute startup period was completed for each run, to allow for spreading of the mixture using a spatula and initial heatup time. After the 1-minute startup period, the samples were allowed to dry on the plate for 2, 3, or 4 minutes, according to the experimental design. At the end of the drying time, the samples were scraped off the surface of the dryer and packaged in zip-top plastic bags.

Moisture content was measured using a microwave moisture meter (Model AVC 80, CEM Corp., Matthews, NC). A target water activity of 0.6 was chosen to ensure no growth of yeast and mold in the dried product.

Tristimulus L*, a*, b* color parameters were determined on the dried samples using a CM 508-d spectrophotometer (MINOLTA, Ramsey, NJ). Hue was calculated as

$$Hue = \arctan\left(\frac{b^*_{dry}}{a^*_{dry}}\right)$$

and wet-to-dried color change (ΔE) was calculated as

$$\Delta E = \sqrt{(L^*_{wet} - L^*_{dry})^2 + (a^*_{wet} - a^*_{dry})^2 + (b^*_{wet} - b^*_{dry})^2}$$

Triplicate values of moisture content, water activity, and color were obtained, and mean values are reported here.

Results

A selection of the dried samples are shown in Figure 3. The regression results for the 4 model terms' effects on the color variables are shown in Table 2.



Figure 3: Twelve of the 48 dried carrot pomace samples. Note range of dryness and color achieved with flat plate drying.

Model Components	Measured Response Variables				
Model Term	L*	a*	b*	ΔE	Hue
(Pomace:Water [1:x])		***	***		
(Maltodextrin [% of total])	**	***	***		
(Time [min])	***	*	***	***	***
(Temperature [°C])	***	**	**	***	***
(Maltodextrin) x (Temperature)	*				
(Pomace:Water) x (Maltodextrin)		**	***		
(Time) x (Temperature)		*			*

Table 2: Split-plot design regression results. Only terms and interactions that had a significant effect on at least one response variable are listed.

* = significant with $p < 0.05$; ** = significant with $p < 0.01$; *** = significant with $p < 0.001$

Regression equations were generated for the L* (lightness), a* (greenness/redness), and b* (blueness/yellowness) color values of the dried material, as well as for the overall color change (ΔE) and hue. The R^2 values for the fits of these quality metrics were 83.1%, 90.6%, 89.0%, 83.3%, and 86.4%, respectively. The significance of the various formulation and process variable terms, as well as that of their square and interaction terms, is shown in Table 2. In summary, all the measured color parameters were significantly ($p < 0.05$) affected by the drying time and the plate surface temperature. In addition, L*, a*, and b* were significantly affected by the maltodextrin content; a* and b* were additionally significantly affected by the added water content. Some factor interaction terms were also found to have a significant influence on L*, a*, and b*; notably, the interaction between added water and maltodextrin had a strong effect on b*.

Results (continued)

The combined goal of drying the carrot pomace would be to minimize the color change (ΔE) between the wet feed and dried material while at the same time drying the pomace to $a_W < 0.6$. The optimal conditions that can achieve this goal are depicted in the prediction profile (Figure 4). In the profile, a desirability of 1 would indicate perfect achievement of the combined goal, while a desirability of 0 would indicate failure at both components of the goal. The maximum desirability possible within our experimental space (0.36) is achieved with the settings of pomace:water ratio = 1:2, maltodextrin content = 20%, drying time = 2.9 minutes, and surface temperature = 132°C.

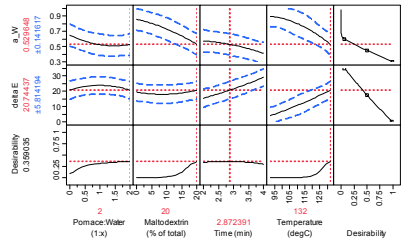

Figure 4: Prediction profile for water activity (first row), ΔE (second row), and composite desirability (third row). The depicted controlled variable settings, shown in red font, result in the maximum composite desirability that can be achieved in the experimental space.

The above scenario balances the two goals of minimizing both a_W and ΔE. If minimization of the color change between the wet feed and dried material is made a primary goal, dryer surface temperature and dwell time should be minimized, content of added water should be maximized, and maltodextrin content should be 18% (while still using conditions that produce a fully-dried product). These conditions are shown in the prediction profile in Figure 5 below.

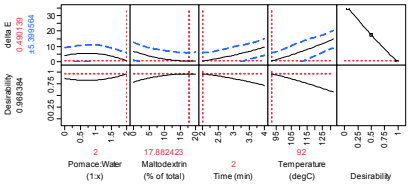

Figure 5: Prediction profile for ΔE (first row) desirability (second row). The depicted controlled variable settings, shown in red font, result in the maximum desirability based on color change alone (i.e. minimizing color change from wet to dried product).

Discussion / Next Steps

The results of this work will inform the design of a solar thermal-powered drum dryer that can produce high-quality dried specialty crop purees and pomaces (see the project concept diagram in Figure 6). Since the trend for the process variables is that the a_W decreases with increasing time and temperature, we will pursue further pushing the limits of these variables with the solar thermally-run drum dryer, in an effort to reduce or eliminate the need for a drying carrier. This will need to be blanched with the goal of minimizing color change and nutrient content degradation.



Figure 6: Overall concept diagram for solar thermal drum dryer project

Acknowledgements and Disclaimers

The authors thank Grimmway Farms, (Arvin, California, USA) for supplying the carrot pomace for this study. This project is supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

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SCB14033 Attachment 3

Solar Thermal Powered Drum Drying of California Specialty Crops

Jonathan Ferry, Ph.D. Student | Dr. Roland Winston, Principle Investigator | University of California, Merced | U.S. Department of Agriculture, Agricultural Research Service

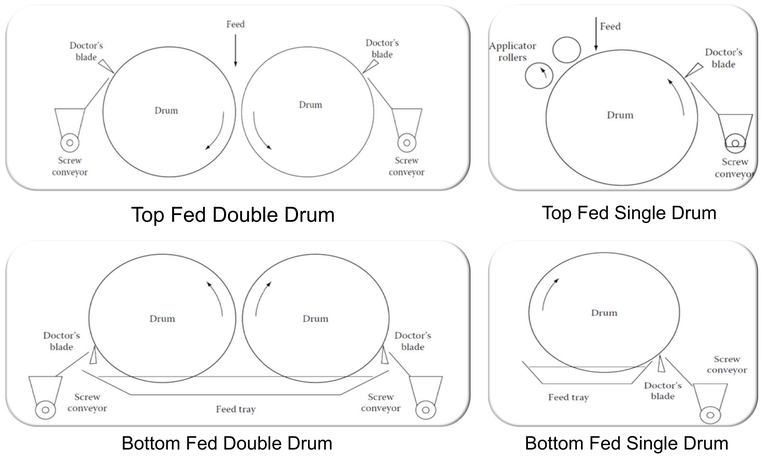
Project Background

- Use of drum drying to remove water content from California specialty crop pomaces and purées.
- Provide heating power needed for drying from innovative solar thermal collectors.
- Identify the feasibility of adapting solar thermal energy for use with existing drum drying technologies.

Drum Drying

- Consist of one or more rotating steel cylinders.
- Traditionally powered by steam condensing on the inside surface.
- Highly versatile in the ability to adjust surface temperature, rotation speed, and application thickness.
- Ideal for agricultural and food processing where there is a solid/liquid combined byproduct or waste stream.

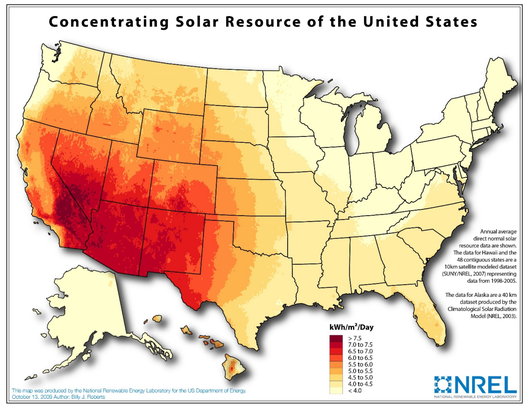
Types of Drum Dryers



Figures from Ramli, W., & Daud, W. (2014). Drum Dryers. In A. S. Mujumdar, Handbook of Industrial Drying, Fourth Edition (pp. 249-257).

Solar Resource

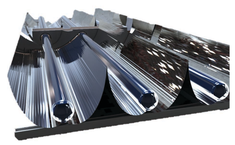
- California has an abundant solar resource.
  - Average direct normal irradiance of 5.0-6.0 kW/m^2/day.
- Sunlight to heat conversion generally more efficient than sunlight to electricity.
- Concentrating solar irradiation can improve heating power.
- Solar thermal is a well established industry.



Map provided by NREL at http://www.nrel.gov/gis/solar.html

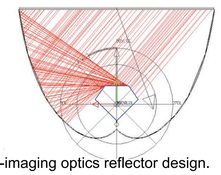
The External Compound Parabolic Concentrator (XCPC)

XCPC Collector



- Evacuated tubes with concentrating reflectors
- Medium temperature range
  - (100°C ≤ T ≤ 300°C)
- High solar to thermal efficiency
- Non-Tracking
  - Low cost and low maintenance

Optical Design



- Non-imaging optics reflector design.
  - Ideal theoretical concentration ratio.
  - Accepts both diffuse and direct light within angular limit.
- Evacuated glass tube reduces heat loss from conduction and convection.
- Mineral oil heat transfer fluid carries heat from absorber.

Solar Integration of a Drum Dryer

- Drum dryer to be operated using mineral oil heat transfer fluid rather than steam.
- Heating power to be provided by and XCPC array connected to a double drum dryer via a heat exchanger.

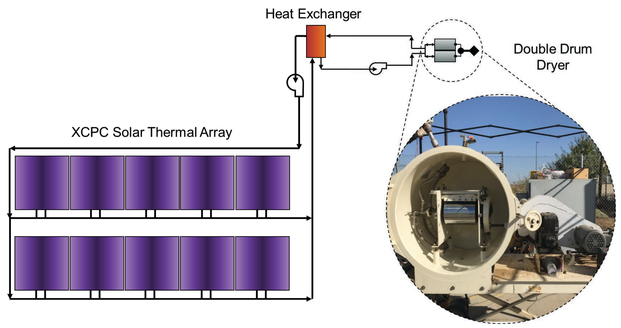


Figure 1 – Illustrative diagram showing integration of a small double drum dryer with an XCPC solar array.

Drum Characterization

- In order to determine how effective the drum is at drying different materials, a characterization of the surface temperature and rotational speed is necessary.
  - The drum rotation corresponds to how long a material will remain on the hot surface, or its "dwell time."
  - The surface temperature of the drum corresponds to how much heat is being transfer to a material in order to remove water content.
- Each of these parameters will be used to set up a split plot experiment to determine the optimum parameters for drying different purees and pomaces.

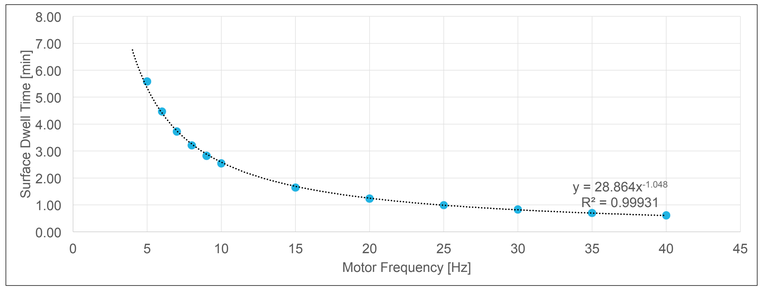


Figure 2 – Characterization of drum rotation speed and 65.5% surface dwell time.

Table 1 - Characterization of drum surface temperatures for various set point oil temperatures

T_{set} [C]	m_{dot} [g/s]	T_{in} [C]	T_{out} [C]	T_{s_ave} [C]
100	89.8	100.5	98.8	89.2
130	90.2	132.1	129.3	119.3
160	92.3	164.8	160.1	137.6
165	92.5	168.5	163.7	142.3

Next Steps

- Using the parameters defined in the characterization of the double drum dryer, a split plot experiment will be designed to dry several different fruit and vegetable pomaces and purees.
- Dried products will be measured for their water content, color, as well as vitamin and mineral content in comparison to before drying.
- Samples to be tested will have different starting water contents, dwell times, and surface temperature settings to bolster the split plot experiment design.

Acknowledgements

- The authors would like to thank Grimmway Farms, (Arvin, California, USA) for supplying the carrot pomace for this study. The authors would also like to thank the USDA-ARS, UC Solar, Dr. Roland Winston, Ron Durbin, Bennett Widyolar, Dr. Lun Jiang, Kaycee Chang, and Jordyn Brinkley.
- This project is supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

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An ASABE Meeting Presentation
DOI: 10.13031/aim.202460180
Paper Number: 2460180

Efficiency and Design Analysis of a Solar Thermal Powered Flat Plate Dryer

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Written for presentation at the
2016 ASABE Annual International Meeting
Sponsored by ASABE
Orlando, Florida
July 17-20, 2016

ABSTRACT. Specialty crop fruit and vegetable pomaces are a common byproduct of the food processing and juicing industries. These pomaces can have high nutritional value, but are currently underutilized or treated as waste. Drum drying is one method that could be adopted to dry and stabilize fruit and vegetable pomaces for long term storage and use. Current drum drying methods utilize conventional heating mechanisms such as gas fired steam generation. However, this heating can be generated just as effectively with solar thermal power, potentially reducing operational cost for the agriculture and food processing industries. In this work a 305 by 305 mm stainless steel flat plate was used to simulate the surface of a single drum dryer. Controlled inlet temperatures (105°C to 145°C) with varying load conditions on the flat plate represent typical operating conditions seen in a drum dryer. The heating power required to operate the flat plate within the desired temperature range was calculated to be 494 W to 835 W respectively. These results were incorporated into and compared to a heat transfer model of a 4.5 m^2 External Compound Parabolic Concentrator (XCPC) solar thermal collector designed to produce approximately 2 kW of heating power. Our simulations modeled the flat plate in series with the solar collector, predicting the temperature rise and power supplied to the flat plate. The XCPC collector operating at a fixed flow rate (100 g s^{-1}) with global solar irradiance of 900 W m^{-2}, produces a temperature rise to the system of 5°C to 8°C. Modeling the heat loss from the flat plate predicts a temperature drop of 2°C to 4°C, which agrees with experimental measurements. Analysis of the model with experimental results suggests that a single solar thermal collector can provide an adequate temperature rise to heat the solar thermal-powered flat plate system. An additional cooling power of 1.8kW is needed to maintain operating temperature once the system stabilizes. The results of this work will inform the design of a solar thermal-powered drum dryer for use in drying specialty crop purees and pomaces.

Keywords. *Food processing, heat and energy transfer, modeling, solar, specialty crops.*

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Introduction

Drum Drying

Drum dryers are commonly used equipment in food processing, consisting of one or more rotating steal cylinders heated by condensing steam on the inside surface. A thin layer of some viscous substance is spread evenly on the surface of the drum(s), and scraped off after the desired dryness has been reached. Drum dryers are extremely versatile in their ability to dry different materials, because of the ability to adjust the drum temperature, rotation speed, and application thickness. Various drum dryer configurations and drying procedures are described by (Ramli & Daud, 2014). The substance spread on the drum's surface can be a variety of materials in which water needs to be removed. Many byproducts of the food processing and agricultural industries consist of a solid/liquid combined waste stream. In some instances this waste stream contains valuable nutritious materials that can be repurposed if processed appropriately. By using a drum dryer, materials such as fruit and vegetable pomaces and purees can be dehydrated to improve storage life and save on transportation costs. Common methods of supplying the steam used to heat drum dryers use conventional gas fired boilers. This heating can be accomplished just as effectively using solar power. The goal of this paper is to analyze the feasibility of adopting solar thermal energy as a substitute for drum drying and similar technologies. As an initial approximation, a flat steel plate is substituted for a drum dryer both for experimentation and modeling.

Solar Thermal Energy

Solar thermal technologies come in many forms, ranging from home hot water heating to utility scale supercritical steam generation. For the purpose of drying food products, a solar technology that can achieve temperatures within the range of 100°C to 200°C should be chosen. The most common solar thermal technology that fits this criteria, are parabolic trough collectors. Though mature in their design and use, parabolic troughs are large, inefficient, and need to continually track the sun to produce thermal power. Another solar thermal technology that operates in the 100°C to 200°C temperature range are the External Compound Parabolic Concentrators (XCPC), as characterized by (Jiang, Widyolar, & Winston, 2015). The advantage to the XCPC is its ability to concentrate sunlight and reach high temperatures without the need to track the sun. This ability is accomplished by the use of ideal optics developed from nonimaging optics theory, outlined thoroughly in the work of (Winston, Minano, & Benitez, 2005). The XCPC has considerable advantages over parabolic troughs, both in performance efficiency, and the requirement to track the sun, which can be costly to develop and maintain. For these reasons, the XCPC technologie seems to be an ideal choice to use in drying technology applications.

Modeling

Flat Plate Model

The flat plate being modeled is stainless steel rectangular box dimensioned 305 by 305 by 25 mm. The plate's surface is heated by flowing a heat transfer oil through the narrow section of the plate. Flow through the plate is assumed to be uniform, and heat loss to the ambient environment is due only to free convection. The temperature of each surface is assumed to be uniform across its thickness, and for simplicity, flow through the plate is treated as flow through a narrow rectangular duct. An energy balance is performed on each surface to calculate the surface temperature of the plate, and exit oil temperature, for a given mass flow rate and inlet oil temperature. The heat transfer into the plate is defined as:

$$Q_{in} = \dot{m} c_p \left(T_{in} - T_{out}\right) \tag{1}$$

where
Q_{in} = heat transfer into plate (W)
$\dot{m}$ = oil mass flow rate (kg s^{-1})
c_p = specific heat of oil (J kg^{-1} K^{-1})
T_{in} = inlet oil temperature (C)
T_{out} = outlet oil temperature (C).

Creating an energy balance with the plate surface, the heat transfer from the oil to the plate surface is calculated as:

$$Q_{in} = h_{oil} A_p dT_{lm} \tag{2}$$

where
h_{oil} = convective heat transfer coefficient of oil (W m^{-2} K^{-1})
A_p = surface area of the entire plate (m^2)
dT_{lm} = log mean temperature of the oil (C)

The convective heat transfer coefficient of the oil is calculated from the Nusselt number, as defined by (Shah, London, Irvine, & Hartnett, 2014) for internal forced convection in non-circular ducts.

$$Nu_T = 7.541\left(1 - 2.610\alpha_* + 4.970\alpha_*^2 - 5.119\alpha_*^3 + 2.702\alpha_*^4 - 0.548\alpha_*^5\right) \quad (3)$$

where
α_* = the aspect ratio of the rectangular channel (-)

The log mean temperature is given in (Bergman, Lavine, Incropera, & Dewitt, 2011) for a simple heat exchanger as:

$$dT_{lm} = \frac{T_{out} - T_{in}}{\ln\left(\frac{T_{out} - T_{surf}}{T_{in} - T_{surf}}\right)} \quad (4)$$

where
T_{surf} = surface temperature of the plate (C)

The heat transfer leaving the plate is:

$$Q_{out} = 2h_s A_s\left(T_s - T_\infty\right) + h_t A_t\left(T_t - T_\infty\right) + h_b A_b\left(T_b - T_\infty\right) \quad (5)$$

where
Q_{out} = heat transfer out of plate (W)
h_s = convective heat transfer coefficient for the plate sides (W m^{-2} K^{-1})
A_s = surface area of the side of the plate (m^2)
T_s = temperature of the side of the plate (C)
h_t = convective heat transfer coefficient for the plate top (W m^{-2} K^{-1})
A_t = surface area of the top of the plate (m^2)
T_t = temperature of the top of the plate (C)
h_b = convective heat transfer coefficient for the plate bottom (W m^{-2} K^{-1})
A_b = surface area of the bottom of the plate (m^2)
T_b = temperature of the bottom of the plate (C)

The sides, and top and bottom surfaces are treated as vertical and horizontal plates under free convection respectively. The convective heat transfer coefficients for each surface can be calculated from the general Nusselt number equation. From (Bergman, Lavine, Incropera, & Dewitt, 2011) the Nusselt numbers for free convection are:
Vertical Plate:

$$Nu_T = 0.68 + \frac{0.67Ra^{1/4}}{\left(1 + \left(\frac{0.492}{\mathrm{Pr}}\right)^{9/16}\right)^{4/9}} \quad (6)$$

Horizontal Plate (Top):

$$Nu_T = \begin{cases} 0.54Ra^{1/4}, 10^4 \le Ra \le 10^7 \\ 0.15Ra^{1/3}, 10^7 \le Ra \le 10^{11} \end{cases} \quad (7)$$

Horizontal Plate (Bottom):

$$Nu_T = 0.52Ra^{1/5} \quad (8)$$

where
Nu_T = Nusselt number (-)
Ra = Rayleigh number (-)
Pr = Prandtl number of air (-)

The Rayleigh number for free convection in air is calculated as defined by (Bergman, Lavine, Incropera, & Dewitt, 2011):

$$Ra = \frac{g\beta\left(T_s - T_\infty\right)L^3}{\nu\alpha} \quad (9)$$

where
g = gravitational acceleration (m s^{-2})
β = thermal expansion coefficient of air (K^{-1})
L = characteristic length of the free convection surface (m)
ν = kinematic viscosity of air (m^2 s^{-1})
α = thermal diffusivity of air (m^2 s^{-1})

Using equations 1, 2, and 5, the plate surface temperatures, and outlet oil temperature can be calculated by iteration for a given mass flow rate and inlet oil temperature.

Solar Collector Model

The XCPC collector is designed using nonimaging optics mirrors to concentrate sunlight onto six 2 m long glass vacuum tubes. An example of XCPC modeled in this paper is shown in figure 1. Each vacuum tube contains a copper absorber fin, coated with a spectrally selective coating to capture solar radiation. The absorber fin conducts heat to a copper tube in which a heat transfer oil flows. To model the XCPC, the radiation on the absorber fin is assumed to be uniformly distributed. The total incoming power to the XCPC is defined as:

$$Q_{col\_in} = \rho\tau\alpha_c C_x G A_{fin} \tag{10}$$

where
Q_{col_in} = Power into the XCPC collector (W)
ρ = reflectance of the mirror (-)
τ = transmissivity of the glass tube (-)
α_c = absorptance of the selective coating (-)
C_x = concentration ratio of the concentrating optics (-)
G = incoming solar irradiation (W m^{-2})
A_{fin} = surface area of the copper absorber fin (m^2)

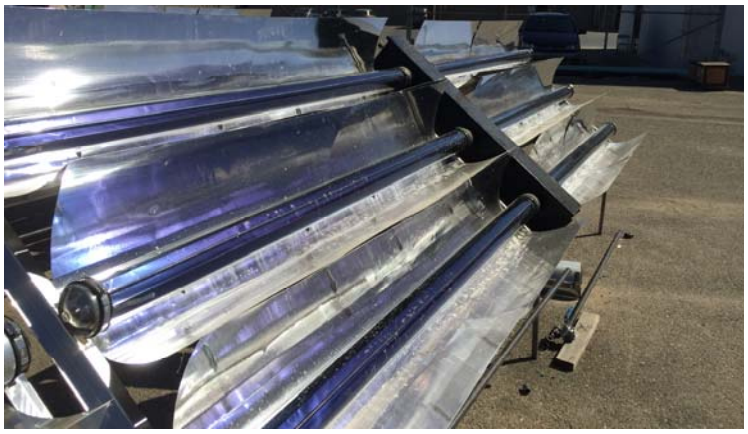

Figure 1. A single XCPC solar thermal collector consisting of six 2 m long vacuum tubes

The heat transfer to the oil tube is modeled by breaking the absorber fin into multiple nodes and calculating the heat conduction between each node using Fourier's Law. The model makes use of both equations 1 and 2 above to simulate the heat transferred to the oil. The heat conducted from the oil tube and convected to the oil is modeled as internal forced convection in a circular tube, described extensively in (Bergman, Lavine, Incropera, & Dewitt, 2011), and will not be reproduced here.

Experiment

To validate the model results, an experimental procedure was developed to test a flat plate with a variety of inlet oil temperatures. The flat plate, as pictured in figure 2, was connected to an electrically controlled hot oil loop designed to precisely control the oil temperature. The mass flow rate of the oil loop was fixed at 100 g s^{-1}. For given inlet temperatures ranging from 105°C to 145°C, the steady state temperatures of the plate surface and oil outlet were measured. To test the plate performance under loaded conditions, samples of carrot and prune pomaces of various consistencies were spread evenly over the top surface of the plate and allowed to dry for times ranging from 2.5 to 4 min. During this drying process the outlet oil temperature was measured for comparison to the steady state number. The XCPC solar collector was excluded from the experiment in order to ensure consistent measurements of the flat plate. Results of an XCPC performance are discussed in detail by (Jiang, Widyolar, & Winston, 2015), and their numbers are used as a comparison for the model.



Figure 2. Stainless steel flat plate used in experimental drying of carrot and prune pomaces

Results

In the experiment, the flat plate was tested over a range of inlet oil temperature of 105°C to 145°C at 20°C increments, for a fixed mass flow rate. Providing these same inputs to the model, a comparison between the experimented and simulated results of the plate surface temperature and change in oil temperature can be seen in table 1. The experimental temperatures listed are for steady state conditions with no load being applied to the plate surface. During the trials of the carrot and prune pomaces, the plate's surface temperature was not measured, but the temperature drop was recorded. There was little, to no measureable effect on the temperature drop across the plate when the pomace samples where applied vs. under the unloaded condition.

Table 1. Comparison of measured and simulated surface temperature and oil temperature drop across the flat plate.

	Measured		Simulated			
T_{in}	T_s[a]	ΔT_{oil}	T_s[a][b]	ΔT_{oil}[b]	T_s[a][c]	ΔT_{oil}[c]
105°C	88.8°C	2.1°C	77.0°C	2.4	88.6°C	1.3°C
125°C	108.3°C	2.9°C	88.8°C	3.0	104.1°C	1.6°C
145°C	122.9°C	3.6°C	100.0°C	3.7	119.8°C	1.9°C

[a] Temperature averaged over top plate surface

[b] Temperature calculated using free convection heat transfer coefficient determined from equations 6-8

[c] Temperature calculated using a constant heat transfer coefficient of h = 5 W m^{-2} K^{-1}

By comparing the measured results with the simulation, it becomes readily apparent that the free convection heat transfer coefficients grossly overestimate the heat loss from the flat plate. Re-conducting the simulation assuming an average convection coefficient to the air of h = 5 W m^{-2} K^{-1}, the surface temperature and oil temperature drop fall much more closely in line with experimental measurements.

For the XCPC collector, (Jiang, Widyolar, & Winston, 2015) report on the collector efficiency, and temperature rise for inlet temperatures to the collector of 160°C, 200°C, and 230°C. Their results are reproduced in table 2 below. Comparing these experimental results to the XCPC simulation, the rise in temperature across a six-tube collector is comparable in both cases. However, the simulated efficiency shows a deviation from the measured values. This signifies an overestimation of the heat loss from the XCPC in the simulation.

Table 2. Comparison of measured and simulated temperature across a six-tube XCPC.

	Measured		Simulated	
T_{in}	ΔT_{col}[a]	η[a]	ΔT_{col}	η
160°C	7.48	55.67%	8.42	51.89%
200°C	6.24	53.37%	6.42	41.70%
230°C	4.99	44.80%	4.89	33.04%

[a] Results duplicated from (Jiang, Widyolar, & Winston, 2015)

Finally comparing the heat power input from the XCPC collector to the power lost from the flat plate, the viability of a solar thermal powered drum dryer becomes clear. Table 3 presents both the experimentally determined power and the simulated estimation for both the flat plate and XCPC. In general, standard operational temperatures for the XCPC are

around 200°C. For the drying of food products, only temperatures slightly above the boiling point of water are necessary. Table 3 shows a general trend of the XCPC producing more thermal power at lower temperatures, and the flat plate losing more heat at higher temperatures, which is expected. The power produced by the XCPC is more than adequate to provide the heat necessary for a flat plate of the dimensions used in this experiment.

Table 3. Heating power of a six-tube XCPC in comparison to the heat loss from a flat plate.

	Q_{col}			Q_{plate}	
T_{in}	Measured[a]	Simulated	T_{in}	Measured	Simulated[b]
160°C	1993 W	2200 W	105°C	459.5 W	459.0 W
200°C	1762 W	1768 W	125°C	652.5 W	590.1 W
230°C	1440 W	1401 W	145°C	835.2 W	721.2 W

[a] Values calculated from data given in (Jiang, Widyolar, & Winston, 2015)

[b] Heat loss from the flat plate calculated using free convection heat transfer coefficient determined from equations 6-8

Conclusion

The purpose of this paper was to analyze the heat transfer from a flat plate as an approximate for a drum dryer, and determine the feasibility of using solar thermal energy as the heat source for the plate. The flat plate presents a similar surface area to a small benchtop drum dryer, and thus a valid estimate of how a drum dryer might perform. The XCPC collector was shown to be an effective means for generating heat from the sun. The results of the simulation for both the flat plate and XCPC produced values close to those from the experimental trials. There was some significant deviation from the experiments when simulating the surface temperature of the flat plate, and the collector efficiency. More work can be done to refine the model to account for other sources of heat loss, and non-uniform flow in the plate. However, when just comparing experimental results, it becomes apparent that a six-tube XCPC collector is more than capable of providing the necessary thermal power to a 305 by 305 by 25 mm flat plate. Even with the inaccuracies of the simulation, the model agrees with this assessment. This was an early stage experiment to gain a better understanding of the heat transfer from a flat plate, and simulate the viability of using solar thermal power. Future works will include the acquisition of a small benchtop drum dryer to connect in sequence with an array of XCPC collectors.

Acknowledgements

The authors thank Grimmway Farms, (Arvin, California, USA) for supplying the carrot pomace for this study. The authors would also like to thank the USDA-ARS, UC Solar, Dr. Roland Winston, Ron Durbin, Bennett Widyolar, Dr. Lun Jiang, and Kaycee Chang. This project is supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

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FOOD AND BIOPRODUCTS PROCESSING 106 (2017) 53–64

Contents lists available at ScienceDirect

Food and Bioproducts Processing

journal homepage: www.elsevier.com/locate/fbp

Solar thermal drum drying performance of prune and tomato pomaces

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ARTICLE INFO

Article history:
Received 31 March 2017
Received in revised form 23 August 2017
Accepted 27 August 2017
Available online 4 September 2017

Keywords:
Pomace
Prune
Tomato
Co-product
Drum drying
Solar

ABSTRACT

Fruit and vegetable pomaces are co-products of the food processing industry; they are underutilized in part because their high water activity (a_w) renders them unstable. Drum drying is one method that can dry/stabilize pomaces, but current drum drying methods utilize conventional, high-environmental-impact heating mechanisms. In this work, a small-scale double drum dryer (20 cm length × 15 cm diameter) was interfaced with a 98.3 m^2 External Compound Parabolic Concentrator (XCPC) [solar thermal collector] array designed to produce up to approximately 40 kW of heating power. The conditions for drying prune and tomato pomaces were optimized on this system via a split-plot design. The design had 4 variables: added water, added maltodextrin carrier, dwell time, and drum surface temperature. Moisture content, a_w, and color of the dried pomaces were assessed to determine the effectiveness of the drying. Both pomaces were rendered shelf-stable ($a_w < 0.6$) for all tested conditions. However, prune pomace exhibited a narrower range of a_w values than did tomato pomace. Conditions for adequate drying with minimal color change (and thus expected minimal nutrition loss) were established. This work demonstrates the potential for solar thermal energy to provide the heat for drum drying fruit and vegetable pomaces.

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1. Introduction

The manufacture of value-added products from fruits and vegetables often generates a semisolid co-product called pomace (also sometimes termed "marc", "lees", or "press cake residue"). Pomace consists of the skins, seeds, and other fibrous parts of the plant but also can contain an appreciable amount of water. This renders pomace unstable at ambient conditions, as it will be subject to mold growth. Drying pomace is one straightforward method of achieving shelf-stability. If pomace could be dried to a stable form efficiently, it could be a source of nutritious food ingredients. Indeed, bioactive compounds from whole pomaces and extracts thereof have been explored by several groups (Wijngaard et al., 2012; Paraman et al., 2015; Goula et al., 2016). At minimum, the financial and environmental costs of transporting pomace for use as fertilizer or animal feed would be reduced if the moisture content were reduced.

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http://dx.doi.org/10.1016/j.fbp.2017.08.009
0960-3085/Published by Elsevier B.V. on behalf of Institution of Chemical Engineers.

Drum drying[1] is a food processing unit operation that is well-suited for drying purees and syrups. The technology has recently been explored for production of flour from white-fleshed potato (Carillo et al., 2009; Kakade et al., 2011) and purple-fleshed sweet potato (Soison et al., 2014). Drum drying has also been demonstrated as a method for adding value to watermelon pomace (Arocho and Bellmer, 2012), apple peel (Henríquez et al., 2010), and condensed distillers solubles (the slurry co-product from ethanol production from corn/maize) (Milczarek and Liu, 2015). For each material to be drum-dried, multiple feed formulation and processing conditions must be tested and optimized. Water may be added to the feed stream to reduce viscosity and enable smoother coating of the drums. Drying carriers such as maltodextrin have been used in other drying processes (Jaya and Das, 2004; Sablani et al., 2008; Kim and Kerr, 2012; Sedej et al., 2016) and may prove helpful for drum drying, as well. Processing conditions which can be optimized include the dwell time (sometimes termed "residence time") of the product on the drum and the interior drum steam pressure/temperature (which determine the drum surface temperature experienced by the product).

While solar cabinet drying has been attempted for stabilizing olive pomace (Montero et al., 2010), there have been no reports of using advanced solar thermal[2] technologies for drying this type of material. In general, solar thermal collectors use reflection and/or refraction optics to focus sunlight on a fluid that is pumped through the focal point (Kalogirou et al., 2016). The fluid can be water, as in the case of domestic and commercial solar thermal water heating systems. Solar thermal water heating systems have been in use in the food industry since the late 1970s (Proctor and Morse, 1977) and have good potential for expanded utilization as a process heat source in this industry (Atkins et al., 2010). The fluid heated by sunlight may instead be an oil; heat transfer oils can reach temperatures greater than 100 °C without the associated phase change and pressure increase seen with water. Indeed, Ferry et al. (2016) demonstrated that a griddle-style flat plate dryer can be heated with heat transfer oil from a solar thermal system. In theory, a drum dryer could also be heated using the same mechanism, but this approach has not been attempted til the current work.

The pomaces generated from the processing of prune (dried plum — *Prunus domesticus*) and tomato (*Solanum lycopersicum* L.) were chosen for this study. While other works involving prune pomace (i.e. pomace from the processing of dried plums) could not be identified in the existing literature, some groups have examined the pomace from the processing of fresh plums as a source of dietary fiber and polyphenols (Milala et al., 2013; Dwivedi et al., 2014; Sójka et al., 2015). Tomato pomace has recently been used to make high-fiber ketchup (Torbica et al., 2016), and modern drying modalities such as microwave (Al-Harahsheh et al., 2009) and lyophilization (Zhang et al., 2011; Previtera et al., 2016) have been brought to bear on this material. Shao et al. (2015) found that the seeds and peels of tomato pomace can be separated using an air aspirator system, and that separation efficiency increased when the moisture content of the pomace was lower. This is an additional motivation for drying tomato pomace, in particular.

Thus, the objectives of the present study were to demonstrate that both prune pomace and tomato pomace could be drum-dried using solar thermal energy and to optimize the formulation and processing conditions for each material.

[1] Here, "drum drying" refers to the drying process in which a pumpable material is loaded in a thin layer onto the *exterior* of one or two rotating, heated metal drums, and the dried product is scraped off the drum with a doctor blade. This is in contrast to another drying technology – "rotary drum drying" or "rotary drying" – in which the material to be dried is bulk fed into the *interior* of a rotating drum with co-current or counter-current hot air flow.

[2] Solar thermal technologies involve the conversion of energy from sunlight to usable heat. This is in contrast to photovoltaic technologies, which convert energy from sunlight to electricity.

2. Material and methods

2.1. Materials

Prune pomace was obtained from Papagni Fruit & Juice (Madera, CA, USA) in March 2015; tomato pomace was obtained from Ingomar Packing Company, LLC (Los Banos, CA, USA) in July 2016. These pomaces are co-products of the production of prune (dried plum) concentrate and hot-break tomato paste, respectively. The commercial pomaces were collected in 4 gallon (15 L) plastic buckets at the processing plant, transported immediately to the USDA — Agricultural Research Service laboratory (Albany, CA, USA), stored at −20 °C, and thawed just before blending and/or analysis. For making the pomace blends (described in more detail in Section 2.4), food-grade maltodextrin (dextrose equivalent 18) was purchased from Grain Processing Corp. (Muscatine, IA, USA), and filtered tap water was used. Due to the different textures of the two pomaces, the prune pomace blends were mixed using an immersion blender for 10 s, and the tomato pomace blends were mixed by hand for 30 s.

2.2. Solar thermal heating system

The External Compound Parabolic Concentrator (XCPC) array which was used to provide heat to the drum dryer is located on the University of California, Merced campus (Atwater, CA, USA — latitude 37° 22′ N). The array has been characterized by the method developed by Jiang et al. (2015). Briefly, sunlight strikes the reflective surface of curved collectors and focuses onto an evacuated-tube manifold containing a copper pipe through which heat transfer fluid is pumped. The heated fluid can then be circulated through a load; the Atwater system has been previously demonstrated with a double effect chiller (Widyolar et al., 2014). An advantage of the particular design of the XCPC collector over other solar thermal technologies is that it can concentrate sunlight and reach high temperatures (100 °C–200 °C) without the need for solar tracking. The XCPC array in Atwater consists of 2 banks of east-west (EW) oriented collectors with 5 collectors in each bank and 2 banks of north-south (NS) oriented collectors with 8 collectors in each bank, for a total of 26 collectors. The EW and NS systems have aperture areas of 45.0 m^2 and 53.3 m^2, respectively, for a total area of 98.3 m^2. When both systems are operated together under peak sun conditions, the array can produce about 40 kW of thermal power. The EW and NS systems can be isolated from each other using valves within the heat transfer fluid circulation system. In general, all the collectors were uncovered at the beginning of each work day to enable rapid heating of the system, and the EW system was shut off when the drum inlet temperature was within 5–10 °C of its setpoint. In the present configuration of the XCPC array, the temperature of the heat transfer fluid was then fine-tuned by covering individual collectors in the NS system with an opaque cloth barrier; this is depicted in Fig. 1.

2.3. Drum drying apparatus

A small-scale double drum dryer (each drum 20 cm length × 15 cm diameter) was interfaced with the XCPC array. The inlet and outlet ports of the dryer – normally connected to a steam/condensate line – were modified to accommodate the heat transfer oil (Duratherm 600,



Fig. 1 – Covering solar thermal collectors to adjust heat transfer fluid temperature.

Duratherm Extended Life Fluids, Lewiston, NY, USA) used in the circulation loop. A calibration curve was developed to relate oil temperature at the drum inlet to the surface temperature of the drums. The relationship was found to be nearly linear ($R^2 = 0.98$) for the range of temperatures tested; in addition, the response time of the drum (time to reach new equilibrium surface temperature after a step change in inlet oil temperature) was observed to be less than 1 min. A known quantity (approximately 33 g for prune pomace blends, 60 g for tomato pomace blends) of the sample material was fed into the gap between the two drums, adhered to the drums for 59% of a full rotation, and was scraped off by a doctor blade near the top of each drum. The drum rotation rate was controlled using a variable frequency drive connected to the drum drive motor. A calibration curve was developed to relate product dwell time to the frequency setting (Hz) on the variable frequency drive. Drive rates of 12.57 Hz, 8.22 Hz, and 6.08 Hz corresponded to product dwell times of 2 min, 3 min, and 4 min, respectively. The gap between the drums was adjusted using shimming handles on both ends of one of the drums. Gap width was held constant at 0.125 mm, which was the average between the thinnest gauge that was blocked by the gap (0.15 mm) and the thickest gauge that would pass through the gap (0.10 mm). Gap width was measured and adjusted before every run.

The drum dryer was interfaced to the solar thermal array via a heat exchanger; a schematic of the system is shown in Fig. 2. The purpose of the heat exchanger was to separate the oil circulation loops of the XCPC array and drum dryer, so the dryer (or any other load) could be installed or repaired without draining the heat transfer fluid from the entire solar thermal array. Two type K thermocouples were placed at each of 7 points in the oil circulation system, and the average reading of the two thermocouples was transmitted every 6 s to the data logging system. Venturi flowmeters measured the volumetric flow rate of the heat transfer fluid in both loops; flow of the XCPC array loop was logged automatically, while flow of the drum dryer loop was read off the meter and recorded at the beginning of each run.

Ambient temperature (°C) and insolation (W/m^2) were measured by a Vantage Pro 2 weather station (Davis Instruments, Vernon Hills, IL, USA) and relayed to the data logging system. The number of uncovered (i.e. active sunlight-capturing) collectors (out of a possible total of 26) and the total processing time were recorded for each run.

2.4. Experiment design

A primary purpose of this experiment was to determine the effects of added water, added maltodextrin carrier, dwell time, and drum surface temperature on the drying performance of the two pomaces. Of these variables, added water, added maltodextrin carrier, and dwell time are easy to adjust. Drum surface temperature, however, had to be adjusted as the insolation changed, and the thermal inertia of the oil within the circulation loop was considerable. This made drum surface temperature difficult to vary, making a fully-randomized factorial response surface design impractical. Thus, a split-plot design with drum surface temperature as the whole plot variable was generated in JMP (Version 9.0.1, SAS Institute, Inc., Cary, NC, USA). The low and high values for the four independent variables were as follows: 0 parts and 2 parts added water per part pomace for added water, 0% and 20% of total weight for added maltodextrin, 2 min and 4 min for dwell time, and 92 °C (198 F) and 132 °C (270 F) for drum surface temperature. (Based on the calibration curve described earlier, the drum surface temperatures of 92 °C and 132 °C would be achieved with drum inlet oil temperatures of 139 °C and 164 °C, respectively. Since drum surface temperature could not be measured in real time but drum inlet oil temperature was easily measured automatically with inline thermocouples, the latter quantity was the basis for control.) The design consisted of 48 runs, arranged in blocks of 4 runs at the same drum surface temperature. Analysis of variance (ANOVA) was performed to determine the significance of each of the independent variables as main effects, the first-order interactions of the independent variables, and the squared terms. Once the significance of the independent variables was established through ANOVA, standard least squares regression was applied in JMP to determine coefficient estimates for a prediction equation for each response variable. The general format for the prediction equations for the response variables is shown below in Eq. (1). In Equation (1), Z is the value to be predicted, c_0 through c_8 are standard least squares regression coefficients, w is parts added water per part pomace, m is maltodextrin content in percent of total weight, t is dwell time in minutes, and T is drum surface temperature in degrees Celsius.

$$\begin{aligned} Z = {} & c_0 + c_1*(w-1) + c_2*((m-10)/10) + c_3*(t-3) \\ & + c_4*((T-112)/20) + c_5*(t-3)*((T-112)/20) \\ & + c_6*(w-1)*((m-10)/10) + c_7*(w-1)*(t-3) \\ & + c_8*(w-1)*((T-112)/20) \end{aligned} \quad (1)$$

2.5. Measurement of response variables

The response variables used to assess drying performance were moisture content, a_w, and overall color change (from wet to dry). Moisture content was determined gravimetrically using a microwave oven moisture analyzer (Model AVC 80, CEM, Matthews, NC, USA). Settings on the analyzer were as follows: power = 40%, mass change to trigger end of drying = 0.9 mg, time change over which mass change occurred = 10 s. a_w was measured at 25 °C by the dew-point method with an AquaLab 4TE water activity meter (Decagon Devices, Pullman, WA, USA). Tristimulus (L*, a*, b*) color values

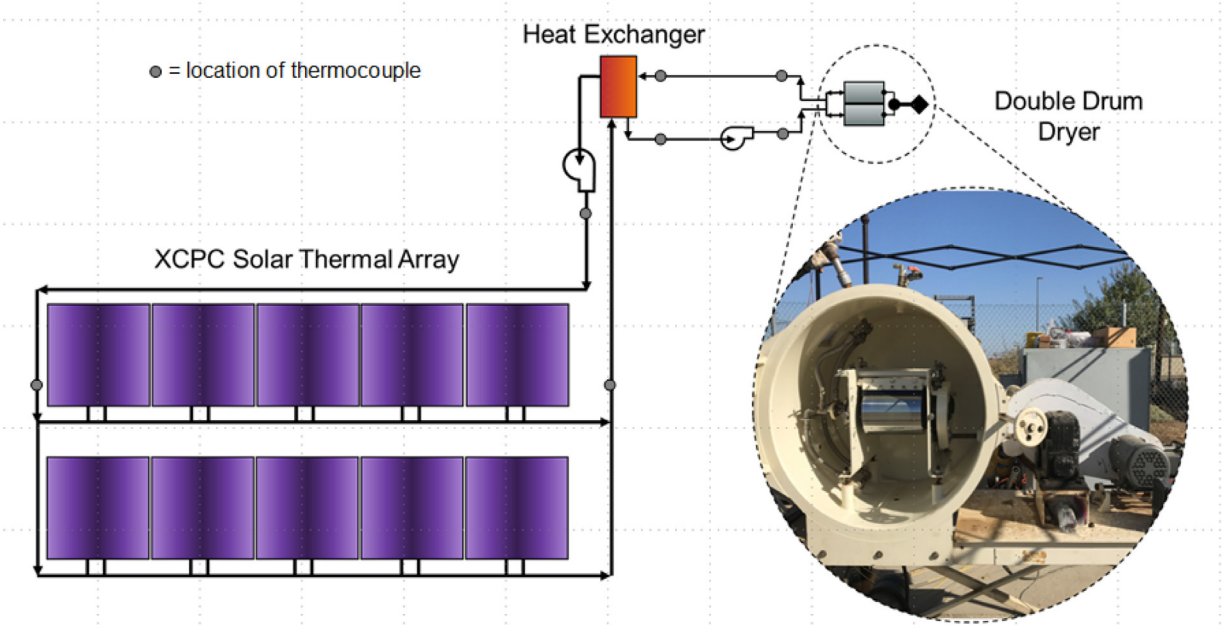

Fig. 2 – Schematic representation and photograph of the solar thermal array and drum drying system in Atwater, California, USA.

were measured using a portable spectrophotometer (Model CM-700d, Konica Minolta Sensing Americas, Inc., Ramsey, NJ, USA). Overall color change (ΔE) from wet material to dry material was defined as:

$$\Delta E = \sqrt{\left(\left(L*^2_{wet} - L*^2_{dry}\right) + \left(a*^2_{wet} - a*^2_{dry}\right) + \left(b*^2_{wet} - b*^2_{dry}\right)\right)} \quad (2)$$

All measurements were performed in triplicate, and mean values were used for the responses in the split-plot design.

3. Results and discussion

3.1. *Solar thermal drum drying conditions*

The pomace blends were dried using the above-described system during the months of November 2016–January 2017. On each testing day, 1–4 blocks (4 runs per drum surface temperature whole plot block) were completed. The individual runs lasted from a minimum of 3 min 13 s to a maximum of 32 min 45 s, with most runs in the 4–8 min range. (Although the dwell times were set at 2, 3, or 4 min as per the experiment design, the time to run the entire sample would vary depending on the consistency of the sample — runs of thicker, stickier samples took longer to complete compared to those of thinner, runnier samples.) For the prune pomace runs, insolation ranged from 154 W/m^2 to 808 W/m^2, and ambient temperature ranged from 14.7 °C to 33.3 °C. The oil temperature difference between the drum inlet and outlet averaged 2.2 °C, 3.4 °C, and 3.1 °C for the 139 °C, 151 °C (midpoint), and 164 °C inlet setpoints, respectively. For the tomato pomace runs, insolation ranged from 176 W/m^2 to 728 W/m^2, and ambient temperature ranged from 11.6 °C to 21.5 °C. The oil temperature difference between the drum inlet and outlet averaged 4.1 °C, 4.2 °C, and 4.5 °C for the 139 °C, 151 °C, and 164 °C inlet setpoints, respectively. The number of collectors needed to maintain the drum inlet oil temperature near the setpoint varied from 4 to 26 (full array) for the prune pomace runs and 8 to 26 for the tomato pomace runs.

3.2. *Initial material characteristics and qualitative observations during drum drying*

Initial characteristics of the pomaces are listed in Table 1. The prune pomace had uniform dark purple/brown color and paste-like, viscous consistency. The high viscosity was the reason added water was included as an independent variable in the split-plot experiment design. The hypothesis was that thinning the pomace would enable it to spread more easily and evenly on the drums, offsetting any extra energy that would be needed to drive off the added water. The tomato pomace consisted of large (approximately 5–30 mm) fibrous particles of skin as well as identifiable seeds. Color of these tissues corresponded with that of the source tomatoes: red/orange/yellow for the skin and light yellow for the seeds. (Reported L*, a*, b* color values are for the pomace blends as a whole.)

For both the prune and tomato pomaces, ease of application of the pomace blend into the nip of the dryer was observed to correspond with (visually-assessed) viscosity. Thicker blends required more manual pressing (with a spatula) to ensure the material would continue feeding through and adhere to the drums. The dried prune pomace blends ranged from sticky to dry/flaky in consistency. Tomato pomace blends that contained maltodextrin sometimes exhibited a woolly or white-crystal-forest appearance on the drums; this indicated the bulk of the maltodextrin remained in the liquid portion of the pomace blend and dried essentially separately from the solid portion of the tomato pomace. Individual skin and seed particles were still identifiable in the tomato pomace blends after drying.

3.3. *Effect of formulation and processing variables on drying outcomes*

The ANOVA for each regression model indicated that the 4 independent variables (added water, added maltodextrin, dwell time, and drum surface temperature) and their interactions affected the response variables with varying degrees of significance (Table 2).

Table 1 – Initial characteristics of prune and tomato pomaces.

	Moisture content (% wet basis)	Water activity	L*	a*	b*
Prune pomace	65.49 (1.84)	0.9877 (0.0022)	15.50 (0.33)	8.58 (0.11)	10.86 (0.22)
Tomato pomace	53.62 (1.33)	0.9911 (0.0015)	43.12 (3.51)	29.00 (0.84)	53.85 (2.86)

Values listed are means of triplicate measurements; standard deviations are in parentheses.

For both pomaces, a_w was significantly affected by both water and maltodextrin, while the a_w of tomato pomace was additionally affected by dwell time, drum surface temperature, and the interaction of these two terms. Moisture content and a_w did not completely track each other for which model terms were significant. Notably, for both pomaces, the (water) × (time) interaction term was a significant source of variation of moisture content but not of a_w. The L*, a*, and b* color components were not affected by dwell time for either pomace. ΔE was strongly ($p < 0.01$) influenced by added water and added maltodextrin contents; in addition, for tomato pomace, the (water) × (maltodextrin) term influenced ΔE.

The general format for the prediction equations for the response variables is shown below in Eq. (1), reprinted below for quick reference. In Eq. (1), Z is the value to be predicted (a_w, moisture content, or ΔE), c_0 through c_8 are standard least squares regression coefficients as listed in Table 3, w is parts added water per part pomace, m is maltodextrin content in percent of total weight, t is dwell time in minutes, and T is drum surface temperature in degrees Celsius.

$$\begin{aligned} Z = {} & c_0 + c_1*(w-1) + c_2*((m-10)/10) + c_3*(t-3) \\ & + c_4*((T-112)/20) + c_5*(t-3)*((T-112)/20) \\ & + c_6*(w-1)*((m-10)/10) + c_7*(w-1)*(t-3) \\ & + c_8*(w-1)*((T-112)/20) \end{aligned} \quad (1)$$

In Table 3, only the model terms found to be significant through ANOVA ($p < 0.05$, see Table 2) are included for each prediction equation. In addition to the estimated values of the prediction equation coefficients, Table 3 lists the statistical parameters associated with the estimates, including the standard error, t ratio, p value, and 95% confidence limits. Below the coefficient list for each variable, the R^2 and root mean square error values of the fit of the predicted values (using the indicated coefficients) vs. the measured values are shown.

The R^2 values for the model fits are greater than 0.5, indicating some predictive ability of the models, but they are not as high as would be desired. Other potential model formats (including, for example, 3-way interaction terms) could not be used due to the limitations of the split-plot experiment design. Even so, the R^2 values are within the range (0.59–0.97) found for quality metrics of conventionally-drum dried condensed distillers solubles (Milczarek and Liu, 2015). The model fits were generally better (higher R^2) for tomato pomace than they were for prune pomace. This was an expected result based on tomato pomace's more straightforward drying behavior compared to that of prune pomace, as will be explained in subsequent sections.

3.3.1. *Water activity and moisture content*

Graphical depictions of the effects of the independent variables on a_w and moisture content are shown in Figs. 3 and 4, respectively. Although Figs. 3 and 4 include all 4 indepen-

Table 2 – Analysis of variance (ANOVA) results for linear regression models for the effects of formulation and process variables on drum drying of prune (A) and tomato (B) pomaces.

Model components	Measured response variables					
Model term	a_w	Moisture content	L*	a*	b*	ΔE
Prune pomace						(A)
(Water)	***		***	**	***	**
(Maltodextrin)	**	**	**			***
(Dwell Time)						
(Temperature)		*				
(Dwell Time)*(Temperature)						
(Water)*(Dwell Time)		*				
(Water)*(Temperature)						
(Water)*(Maltodextrin)		*	*	*		
(Temperature)^2						
Tomato pomace						(B)
(Water)	***	***	***	*	**	***
(Maltodextrin)	***		***	***	***	***
(Dwell Time)	***	***				
(Temperature)	***	***		*	*	
(Dwell Time)*(Temperature)	***	***				
(Water)*(Dwell Time)		**			*	
(Water)*(Temperature)		**				
(Water)*(Maltodextrin)			***	*	**	***
(Temperature)^2			***	*		

* Significant with $p < 0.05$.
** Significant with $p < 0.01$.
*** Significant with $p < 0.001$.

Table 3 – Standard least squares regression coefficient estimates (and their associated statistical values) for a_w (A, D), moisture content (B, E), and ΔE (C, F) for prune pomace (A, B, C) and tomato pomace (D, E, F). Model fit parameters are given below the coefficient list for each variable.

Prune pomace (A)

Prediction equation coefficient estimates for water activity (Z = a_w in Eq. (1))

Coefficient	Estimate	Std error	t Ratio	p Value	95% Confidence limits
c_0	0.25	2.29E−02	10.87	<.0001	0.20–0.30
c_1	2.36E−02	4.72E−03	24.85	<.0001	1.39E−02 to 3.33E−02
c_2	1.44E−02	4.78E−03	24.90	0.0059	4.54E−03 to 2.42E−02

For predicted vs. measured fit: R^2 = 0.76, root mean square error = 0.029

(B)

Prediction equation coefficient estimates for moisture content (Z = m.c. in Eq. (1))

Coefficient	Estimate	Std error	t Ratio	p Value	95% Confidence limits
c_2	−0.940	0.292	−3.22	0.0034	−1.540 to −0.340
c_4	−0.848	0.311	−2.73	0.0268	−1.569 to −0.127
c_6	0.729	0.314	2.32	0.0286	0.083–1.374
c_7	0.787	0.310	2.54	0.0179	0.148–1.427

For predicted vs. measured fit: R^2 = 0.60, root mean square error = 1.775

(C)

Prediction equation coefficient estimates for overall color change (Z = ΔE in Eq. (1))

Coefficient	Estimate	Std error	t Ratio	p Value	95% Confidence limits
c_0	22.45	3.05	7.35	<.0001	15.97–28.93
c_1	1.55	0.55	2.80	0.0098	0.41–2.69
c_2	2.21	0.56	3.93	0.0006	1.05–3.37

For predicted vs. measured fit: R^2 = 0.74, root mean square error = 3.40

Tomato pomace (D)

Prediction equation coefficient estimates for water activity (Z = a_w in Eq. (1))

Coefficient	Estimate	Std error	t Ratio	p Value	95% Confidence limits
c_0	0.15	2.25E−02	6.53	<.0001	0.10–0.19
c_1	2.84E−02	6.36E−03	4.46	0.0001	1.53E−02 to 4.15E−02
c_2	−4.25E−02	6.44E−03	−6.60	<.0001	−5.58E−02 to −2.93E−02
c_3	−4.92E−02	6.38E−03	−7.72	<.0001	−6.23E−02 to −3.61E−02
c_4	−5.16E−02	5.85E−03	−8.83	<.0001	−6.53E−02 to −3.79E−02
c_5	3.07E−02	6.88E−03	4.47	0.0001	1.66E−02 to 4.48E−02

For predicted vs. measured fit: R^2 = 0.88, Root mean square error = 0.039

(E)

Prediction equation coefficient estimates for moisture content (Z = m.c. in Eq. (1))

Coefficient	Estimate	Std error	t Ratio	p Value	95% Confidence limits
c_1	0.270	0.064	4.24	0.0002	0.140–0.401
c_3	−0.330	0.064	−5.16	<.0001	−0.461 to −0.199
c_4	−0.362	0.055	−6.61	0.0001	−0.487 to −0.238
c_5	0.322	0.069	4.66	<.0001	0.180–0.463
c_7	−0.225	0.069	−3.25	0.0031	−0.366 to −0.083
c_8	−0.241	0.069	−3.48	0.0017	−0.382 to −0.099

For predicted vs. measured fit: R^2 = 0.80, Root mean square error = 0.397

(F)

Prediction equation coefficient estimates for overall color change (Z = ΔE in Eq. (1))

Coefficient	Estimate	Std error	t Ratio	p Value	95% Confidence limits
c_0	20.59	2.60	7.92	<.0001	15.22–25.97
c_1	2.63	0.64	4.14	0.0003	1.32–3.94
c_2	3.40	0.64	5.28	<.0001	2.08–4.73
c_6	2.83	0.69	4.09	0.0004	1.41–4.26

For predicted vs. measured fit: R^2 = 0.76, root mean square error = 3.92

dent variables for both pomaces, not all independent variables had a significant effect on the response variables; refer to Tables 2 and 3 for a precise listing of significant independent variables and regression coefficient values.

The results show that prune pomace and tomato pomace differed in their responses to changes in the 4 independent variables. a_w of prune pomace (Fig. 3 top row) remained tightly in the range of 0.24–0.30, no matter what the levels of the formulation or process variables were. Tomato pomace (Fig. 3 bottom row), in contrast, exhibited a straightforward, linear decrease of a_w with linear increases in time and temperature. The relationship for tomato pomace a_w as affected by added water or maltodextrin was a bit more complex but still intuitive: dried tomato pomace a_w generally increased as more water was added and decreased as more maltodextrin (i.e. solid material) was added.

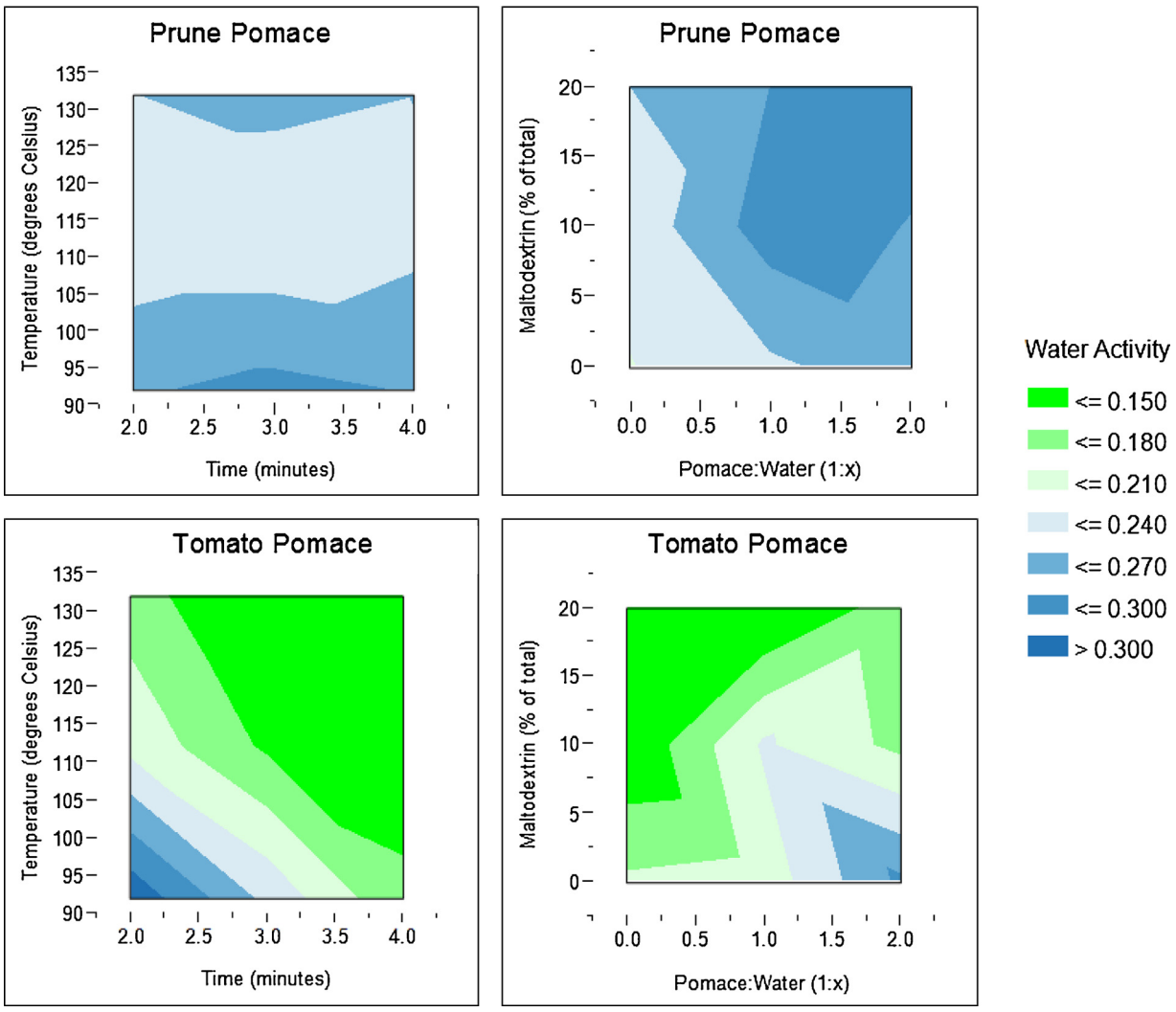

Fig. 3 – Effect of process and formulation variables on water activity (a_w) of prune pomace (top row) and tomato pomace (bottom row).

Although – compared to moisture content – a_w is a more direct metric for determining the stability of a dried food material, the effects of the 4 independent variables on the pomaces' moisture contents (Fig. 4) are still worth noting. Both pomaces were dried by the solar thermal drum drying system to very low moisture contents – less than 10% moisture in all the dried products vs. 52–89% moisture in the starting prune pomace blends and 37–79% moisture in the starting tomato pomace blends. (The range of starting moisture contents exists for each pomace because adding water and maltodextrin affected the moisture contents of the pomace blend samples that were fed onto the drums.) At the lowest temperature setting, the high value of prune pomace moisture content at low dwell time is intuitive — not enough time has been allowed to fully remove the water from the pomace blend. However, the development of similarly-high moisture content at high dwell times is perplexing and merits further investigation. The decrease in dried prune pomace moisture content with increasing added maltodextrin (i.e. added solids) is intuitive. However, the *decrease* in dried prune pomace moisture content with *increasing* added water is, upon first consideration, the opposite of the expected behavior. Here, though, we see evidence that adding water to the prune pomace in order to decrease its viscosity does promote more even coating of the drum surface with the feed material and thus more efficient water removal (enough to overcome the added water, and then some). Comparing Figs. 3 and 4, one can note that the addition of maltodextrin decreased the equilibrium moisture content (the moisture content associated with a given a_w) of the prune pomace. For example, at a_w = 0.24-0.27 (middle color contour band in the upper right panel of Fig. 3), the equilibrium moisture content is 2.0% when no maltodextrin is added but 0.5–1.0% at 20% maltodextrin addition (corresponding sections of the upper right panel of Fig. 4). This is the same phenomenon observed by Farahnaky et al. (2016) when they added maltodextrin to date syrup to improve the drum drying behavior of that material.

As with a_w, the moisture content behavior of the tomato pomace is more straightforward. The linear decrease seen for a_w of tomato pomace with linear increases in time and temperature was replicated for moisture content. Tomato pomace moisture content was rendered so low (less than 2%) by the tested process conditions that it was relatively insensitive to changes in the 2 formulation variables. For both a_w and moisture content, the differing patterns of results between prune and tomato pomaces reinforce the notion that the initial composition of the material strongly affects the material's performance on the solar thermal drum dryer system.

In addition to the trends illustrated in Figs. 3 and 4, the absolute values of the response variables should be noted. Regardless of the wide range of levels of the variables tested in this experiment, the a_w of the dried prune pomace was

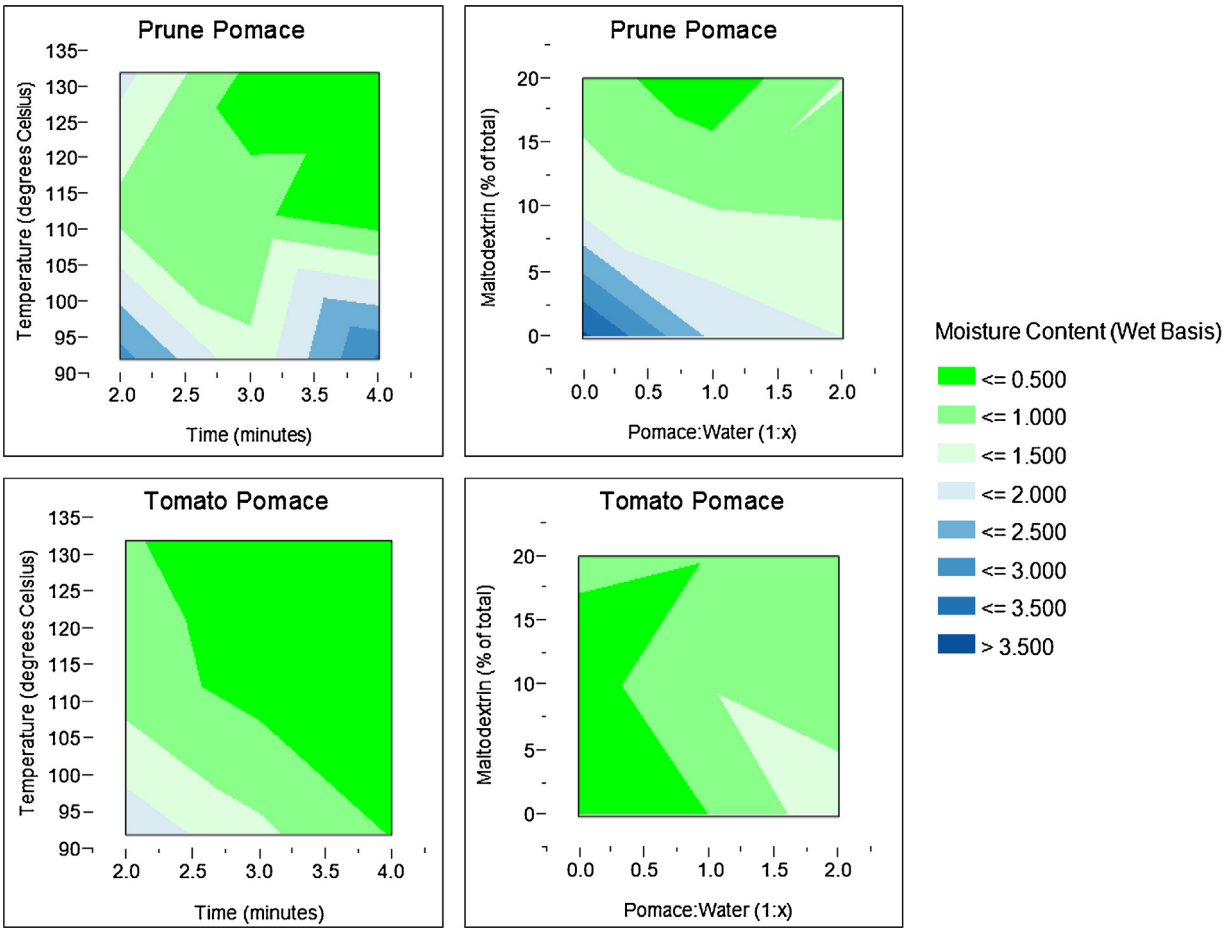

Fig. 4 – Effect of process and formulation variables on moisture content of prune pomace (top row) and tomato pomace (bottom row).

always in a narrow range — roughly 0.18–0.37. (Fig. 3 shows a_w varying only from 0.24 to 0.30 because each contour plot assumes the centerpoint settings of the 2 variables not shown in the plot.) In contrast, it was possible to reach a wide range of a_w in tomato pomace — 0.07–0.58. (Again, Fig. 3 shows a narrower range due to the centerpoint assumption required to construct the graphs.) The trend was reversed for moisture content: prune pomace could be dried to a variety of moisture contents (0.1%–9.3%.) through different combinations of the process and formulation variables, but tomato pomace exhibited a narrow and extremely dry range of 0.2%–4.0% moisture content.

These phenomena may be explained by the differing initial compositions of the pomaces. Plums contain sorbitol, a humectant compound that contributes to the laxative effect of consuming prunes (dried plums) and prune products (Stacewicz-Sapuntzakis et al., 2001; Milala et al., 2013). During production of prune concentrate, some sorbitol may be fractionated into the co-product pomace. The sorbitol present in prune pomace appears to moderate the a_w throughout a wide range of moisture contents, while in tomato pomace, the a_w and moisture content vary more or less linearly with each other, as tomato pomace does not contain appreciable amounts of sorbitol or other humectants.

In can be noted from Fig. 3 that prune pomace required higher process temperatures/times to achieve the same a_w as tomato pomace, despite the 2 pomaces' starting at essentially the same a_w (0.99 — see Table 1). The presence of sorbitol in prune pomace may also explain this material's higher drying recalcitrance compared to that of tomato pomace. The situation is reminiscent of unmodified (high-glycerol) condensed distillers solubles (CDS) and modified (reduced-glycerol) CDS, which were recently examined in our laboratory for their performance on a conventional drum dryer (Milczarek and Liu, 2015). We hypothesize that the sugar alcohols sorbitol (in the prune pomace) and glycerol (in the CDS) act as a_w mediators, creating a "floor" below which a_w cannot be reduced by drum-drying, even if moisture content can be reduced to nearly zero.

To achieve ambient-temperature shelf stability, it is important that the a_w of the dried pomace be sufficiently low to inhibit microbial growth. Generally, a a_w cutoff of 0.6 (product a_w less than 0.6) can be used to determine resistance to yeast and mold growth, since the most dry-hardy food spoilage mold known to date requires a minimum a_w of 0.61 for growth (Grant, 2004). Thus, it is instructive to examine the results of the current work to determine the formulation and process conditions that would render the 2 pomaces shelf-stable (*i.e.* a_w of 0.6 or below). For both materials, there are many possible combinations of added water, added maltodextrin, dwell time, and drum surface temperature that will yield a a_w of 0.6. The exact combination chosen would depend on the relative importance of throughput (determined by dwell time), energy use (determined by dwell time and drum surface temperature), and ingredient cost (determined by added maltodextrin and added water) in a given industrial situation.

It happened that, for both pomaces, all tested levels of the formulation and process variables resulted in a_w lower than 0.6. With the strong caveat that it involves extrapolating the a_w prediction equations beyond the bounds tested in the present experiment, the minimum drum surface temperature

required to bring the a_w down to 0.6 is predicted to be 46 °C for prune pomace and 18 °C for tomato pomace. (This would be for neat pomace – no water or maltodextrin added – and maximum dwell time of 4 min.) This mild drying temperature requirement indicates that much moisture removal occurs simply from mechanical pressing of the pomace in the nip between the 2 drums. Though it was beyond the scope of the present work, this mild-temperature scenario should be tested to determine if practical processing issues are still addressed — i.e., does the pomace still adhere to the drums for the full dwell time, does the resulting product have desired texture, will the pomace feed through the nip without mechanical pressure, etc. If sub-100 °C drum surface temperatures are indeed adequate to dry the pomace to shelf-stability, then steam-heating of the drum dryer would be excessive, and the heated-oil circulation system of the solar thermal drum dryer would be particularly well-suited for this application.

3.3.2. Color

The influence of the independent variables and their interactions on the pomaces' L*, a*, and b* color values is given in Table 2. It can be seen from Table 2 that some of the same variables/interactions that influenced a_w and moisture content also influenced color, but there is not a one-to-one correlation for either pomace. The main result of note for the color values is the influence of added maltodextrin on the L* (lightness) value of the dried pomace. Maltodextrin is a white powder, and as maltodextrin content of the pomace blend increased, L* value of the dried product also increased. Thus, it should be noted that addition of this particular drying carrier to prune and tomato pomaces is not color-neutral for the dried product. The lightening effect of maltodextrin appears to be above and beyond the known lightening effect of drum drying in and of itself, as observed by Arocho and Bellmer (2012) during the drum drying of watermelon pomace.

When assessing the effects of formulation and process variables on the nutritional and sensorial quality of the pomaces, the overall color change from wet to dry material (ΔE) is of greater interest than the absolute L*, a*, and b* color values. Thus, the remainder of the discussion of the present experiment will focus on ΔE. The influence of the independent variables and their interactions on the pomaces' ΔE is given in Table 2, and the standard least squares regression coefficients for the prediction of ΔE are listed in Table 3. Table 3 lists the values for the regression coefficients used in Eq. (1), with Z = ΔE. In contrast to a_w and moisture content, which were affected by multiple formulation and process variables (and their interactions), ΔE for both pomaces was only affected by the formulation variables (added water and added maltodextrin). The trend and magnitude of these effects is depicted in Fig. 5.

Although the pattern is more clear for tomato pomace than it is for prune pomace, maximizing both added water and added maltodextrin maximizes ΔE. This indicates large nutritional and quality losses when both of these ingredients are added to the pomaces. Prune pomace (Fig. 5 top panel) exhibited comparatively large ΔE at all levels of the formulation variables, so it appears that some color change will be inevitable for this material. For tomato pomace (Fig. 5 bottom panel), color change is minimal when no maltodextrin is added, no matter how much water is added. Thus, for tomato, if quality loss were the only consideration, the recommendation would be to drum dry the neat pomace.

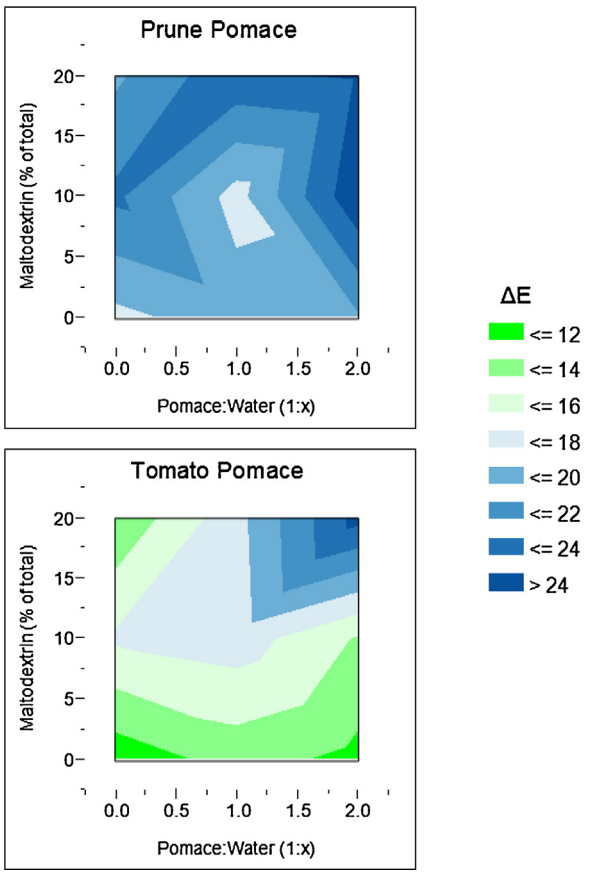

Fig. 5 – Effect of process and formulation variables on pre- to post-drying color change (ΔE) of prune pomace (top) and tomato pomace (bottom).

3.3.3. *Optimization of formulation and process variables for both shelf-stability and minimal color change*

When drying a product such as pomace, both shelf-stability and minimization of quality loss are priorities. Thus, the prediction equations for a_w and ΔE (our proxy for quality loss) were combined and analyzed in JMP with the objective of maximizing a combined desirability (d) function. Minimization of a_w was set to result in maximum d (d = 1) for that response variable; the same was true for ΔE. The d functions for a_w and ΔE were set to be of equal weight; i.e. minimization of a_w and minimization of ΔE were considered to be of equal importance. The resulting optimized combinations of the 4 independent variables are shown in Fig. 6.

The maximum d was 0.71 for prune pomace and 0.83 for tomato pomace, indicating that the combined goal of achieving shelf-stability with minimal color change was more easily achieved for tomato than for prune. This is expected given the prune pomace's higher recalcitrance to drying and greater overall color change under all tested conditions. Following the results for maximum d, the recommended processing conditions for solar thermal drum drying the 2 pomaces would be as follows:

- prune pomace: no added water or maltodextrin, 2.6 min dwell time, 92 °C drum surface temperature
- tomato pomace: no added water, 20% total weight maltodextrin, 4 min dwell time, 92 °C drum surface temperature

For tomato pomace, the strict interpretation of the d results would advocate for the addition of maltodextrin as a drying aid. This would indeed maximize d, but it would represent an

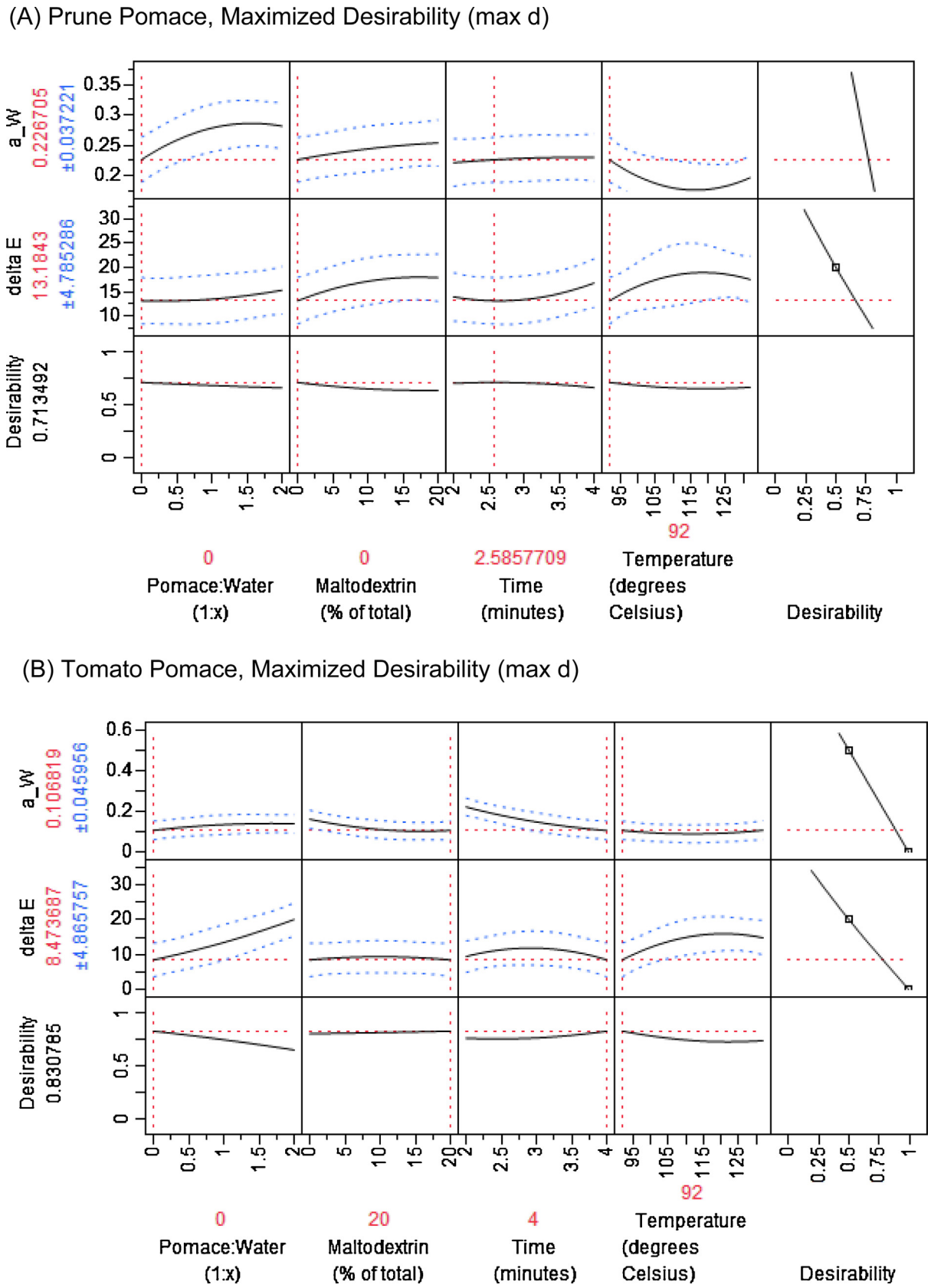

Fig. 6 – Maximized composite desirability scenarioes for prune pomace (A) and tomato pomace (B). Red dashed lines and red numbers indicate the current settings of the independent variables and response variables. Blue dashed lines and blue numbers indicate the bounds of the 95% confidence intervals for the response variables. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

additional ingredient cost for the processor. So, the following scenario was tested to see the effect on d:

- tomato pomace: no added water or maltodextrin, 4 min dwell time, 92 °C drum surface temperature

The resulting d was 0.81, vs. 0.83 for the true optimum situation. The new predicted a_w and ΔE were 0.16 and 8.5, respectively. These values compare favorably to the values of 0.11 and 8.5 obtained in the true optimum situation. Thus, for tomato pomace, adding maltodextrin is a desirable but not strictly necessary measure to obtain stabilized dry material with minimal quality loss.

4. Conclusions and further work

This study demonstrated that both prune pomace and tomato pomace could be processed on a solar thermal drum drying system. On the small-scale system, prune pomace can be dried to shelf-stability but exhibits an apparent a_w floor near 0.18. In contrast, tomato pomace can be dried to a wide range of moisture content and water activity levels, with most of the tested conditions in the present work resulting in a nearly bone-dry product. This study also elucidated the effects of the formulation variables added water and added maltodextrin and the processing variables dwell time and drum surface temperature on the solar thermal drum drying performance of the 2 pomaces. The prediction equations for a_w, moisture content, and ΔE developed in this work can be used to predict these parameters for arbitrary combinations of the formulation and process variables. The reasonably-high R^2 and low RMSE metrics for the predicted vs. measured comparisons for the response variables indicate that the prediction equations adequately describe the pomaces' drum-drying behavior within the tested range, given that the suite of possible predictive models was limited due to the nature of the split-plot experiment design.

Based on balanced goals of minimizing a_w (to ensure ambient-temperature shelf-stability) and minimizing ΔE (to minimize quality loss), recommended settings of the formulation and process variables are given in Section 3.3.3. It is noteworthy that, for both pomaces, the minimum drum surface temperature (92 °C) tested in this experiment is the recommended setting. This temperature was readily achievable with solar thermal energy as the heat source, even at a time of the year (near the winter solstice) when available insolation was low. Industrial generation of tomato pomace would occur closer to the summer solstice, when the solar resource would be greater. Because the source material for prune pomace is already a dried product, prune pomace has nearly year-round generation. These differing generation timeframes should be considered when designing a scaled-up version of the solar thermal drum drying system.

The findings of this study can be used to direct process design for solar thermal drum drying of fruit and vegetable pomaces, and further avenues could be explored. Other formulation and process variables could be tested. For example, drying aids beyond maltodextrin could be considered, and the gap width between the drums could be varied. Other outcomes – such as throughput – could be used as targets for optimization.

This work is part of a larger effort to minimize food waste through innovative processing technologies that have minimal environmental impact. From the results of this study, solar thermal technology has proven to be well-suited for the task of drying selected industrially-generated pomaces while requiring no thermal energy from fossil fuel sources. Some hurdles remain, such as adaptation of the system for 24-h operation, which is critical during the relatively short harvest season for most fruits and vegetables. Thermal storage or integration of the solar-heating system with an electrical- or natural gas-heating system would both be options to address this issue. This work represents a successful starting point for addressing the larger challenge of complete and environmentally-benign utilization of food crops.

Disclaimers

Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture. USDA is an equal opportunity employer.

Acknowledgements

The authors gratefully acknowledge Papagni Fruit & Juice (Madera, CA) and Ingomar Packing Company, LLC (Los Banos, CA) for providing the pomace samples. We also thank Jordyn Brinkley and Kasey Chang for their assistance in operating the XCPC array and drum drying system.

This project was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

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Sustainability Report for The California Cherry Industry[1]

September 2016

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[1] This project was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

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Introduction

Development of the Self-Assessment for Cherry Production in California

A sustainable farm is one whose management is guided by the 3 E's of sustainability, which are **E**conomic Viability, **E**nvironmental Soundness, and Social **E**quity. Retailers, buyers, consumers, as well as regulatory agencies, are taking an increasing interest in how food crops are grown, how farm workers are treated, and in the welfare of animals raised for meat. As a result, many proactive farmers and packer/shippers have begun to use the concept of sustainable farming to develop ways to meet these food supply chain demands. In the process of doing so, they are discovering the use of sustainable practices is a smart and valuable business strategy.

Some important crop sectors in California, such as winegrapes[2] and almonds[3], have demonstrated that self-assessment workbooks provide a great foundation for a sustainable farming program that can benefit the entire industry. Under the auspices of the California Cherry Board, a steering committee of cherry industry representatives and SureHarvest developed a self-assessment workbook for the production of California cherries (Table I). The workbook was based on a self-assessment template created in 2013 by a stakeholder group from the California specialty crop sector funded by a California Department of Food and Agriculture (CDFA) Specialty Crop Block Grant. The template contained important farming practices common to the production of most specialty crops. The goal of the project was to provide a template that a specialty crop sector could fine tune by adding practices specific to the production of that crop and any other farming practices deemed by them to be important. The development of the cherry self-assessment workbook and this sustainability report was also funded by a CDFA Specialty Crop Block Grant awarded to the California Cherry Board in 2014.

Table I. Cherry Workbook Steering Committee

Name	Affiliation	Vocation
Janet Caprile	University of California	Farm Advisor
Max Copello	Primavera	Grower/Packer/Shipper
Albert DalPorto	Rivermaid	Grower/Packer/Shipper
Joe Grant	University of California	Farm Advisor
David Haviland	University of California	Farm Advisor
Chuck Ingels	University of California	Farm Advisor
Nick Matteis	California Cherry Board	Board Administrator
Cliff Ohmart	SureHarvest	Editor & Facilitator
Ron Oneto	KLM Ranches	Grower
Kevin Pitto	Morada Produce	Grower/Packer/Shipper
Natalie Precissi	OG Packing	Grower/Packer/Shipper
Tim Sambado	Primavera	Grower/Packer/Shipper

[2] http://www.sustainablewinegrowing.org/sustainable_winegrowing_program.php
[3] http://www.almonds.com/growers/sustainability#tc-self-assessments

What is a Self-Assessment of Farming Practices

A self-assessment is a list of farming practices, ideally grouped in topic areas, such as soil management, water management, pest management, and so forth. A grower reads the practice and is provided with a set of possible answers. The answer set for most practices is a simple 'Yes' or 'No'. If a grower is doing the practice he/she checks the 'Yes' answer, if not then the 'No'. Some practices may not be completely implemented. For example the practice 'Engines (stationary and mobile) and motors were maintained on a regular schedule to achieve optimum efficiency'. It is possible some on the farm are being maintained regularly and some are not. The answer set for these types of practices is 'Completely, Somewhat, Not at All'. And finally, some practices may not be applicable to the orchard being assessed. For example the practice 'If pest management recommendations from a PCA were relied upon, they were reviewed and discussed with farm management staff before making a decision to take a management action'. A grower may not use the services of a PCA (pest control advisor). The answer set for these types of practices include an 'N/A' selection.

The intension of a self-assessment for permanent crops like orchards and vineyards, is that each orchard or vineyard managed as a separate unit from others be assessed separately. That is because practices used in one orchard or vineyard may not be used in another on the same farm. If more than one block is managed using the same practices then they can be combined and assessed as one combined block. Another important intension is that the self-assessment be done for the practices that were used in the previous growing season. A self-assessment is not done for the up-coming season because although one knows the set of practices intended to be used, things can happen during the growing season that require a different set of practices be implemented. So a self-assessment is always done retrospectively.

A self-assessment is not a scoring exercise. While it contains the complete menu of possible sustainable farming practices it is recognized that growers' farm differently from each other for a range of reasons. There is no expectation that every grower will be using all the practices in the self-assessment. In fact due to the comprehensive nature of the self-assessment it is likely no grower is doing all the practices. The self-assessment is designed so that all growers can use it to identify and record the practices they are using.

A self-assessment is not a survey although it looks like one. The reason it is not is because the self-assessment becomes a permanent record in the program database system so that a grower can retrieve their assessments any time they wish. The self-assessment is designed to be used each year with each assessment being stored and easily retrieved.

Value Propositions for Doing the Cherry Production Self-Assessment

Doing a self-assessment can provide value for a grower in one or more ways. A California cherry grower can use the self-assessment to:

- Document the production practices being used in an orchard
- Monitor practices as they change over time
- Learn about other sustainable practices they are not familiar with

- Compare their assessment results with anonymously summarized assessments of other cherry growers
- Be inspired to try sustainable practices used by other growers
- Provide data to the California Cherry Board anonymously which can be summarized and reported on to demonstrate the California cherry industry's commitment to sustainability

The Cherry Self-Assessment Workbook

The self-assessment workbook for cherry production in California addresses all aspects of growing cherries. It contains 200 practices that are divided into the following 10 modules:

1. Soil Management (includes crop nutrition)
2. Water Management
3. Pest Management
4. Energy Management
5. Food Safety Management
6. Air Quality Management
7. Waste Management
8. Financial Management
9. Ecosystem Management
10. Workplace and Community

The workbook is available for use by any California cherry grower. A printed version can be obtained from SureHarvest[4] or the California Cherry Board[5].

Cherry Sustainable Management Information System (SMIS)

Assessing 200 possible cherry production practices is a significant time commitment for a grower. Furthermore, capturing assessments in an anonymous way so that the results can be provided to growers who have done assessments, as well as to enable aggregation of the results requires significant effort. SureHarvest developed a user-friendly on-line software platform, the Sustainable Management Information System (SMIS), which growers can use to do their assessments, get immediate reporting feedback, and provides the system administrator with analytic tools to aggregate assessments. A California cherry grower can apply for a confidential username and password to log into the on-line SMIS system located at www.sustainablecherries.org (Fig. 1). All information a grower enters into the system is completely confidential.

[4] www.sureharvest.com; Ph (831) 477-7797
[5] http://calcherry.com/; Ph (916) 441-1063

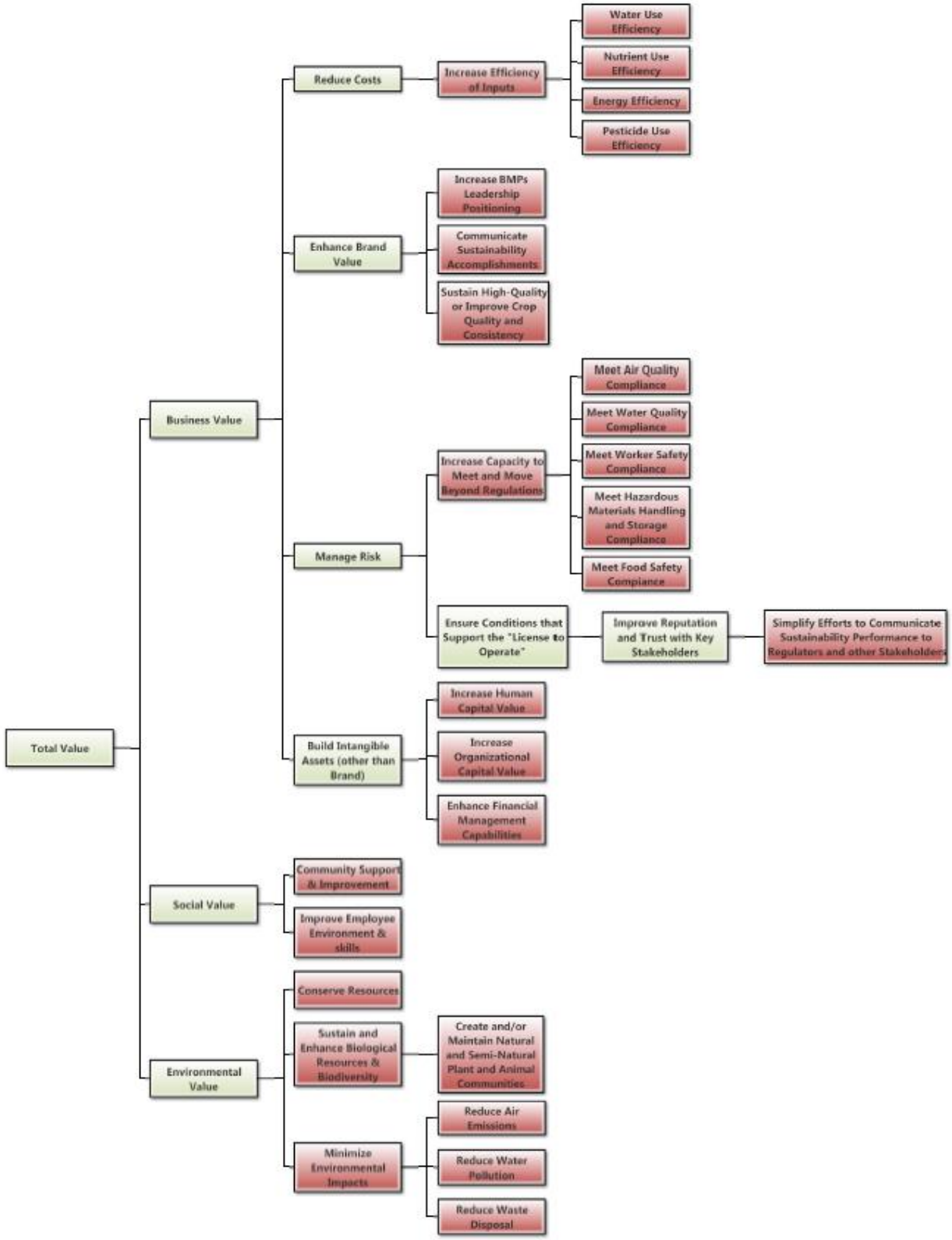
Figure 1. Cherry SMIS User Login Page at www.sustainablecherries.org



Assessing the Value of Practices in the Cherry Self-Assessment

Economic value is what comes to mind with many growers when considering using a new production practice. What will it do for my bottom line? However, a practice can also provide other values that may not be readily apparent but important none the less. A Value Map for the Cherry Production Sustainability Program was constructed using SureHarvest's Sustainability Value Analysis methodology which was developed to provide an objective measure of a range of value propositions. The value map includes 24 value propositions specific to the program organized by a value creation hierarchy (Fig. 2). The hierarchy moves from the broad sustainability areas of business value, social value and environmental value to specific value propositions in each area. This list was created based on the value propositions most directly addressed by the program and having the highest opportunity to generate business, social and environmental value for growers using the best management practices included in the cherry self-assessment.

Figure 2. Value Map for Rating Cherry Production Practices



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Value analysis methodology:

The 24 value propositions identified in Figure 1 can be used to estimate the value to a grower provided by each practice included in the self-assessment. It is one way to rank the level of importance of one practice compared to another. It can also be used to identify where a grower's strengths are as well as where there are opportunities for them to implement practices they currently are not using. A strength is defined as a practice that has high overall value and is being used by a majority of growers. An opportunity is a high value practice that is being used by only a small number of growers. The following methodology was used to estimate the value of each practice in the self-assessment.

1. Defining Industry Best Management Practices (BMPs).
    - An "Industry-accepted BMP" is defined as a BMP that is backed by research and has gone through a review process that has included researchers, growers, and/or handlers, and other technical experts. BMPs also include infrastructure installations and processes. The method used to develop the cherry self-assessment modules qualifies a practice in the self-assessment to be an "industry-accepted BMP". The modules also included some conventional practices. These conventional practices do not qualify as "industry-accepted BMP". Conventional practices are defined as practices that no longer are based on the best available science and economics compared to an available "Industry-accepted BMP".
2. Assessing each self-assessment practice for overall net positive business, social, and environmental impact
    - Impact Assessment Approach and Scale
        - Each BMP scored for net positive impact on a four-category scale:
            - Little to No = 0, a conventional practice
            - Low = 1, less than an industry standard BMP
            - Industry standard BMP = 3
            - High impact 'best of class' BMP = 5.
        - Infrastructure practices, such as installing drip irrigation, that require action to work optimally, are scored a 1.
        - Pre-decision methods, such as pest monitoring or tissue analysis, that require follow-up action/interpretation to be impactful, are scored a 1.
    - Net Positive Business Impact
        - Each BMP was assessed on the basis of generating and/or sustaining net positive grower economic value for one or more key topics: reduce costs, enhance brand value, manage risk, build intangible assets (Fig. 2).
        - If net negative direct grower economic value (e.g. increases input costs, makes environmental compliance more complex and/or difficult, etc.), assessed as conventional practice (No value).
        - If there are grower economic value trade-offs (e.g. significantly increases management costs but lowers input costs), assessed as low impact BMP.
    - Net Positive Social Impact
        - Each BMP was assessed on the basis of generating and/or sustaining net positive social value for the one or more key topics: community support and improvement, improve employee environmental and skills (Fig. 2)

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    - If net negative social impact, assessed as conventional practice (No value).
    - If there are net social trade-offs, assessed as lower impact BMP.
- Net Positive Environmental Impact
    - Each BMP was assessed on the basis of generating and/or sustaining net positive environmental value for the one or more key topics: conserving resources, sustain and enhance biological resources and biodiversity, minimize environmental impacts (Fig. 2)
    - If net negative environmental impact (e.g. causes dust, etc.), assessed as conventional practice (No value).
    - If there are net environmental trade-offs (e.g. tillage for weed control which leads to dust but also reduces herbicides), assessed as lower impact BMP.
- Assessing each BMP by each of the 24 value propositions in terms of generating and/or sustaining net positive business and/or social and/or environmental value.

Sustainability Report – Grower Self-Assessment Summaries from 2014/2015 Growing Season

The results of the self-assessments are presented in three parts. The first, titled 'Grower Strengths', lists the highest value practices used in a majority (>70%) of the orchards assessed by growers for the 2014/2015 growing season. The confidence interval is also presented to indicate to what degree the data is representative of what is happening in the 'average' cherry orchard. The second part, titled 'Grower Opportunities' lists high value practices that are being used in a lower proportion of orchards assessed. They are considered opportunities because they offer growers high value and yet according to the summaries of the self-assessments they are currently not being used in a majority of orchards. The third part of the report is a complete reporting of the aggregated self-assessments for the 2014/15 growing season. Each practice in the self-assessment workbook is listed along with the percentage of orchards in which it was used.

Grower Participation and Orchards Assessed

Twenty three growers used the on-line SMIS to assess the production practices used in 105 orchards during the 2014/2015 production season. The total number of acres of these orchards was 5,249. They represent 15.9% of the estimated 33,000 total acres[6] of cherry orchards in the state.

Cherry Grower Strengths

The high value soil management practices used in almost every orchard during the 2014/15 production season were (Table 2):

- Knowledge of orchard soil type: Knowing the type of soil in the orchard so it's properties such as water holding capacity, soil chemistry, texture and rooting depth are

[6] CDFA 2014-2015. California Agricultural Statistics Review. 128pp.

incorporated into a soil management plan that will optimize cherry production through implementation of best practices for that type of soil

- Enhancing water infiltration rates: Ensuring good water infiltration rates to optimize water use and maintain good tree health and production
- Monitoring of soil chemistry: Continual monitoring of soil chemistry to ensure the application of optimum amounts nutrient inputs and proper tree nutrition
- Enhancing soil quality with cover crops: Improving soil quality through management of cover crops
- Use of fertigation: Applying fertilizers through the irrigation system so that they are applied in the right place, at the right time, and at the right rate (3 of the 4Rs of nutrient management)

Table 2. Soil Management Strengths

Soil Managememt Practices in the Self-Assessment	% of Orchards Practice Used	Confidence Interval (95%)	Value Score
1. The soil types in the field were identified (e.g., using NRCS soils maps or from digging soil pits) and soil properties including water holding capacity, cation exchange capacity (CEC), texture, and rooting depth were known and recorded for each soil type and used for soil management planning and practices	94%	4.9%	12
2. If water infiltration was poor (water puddles and runs off when soil is dry underneath), the soil was amended either chemically (e.g. with gypsum or organic matter such as compost or manure) or physically (e.g., disking, chiseling or shallow ripping)	94%	2.0%	16
3. A soil sample was taken and measured for important physical and chemical properties, such as pH, cation exchange capacity, bulk density, salts, macro and micronutrients, and the results used to develop and implement a soil management plan/strategy	93%	5.3%	13
4. Cover crops were planted or resident vegetation was allowed to grow between the tree rows to add organic matter and nutrients to the soil and to improve water infiltration	99%	2.1%	17
11. Most nitrogen fertilizers were applied through the irrigation system (fertigation)	75%	8.8%	14

The high value water management practices used in almost every orchard during the 2014/15 production season were (Table 3):

- Enhancing soil drainage: Ensuring drainage of the orchard soil prior to planting was optimum for the site
- Monitoring water infiltration rates: Monitoring water infiltration rate to during and after irrigation to optimize irrigation timing and rates
- Irrigation system distribution uniformity: Measuring the distribution uniformity of the irrigation system to ensure water is reaching all the trees in the orchard equally and not creating areas of either over or under irrigation.

Table 3. Water Management Strengths

Water Management Practices in the Self-Assessment	% of Orchards Practice Used	Confidence Interval (95%)	Value Score
3. Ripping, plowing, chiseling, or other practices were implemented if pre-planting soil tests indicated water percolation and/or drainage problems	100%	0.0%	17
11. Water percolation rate and infiltration depth was monitored during the irrigation season and irrigation was adjusted accordingly	84%	8.8%	14
22. Distribution uniformity of the irrigation system was tested within the last 2 years and adjustments made if warranted	77%	12.6%	21

The high value pest management practices used in almost every orchard during the 2014/15 production season were (Table 4):

- Pest monitoring: Monitoring for key pests using established monitoring protocols to ensure consistency among orchards and over time so that sound pest management decisions were made
- Use of economic thresholds: Using economic thresholds for key pests to ensure that control actions were taken only when the cost of pest damage if a treatment is not done will exceed the cost of the control measure
- Comprehensive action thresholds: Basing pest management decisions on a comprehensive set of measures, not just pest numbers
- Pest monitoring record keeping: Keeping pest monitoring records that can be referred to when making control decisions and that can be used in subsequent seasons to learn from past history
- Pesticide resistance management: using a pesticide resistance management strategy to ensure the continued efficacy of important pest control materials
- Sprayer calibration: Regularly calibrating sprayers and testing spray coverage to optimize pesticide use and efficacy

Table 4. Pest Management Strengths

Pest Management Practices in the Self-Assessment	% of Orchards Practice Used	Confidence Interval (95%)	Value Score
1. Monitoring protocols for key pests were established and followed	98%	3.0%	8
2. Economic thresholds for key pests were established and used to make management decisions	91%	5.9%	8
8. Cultural factors, such as time to harvest, preexisting plant damage, plant moisture stress, plant health, and/or crop load, were considered in pest management decision-making	96%	4.3%	8
9. Pest monitoring records were kept and reviewed during the pest management decision-making process	100%	0.0%	8
15. Pesticides with different ˜modes of action" (i.e., how they kill the pest) were rotated from one spray to the next as a part of a pesticide resistance strategy	89%	6.5%	6
17. Calibration and spray coverage tests were done for each sprayer at least once in the last 12 months and based on manufacturersâ€™ recommendations as well as site characteristics such as orchard canopy stage	97%	3.7%	14

Other high value practices used in almost every orchard during the 2014/15 growing season were (Table 5):

- Food safety program: Participating in a food safety program approved by the farm's packer/shipper
- No burning: Improving air quality by shredding or chipping orchard prunings rather than burning them
- Regulating vehicle speed: Ensuring vehicle speed was reduced on dirt roads around the farm to minimize dust
- Hazardous material training: Employees were trained in proper handling and disposal of hazardous wastes and the farm participated in a pesticide container recycling program
- Pesticide container recycling: The farm participated in a third party pesticide container recycling program.
- Vegetation buffers on water courses: The banks of some water courses on the farm were vegetated to act as buffers for offsite movement of nutrients and pesticides and also to provide habitat for wildlife, bees and pest natural enemies
- Marketing and production plan: A marketing and production plan was prepared for the farm and the seasonal production and sales results were compared to the plan to gauge seasonal performance.
- Cost and revenue tracking by orchard: Production costs and revenues were tracked for each orchard individually, rather just for the farm as a whole, to better track production performance and enable more targeted management decisions to increase profitability
- Cost benefit analyses of practices: Cost/benefit analysis of important farming practices was done to justify their use

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Table 5. Strengths in management of food safety, air quality, waste, habitat and finances

Food Safety Practices in the Self-Assessment	% of Orchards Practice Used	Confidence Interval (95%)	Value Score
1. The farm participated in a third party food safety certification program (e.g., Agriculture Marketing Service GAP Certified, Primus, SQF, Global GAP) or a food safety plan approved by the farm's packing/shipping company	100%	0.0%	17
Air Quality Management Practices in the Self-Assessment			
1. Orchard prunings were chipped or shredded rather than burned	100%	0.0%	12
3. Vehicle speed was restricted to 5 mph on dirt roads around orchards during the dry parts of the growing season to minimize airborne dust	91%	5.9%	6
Waste Management Practices in the Self-Assessment			
3. Employees were trained on the proper handling and disposal of hazardous materials (e.g. solvents, cleaning materials, explosives, compressed gases, fuel, acids, and lubricants)	100%	0.0%	6
6. The farm participated in a pesticide container recycling program	100%	0.0%	7
Ecosystem Management Practices in the Self-Assessment			
7. Water course banks were vegetated with a mix of grasses, trees and shrubs - Somewhat	88%	-	11
Financial Management Practices in the Self-Assessment			
1. A marketing and production plan was developed for the farm and seasonal outcomes compared to the plan	83%	7.7%	6
11. Production costs and revenue were tracked for each production block (orchard) in financial management reports to better track and improve profitability	96%	4.3%	10
12. Costs and returns were tracked for all important farming practices to help identify practices that are paying for themselves and those that are not	91%	5.1%	8

The high value workplace management practices used on the farms that manage the orchards that were assessed during the 2014/15 production season were (Table 6):

- Employee education: Regular training was provided for employees, either by company staff or external classes, that improves their knowledge, work skills, and/or professional competencies increasing their value as employees and improving work satisfaction
- Industry awareness: Company personnel participated in one or more local grower associations to stay informed with important local issues relevant to cherry production, human resource management, and its neighbors and community and these issues were communicated to company employees
- Industry leadership: Company personnel took a leadership role in local, state and/or federal industry associations to influence issues that impact the farm
- Job performance: Implement a job performance process for employees that was linked to pay and promotion
- Land use planning: Farm staff were involved in regional land use planning to ensure sustainable community development
- Charitable contributions: The company made charitable contributions to community organizations focused on community well-being
- Regional water use and quality: Company staff worked with water quality coalitions, irrigation districts, and/or other agencies to tackle the challenging issues of water use and maintaining the quality of regional surface and ground water

Table 6. Workplace Management Strengths

Work Place Management Practices in the Self-Assessment	% of Orchards Practice Used	Confidence Interval (95%)	Value Score
8. Employees were provided the opportunity to enhance their workplace knowledge, skills, and competencies through in-house or external company sponsored training or education at least once in the last 12 months (e.g. SpraySafe)	91%	5.8%	7
12. The company was a member and one (or more) staff participated in a local grower association(s) to stay informed about, internally communicate, and affect local issues relevant to the sustainable production of cherries, human resources, and neighbors and community	97%	3.7%	5
14. In the last 12 months one (or more) farm staff took a leadership role in local, regional, and/or statewide industry associations to influence business and social issues that impact the farm	80%	8.2%	9
15. A job performance process was in place and was linked to pay and promotions	74%	9.1%	9
24. Within the last 12 months one (or more) farm staff was involved in regional land use planning	72%	9.3%	6
25. Within the last 12 months the company made one or more charitable contributions (products, money, and/or time) to recognized organizations committed to community wellbeing	92%	5.5%	5
26. Within the last 12 months one (or more) farm staff protected water quality by working with regional water quality coalitions, irrigation districts, and/or committees affecting ground water use or irrigated lands waiver planning	98%	3.0%	5

Cherry Grower Opportunities

It was clear from the analyses of the self-assessment data that there are many more grower strengths (29 – Tables 1 to 6) than opportunities (11 – Table 7). Furthermore, of the eleven high value practices listed as opportunities in Table 7, six were used in 40 – 60% of the orchards. They were listed as opportunities because even though they are being used in a significant number of orchards already, being high value practices it is helpful to identify them and encourage their use in an even more orchards. The opportunities are:

- Nitrogen management planning using a budget approach: This was chosen as an opportunity even though it was being used in 53% of the orchards assessed (Table 7). The practice is now a legal requirement for the California Water Board's Irrigated Lands Regulatory Program. Moreover, experience has shown many growers find value in managing their nitrogen using this approach because it provides for a much more fine-tuned way to manage nitrogen.
- Use of flow meters: Assessments showed that flow meters to measure the amount of water applied to the orchard were not used in only 88% of the orchards assessed (Table 7). Given the scarcity of water, and the likely increase in its cost over time, installing and using a flow meter to measure orchard water will add economic and environmental value to orchard management.

Table 7. Practices that Provide Opportunities with Cherry Growers

Soil Management	% Not Using Practice	Value Score
6. A nutrient management plan was implemented that used a "budgeting approach" to determine crop nutrient needs and it included factors like crop tissue analyses, soil type, time of year, soil moisture, crop demand, predicted yield, and nitrates in irrigation water	47%	30
Water Management		
17. A flow meter was installed on wells and/or pumps and monitored and the amount of water used per irrigation was tracked to optimize water use	88%	4
41. A berm or other barrier exists around the wellhead that prevents surface water running from the perimeter to the wellhead:	53%	7
Pest Management		
4. The UC IPM Year Round Plan for cherries was followed by those responsible for pest management on the farm	74%	13
13. Smart™ sprayers (sprayers that automatically switch off when trees are missing and at row ends) were used when applying pesticides	64%	9
Energy Management	**% Not Using Practice**	
5. One or more solar energy systems were on the property and generated electricity	88%	19
10. An energy audit for the farm was done to identify the areas of farm management that require the most energy and which can therefore become the targets for optimizing energy use	98%	7
Waste Management		
4. Employees were trained on legal requirements related to cleaning of farm equipment with water or steam cleaners and the resulting runoff	49%	4
Financial Management		
13. Costs and returns were tracked for newly implemented sustainability practices and compared to costs and returns of practices they replaced	58%	4
Workplace Management		
20. Basic health benefits were provided to non-seasonal employees	50%	5
23. Non-seasonal employees were provided access to a formal pension plan or a company 401k	58%	5

- Well head protection: Another water management opportunity that can greatly reduce the risk of ground water contamination is to install a berm or other barrier around wellheads. This practice was not done in 53% of the orchards assessed.
- Use of UC IPM Year Round Plan for cherries: The University of California's Statewide IPM Program year round plan for pest management in cherries was not used in 74% of the orchards assessed. Experience and research has shown that pest management is most successful when done using a holistic approach. The year round IPM plan for cherries is based on years of research and experience and is a valuable resource that growers and pest control advisors can use to guide their pest management approach in the cherry orchards they manage.
- Use of 'Smart Sprayers': Smart sprayers were not used in 64% of the orchards assessed. A smart sprayer is one equipped with optical sensors that turn off the sprayer nozzles when they are opposite gaps in the orchard canopy. Research has shown that smart sprayers can significantly reduce the amount of pesticide used in an orchard. However,

smart sprayers are expensive so this is a case where money has to be spent to save money.

- Installation of solar energy panels: Solar energy systems were not used in 88% of the orchards assessed. Many orchard and vineyard operations are installing solar panels to generate electricity for irrigation pumps and/or offices and shops. There still are incentives available from energy utility districts and/or solar system installation companies that may make installing a system attractive.
- Energy audit: Energy audits were not done in 98% of the orchards assessed. The value of doing an energy audit is to identify areas in cherry production where energy savings can be realized. Doing an energy audit is a very new concept for orchard production, as indicated by the results of the assessment. They have shown to be a very good business practice in packing/processing facilities.
- Water quality and cleaning farm equipment: Employees that worked in 49% of the orchards assessed were not trained on legal requirements related to cleaning farm equipment with water or steam cleaners and the resulting runoff. Proper procedures for cleaning farm equipment, particularly pesticide sprayers and fertilizer application equipment, can significantly reduce runoff of hazardous materials into surface and ground water.
- Cost benefit analysis of new sustainable practices: A cost/benefit analysis of newly implemented sustainable farming practices was not done in 58% of the orchards assessed. While it may be challenging to do a cost/benefit analysis of a new farming practice it is important to know if a practice is really paying for itself or not.
- Employee health benefits: Employees in half the orchards assessed were not being paid health benefits. Labor costs are a significant part of the farms operating budget. Health care is expensive and costs are going up. However, adding health benefits to an employee's benefits package are likely to attract and retain the best employees. Despite the cost of providing health benefits, assessment results show employees working in half the orchards assessed were being provided health benefits.
- 401k plan: A 401k plan was not provided to employees working in 58% of the orchards assessed. As with health benefits, providing a 401k plan for employees is likely to attract and retain the best employees.

Complete Summary of the Self-Assessments

Soil Management Module

Soil Properties Management

1. The soil types in the field were identified (e.g., using NRCS soils maps or from digging soil pits) and soil properties including water holding capacity, cation exchange capacity (CEC), texture, and rooting depth were known and recorded for each soil type and used for soil management planning and practices.

91% of orchards assessed used this practice

The properties of the soil in an orchard have a great influence on the ability of the soil to:

- store and release nutrients to the trees,
- store water after rain and irrigation events and releasing it to the trees
- allow for water infiltration
- regulate the trees' rooting depth and the roots abilities to mine soil for water and nutrients

All of these effects should be taken into account when developing the soil management plan for an orchard.

2. If water infiltration was poor (water puddles and runs off when soil is dry underneath), the soil was amended either chemically (e.g. with gypsum or organic matter such as compost or manure) or physically (e.g., disking, chiseling or shallow ripping)

92% of orchards assessed used this practice

This result indicates that water infiltration in most orchards was less than ideal and that growers took steps to improve it. A very important step in optimizing water use in California cherry orchards.

3. A soil sample was taken and measured for important physical and chemical properties, such as pH, cation exchange capacity, bulk density, salts, macro and micronutrients, and the results used to develop and implement a soil management plan/strategy

97% of orchards assessed use this practice

It is important to not only know the soil type in the orchard and its properties (see Practice #1) but also to test it for specific chemical properties. The results are very important in developing a soil management plan for the orchard that optimizes the use of nutrients and water.

4. Cover crops were planted or resident vegetation was allowed to grow between the tree rows to add organic matter and nutrients to the soil and to improve water infiltration

100% of orchards assessed use this practice

Planting a cover crop or allowing vegetation to grow between the tree rows has many benefits, such as improving soil health, improving air quality through reduction in dust that would otherwise occur if the soil was bare, and providing habitat for animals.

5. Equipment was chosen or was modified to minimize soil compaction (e.g. lightest equipment possible, track-layers, wider or bigger diameter tires, tire pressures as low as possible)

Completely for 19% or orchards assessed, Somewhat for 80%, and Not at All for 1%

This result indicates that most growers have taken at least some steps to minimize soil compaction in their orchards that can result from equipment use.

Crop Nutrition Management

6. A nutrient management plan was implemented that used a "budgeting approach" to determine crop nutrient needs and it included factors like crop tissue analyses, soil type, time of year, soil moisture, crop demand, predicted yield, and nitrates in irrigation water

Completely for 23% or orchards assessed, Somewhat for 44%, and Not at All for 33%

Basing an orchard nutrient management plan on a budgeting approach to determine crop nutrient needs involves a considerable amount of work. Nitrogen is the key element because it is critical for yield and quality as well as its tendency to move off site as nitrate in surface water or leach below the root zone into the ground water. There are several possible sources of nitrogen for trees, including irrigation water, applied fertilizer, cover crops, compost, and from existing reserves in the soil. Calculating the amount of nitrogen from each source takes a lot of work. Furthermore, the amount of nitrogen needed by the trees needs to be considered so that the amount of nitrogen available meets the trees' needs but not in excess. The above results for this practice indicates that nutrient management planning in the majority of orchards assessed is based at least in part on the budgeting approach.

It is important to note that starting in 2016, the Region 5 Water Quality Control Board's Irrigated Lands Regulatory Program requires that a nitrogen management plan based on a budgeting approach is developed and kept on file in the office by the grower for their orchards.

8. Plant tissue samples were taken at least once during the past growing season, analyzed and used to help assess crop nutrient needs

Not in data summary

9. The amount of nitrogen applied per acre and/or per unit of crop yield was documented and tracked for the orchard to optimize nitrogen management

Not in data summary

10. The amount of potassium applied per acre and/or per unit of crop yield was documented and tracked for the orchard to optimize potassium management

34% of the orchards assessed used this practice

11. Most nitrogen fertilizers were applied through the irrigation system (fertigation)

77% of orchards assessed used this practice

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Applying fertilizer through the irrigation system is a very efficient way to deliver nutrients to orchards. It allows for a very precise way to apply them in terms of location and timing and minimizes losses to the environment.

12. Nitrogen fertilizer applications were split (2 or more applications per season) to match crop nutrient demand by growth stage

88% of orchards assess used this practice

Applying nitrogen fertilizer to orchards in more than one application allows the grower to more closely match the tree's nutrient demand throughout the growing season, optimizing the amount that gets taken up by the tree and minimizing the amount that moves off-site.

13. Potassium fertilizer applications were split (2 or more applications per season) to match crop nutrient demand by growth stage

40% of orchards assessed used this practice

14. Micronutrients were applied based on visual deficiency symptoms

85% of the orchards assessed used this practice

Micronutrients can be a problem in orchards if not present in adequate amounts. However, as their name implies, they are needed in small amounts and most growers only apply them if the trees are showing visual symptoms of a micronutrient deficiency.

15. Micronutrients were applied based on crop tissue sample test results

83% of orchards assessed used this practice

Based on the results from practice #14, this result indicates that growers use more than one practice to confirm a micronutrient deficiency.

Soil Erosion

16. Vegetation was maintained along farm roads, on orchard edges, and along irrigation canals

Completely for 22% or orchards assessed, Somewhat for 75%, and Not at All for 3%

Vegetation along farm roads, on orchard edges and along irrigation canals can provide benefits like soil stabilization that minimizes soil erosion, habitat for animals, and a nicer visual experience than bare soil. However, maintaining vegetation outside the orchard can cost money and may be hard to justify economically. Also, the recent focus on food safety has resulted in some requirements that actually discourage the presence of vegetation near the orchard. The response to this practice reflects the complicated nature of the outcomes of this practice

17. No tillage was done on orchard borders or along irrigation canals unless required for planting cover crops or hedgerows

Completely for 37% or orchards assessed, Somewhat for 49%, and Not at All for 14%

Tillage destabilizes soil, making it more prone to erosion through the action of wind and/or water. It also increases soil metabolism that results in increased breakdown of organic matter and release of CO_2. It therefore should be avoided if possible. The response to this practice shows that tillage adjacent to orchards is not done at all for a third of cherry orchards and is only partly done for half.

18. Ditches were grassed or hardened to prevent erosion of the banks

Completely for 37% of orchards assessed, Somewhat for 3%, and Not at All for 60%

Erosion is a problem in many drainage ditches and stabilizing them through either planting grass or hardening them is expensive. While a third of the assessments reported this practice, the majority does not use it. Likely due to the expense of doing so. It is also possible that the soil types around many of the orchards are resistant to erosion so hardening is not necessary.

19. Culverts were properly sized to accommodate high flows, and inlets and outlets were hardened to prevent scour or energy dissipaters have been installed

77% of orchards assessed used this practice

Water Management Module

Orchard Establishment

1. Records are available for what was done before and during orchard planting

32% of the orchards assessed had records available

The results of the assessments for practices 2 – 6 are based on the 32% of orchards where pre-planting records were available.

2. Pre-planting analyses of the site was done to identify factors that affect effectiveness of irrigation water and infiltration rate such as existence of soil compaction, a root restricting layer, soil type, soil texture, soil chemistry (pH, salinity, etc.) and soil organic matter

Completely for 33% of orchards assessed, Somewhat for 67% and Not at All for 0%

Understanding the characteristics of a site where a new orchard will be planted can be used to determine many important things, such as the degree of site preparation necessary before planting, the root stock used, how the orchard is laid out, and specifics of the irrigation system

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(see the following practices). Many things can be done to analyze the site and the response to this practice shows that some orchards are analyzed more pre-planting than others but at least some was done for every orchard.

3. Ripping, plowing, chiseling, or other practices were implemented if pre-planting soil tests indicated water percolation and/or drainage problems

100% or orchards assessed used this practice

If water percolation rates are less than desirable for a site, one of the most important practices to be done is to break up the surface soil layers through ripping or chiseling.

4. Soil amendments were applied to correct soil chemical or physical issues if sampling identified factors that would affect water percolation

100% of orchards assessed used this practice

Soil amendments such as compost or gypsum can improve water infiltration. The response to this practice indicates amendments were applied to all assessed orchards with an identified water infiltration problem.

5. Water source was sampled and evaluated for water quality

95% of orchards assessed used this practice

Before an orchard is planted, it is very important to know the quality of the water that will be used to irrigate it during its lifetime. Ground water may contain contaminants and may need amending if quality is poor. Or it may contain nitrates, which need to be taken into account when developing a nitrogen management budget for the orchard.

6. The irrigation system was designed to deliver the quantity of water required for the crop and accommodate for variation in topography as well as in soil texture that affects water percolation and water holding capacity

Completely for 38% of orchards assessed, Somewhat for 62% and Not at All for 0%

If the variation in soil in an orchard site is high it may not be possible to design an irrigation system to completely solve the problem. However, the response from this practice indicates for the orchards assessed all of them attempted to optimize the design of the irrigation system to meet the site demands.

Irrigation

7. The total amount of water used in the orchard for the year was measured and recorded and year to year comparisons made to optimize water use

DRAFT

73% of the orchards assessed used this practice

It is not possible to optimize water use without measuring how much is applied to the orchard each year. This information is known for the majority of orchards assessed.

8. A water management plan for the orchard was developed that included goals for the growing season and took into consideration annual rainfall, crop development, water-related pest management issues, soil type, soil preparation, slope, water quality, irrigation efficiency, irrigation uniformity, and energy efficiency

Completely for 13% of the orchards assessed, Somewhat for 83%, and not at all for 5%

Ideally a water management plan should be very detailed to optimize water use and ensure the right amount of water is delivered to the orchard at the right time. However, the more detail it contains the more work it takes to maintain it and time is money. The result of the assessment of this practice indicates that most assessed orchards have a water management plan but the amount of detail likely varies from one grower to another.

Irrigation Scheduling and Rates

9. Irrigation was initiated at the start of the season based on measured soil moisture depletion

97% of the orchards assessed used this practice

To optimize water use in an orchard, it is important to not initiate irrigation for the year until the amount in the soil from the previous rainy season is below what is needed by the trees. It is clear cherry growers monitor soil moisture to determine when irrigation for the year should be started.

10. Irrigation scheduling (timing and amounts applied) was adjusted to take advantage of-peak energy pricing to save on irrigation costs

80% of orchards assessed used this practice

11. Water percolation rate and infiltration depth was monitored during the irrigation season and irrigation was adjusted accordingly

75% of orchards assessed use this practice

To avoid runoff of irrigation water, it is important to apply it at a rate that can be absorbed by the soil. Three quarters of the orchards assessed ajust irritation rates to match water infiltration rates.

12. Irrigations were scheduled (timing and amounts applied) by using one or more of the following practices:

12.1. Soil sampling to determine soil moisture

90% of orchards assessed used this practice

12.2. Using soil-installed moisture monitoring devices

55% of orchards assessed used this practice

12.3. Amount of irrigation and timing were dictated by the amount and timing of water available through the Irrigation District

15% or orchards assessed used this practice

12.4. By determining ETo through using data from onsite weather station or the nearest CIMIS weather station

10% of orchards assessed used this practice

12.5. By converting ETo to Etc by using the appropriate crop coefficient factor (Kc), which takes into account crop canopy

37% of orchards assessed used this practice

Ideally, the timing of irrigation and the amount of water applied to the orchard should be done to match the water demand of the trees. The results from the above practice assessments indicate that growers managing the orchards assessed are determining the timing of irrigation and the amount of water to apply primarily by measuring soil moisture rather than directly measuring tree water demand as measured by evapotranspiration.

13. When appropriate, less than full water demand was applied to the crop (deficit irrigation) to conserve water

58% of the orchards assessed are using this practice

Research has shown that for some permanent crops, irrigation that provides less water than crop demand does not have a significant effect on crop quality and yield. It appears a significant number of cherry growers are using this practice in their orchards.

Irrigation System Performance and Maintenance – Pumps and Filters

14. Pumping plant efficiency:

14.1. Pump for orchard is less than 3 years old

For the orchards assessed, 38% had pumps less than 3 years old.

14.2. Was measured within the last 3 years and adjustments made if warranted

46% of orchards assessed measured pump efficiency within the last 3 years and made adjustments of warranted.

14.3. Was measured within the last 5 years and adjustments made if warranted

69% of orchards assessed measured pump efficiency within the last 5 years

14.4. Was measured more than 5 years ago or never

97% of orchards assessed had not measured pump efficiency within the last 5 years
(need to figure out how to report on results from Pump efficiency practice since 14.4 does not make sense compared to 14.1 – 14.3. Orchards assessed were 24, 13, 32 for 14.2, 14.3 14.4 respectively)

15. Energy use for irrigation was tracked on an annual basis and year-to-year comparisons were made to improve energy use efficiency

31% of orchards assessed used this practice

Irrigation pumps

16. Electrical irrigation pumps were on time-of-use metering to save on irrigation costs

75% of orchards assessed used this practice

17. A flow meter was installed on wells and/or pumps and monitored and the amount of water used per irrigation was tracked to optimize water use

18% of orchards assessed used this practice

(according to practice #7 73% of orchards assessed measured total about of water applied, this does not jive with the above result)

18. Pressure check points were installed on key lines from pumps and monitored to optimize system performance

62% of orchards assessed used this practice

19. Filter status (and flushing system) was manually checked at least twice a season and corrected if necessary

95% of orchards assessed used this practice

It is important to ensure irrigation system filters are operating optimally to reduce the likelihood of clogging of lines, sprinkler heads, and emitters. Virtually all growers managing orchards that have been assessed used this practice regularly.

20. Pressure gauges were installed for measuring pressure drops through filters to optimize system performance

84% of the orchards assessed used this practice

Irrigation Performance and System Maintenance – Drip and Non-rotator Micro-sprinklers

21. Drip irrigation is used in the orchard:

44% of orchards assessed have drip irrigation systems, the remaining 56% had other types of irrigation systems. Only orchards with drip systems were assessed for practices #22 - #26.

22. Distribution uniformity of the irrigation system was tested within the last 2 years and adjustments made if warranted

63% of orchards assessed used this practice

For optimum performance, a drip irrigation system should be adjusted to deliver water uniformly throughout the orchard. The irrigation systems in the majority of orchards assessed used this very important practice.

23. The system had pressure compensating emitters to help maintain system distribution uniformity

This practice was considered not applicable in 92% of orchards assessed

24. The irrigation system was monitored for leaks, breaks, and clogging:

24.3. More than twice in the last 12 months

100% of the orchards assessed used this practice

Regularly checking a drip irrigation system for leaks and clogs is essential for minimizing waste of water. It is clear growers managing the cherry orchards assessed used this very important practice.

25. An interlock system/backflow prevention device was installed so the injection pump shuts down if the irrigation pump shuts down, to prevent water source contamination

82% of orchards assessed used this practice

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26. Irrigation lines were flushed at the start of the season and then again at mid-season, or more often as needed

This practice was implemented Completely for 12% of the orchards assessed, Somewhat for 88%, and in no orchards was it not done at all.

Silt and sand can build up in irrigation lines so it is important to periodically flush them to ensure optimum system performance. The practice was used in all orchards, the frequency during the year varied from one orchard to the next.

Irrigation Performance and System Maintenance – Impact or "Rotator" Type Sprinklers

27. Sprinkler irrigation (Impact or rotator type) is used in the orchard:

98% of the orchard assessed had impact or rotator sprinkler irrigation systems installed

28. The irrigation system was monitored for leaks, breaks, and clogging:

28.3. More than twice in the last 12 months

100% of the orchards assessed had their sprinkler irrigation system checked more than twice in the last 12 months.

29. Sprinkler head rotation and nozzle clogging and nozzle wear was checked, repaired if necessary, and/or replaced with the correct nozzle size if necessary to maintain distribution uniformity:

29.1. Within the last 12 months

100% of orchards assessed used this practice

The results of the assessment for practices #28 and #29 indicates that growers managing the orchards assessed regularly monitor their sprinkler irrigation systems for problems.

30. Distribution uniformity of the irrigation system was tested within the last 2 years and adjustments made if warranted

74% of orchards assessed used this practice

31. An interlock system/backflow prevention device was installed so injection pump shuts down if irrigation pump shuts down to prevent water source contamination

79% of orchards assessed used this practice

Irrigation Performance and System Maintenance – Flood or Furrow

32. Flood or furrow irrigation is used in the orchard:

0% of the orchards assessed were irrigated by furrows

Furrow irrigation is considered the least precise way to irrigate because it cannot be as frequent as other types of irrigation and therefore it cannot be timed as precisely to tree water demand. The fact that no orchards assessed used this type of irrigation indicates that the growers managing these orchards prefer micro or sprinkler irrigation systems.

Practice #33 - #35 were not assessed because they pertained only to furrow irrigation.

Water quality – Source and resource

36. Irrigation water was tested within the last 3 years for quality, including pH, total salt, nitrates, and biological contamination

95% of the orchards assessed used this practice

The quality of well water can change over time so it is important to periodically test it for important quality parameters. Some Food Safety programs require periodic irrigation water testing for biological contaminants. The results of this practice assessment indicates growers managing the assessed orchards feel this is an important practice.

37. If a water distribution reservoir is on the farm, the quality of water was tested within the last 3 years for quality, including pH, total salt, nitrates, and biological contamination

18% of orchards assessed used this practice and for 78% it was not applicable (they are not irrigated from a reservoir)

38. If a water quality problem exists it was addressed:

23% of orchards assessed used this practice and for 77% it was not applicable, indicating water quality problems did not exist in the irrigation water

39. Resource maps were accessed to determine if the orchard was in a Ground Water Protection Area (GWPA)

89% of the orchards assessed used this practice

If an orchard is in a GWPA, certain pesticides cannot be used and others used with restrictions.

40. If an orchard is in a GWPA, the legal requirements for handling restricted use pesticides in GWPA areas were accessed and read, and they are on file in the office

37% of orchards assessed used this practice and for 73% it was not applicable, indicating they were not in a GWPA.

41. A berm or other barrier exists around the wellhead that prevents surface water running from the perimeter to the wellhead:

53% of orchards assessed used this practice

42. Unused/abandoned wells were sealed to prevent ground water contamination:

60% of orchards assessed used this practice and for 38% it was not applicable, indicating there were no unused or abandoned wells in or near the orchard
43. If significant storm water run-off occurred, one or more of the following mitigation practices were implemented:

97% of orchards assessed did not experience significant storm water run-off so practice #43.2 - #43.7 were not assessed

Storm water run-off from an orchard has the potential to carry pesticides, nutrients, and sediment off-site and risk contaminating nearby surface water in streams, reservoirs, and lakes. Therefore, if an orchard frequently experiences storm-water run-off during the rainy season, it is important to minimize it through the several practices that are available.

Pest Management Module

Pest Risk Assessment

1. Monitoring protocols for key pests were established and followed

Completely for 95% of the orchards assessed, Somewhat for 5%, and Not at All for 0%

To ensure pest monitoring results are consistent from one orchard to the next and one year to the next, it is important that the same protocols are used each time. It is clear from the assessment of this practice that virtually all cherry growers completing the assessment are using this practice.

2. Economic thresholds for key pests were established and used to make management decisions

Completely for 95% of the orchards assessed, Somewhat for 5%, and Not at All for 0%

One key to practicing integrated pest management is to only take action against a pest if its numbers are great enough that the damage they will cause if not controlled will exceed the cost of the control action. Virtually all growers who assessed orchards are following this practice.

3. Environmentally sensitive areas in and near the orchard, such as streams, reservoirs, wetlands, vernal pools, swales, distance to ground water, houses, schools, public and private roads, have been identified and mapped

98% of the orchards assessed used this practice

It is important to not only know where sensitive areas are around an orchard but also have them mapped so that anyone new to the site can refer to it and act accordingly.

Pest Monitoring

4. The UC IPM Year Round Plan for cherries was followed by those responsible for pest management on the farm

31% of the orchards assessed used this practice

The University of California Statewide IPM program developed a set of science-based practices a grower and/or PCA can use throughout the year to achieve pest management in cherry orchards. Years of research and experience have proven using this plan is efficacious. Based on the results of the assessment this is an opportunity for more growers to use it to improve their orchard pest management.

5. The UC IPM Guidelines for cherries were used in making pest management decisions by those responsible for pest management on the farm

51% of the orchards assessed used this practice

Likely more growers used this practice because they are guidelines rather than a plan.

6. The UC IPM Manual for Stone Fruits was used as a reference for pest management by those responsible for pest management on the farm

48% of the orchards assessed used this practice

7. Natural enemies of mite pests were monitored and treatments were NOT made or were delayed if the number of leaves with mite predators is nearly the same as the number of leaves with pest mites

71% of the orchards assessed used this practice

8. Cultural factors, such as time to harvest, preexisting plant damage, plant moisture stress, plant health, and/or crop load, were considered in pest management decision-making

Completely for 92% of the orchards assessed; Somewhat for 8%; Not at All 0%

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The level of a pest population at which a control action should be taken can vary depending on many factors. It is clear from the assessment of this practice that the growers managing the cherry orchards assessed apply this concept in their pest management decision-making.

9. Pest monitoring records were kept and reviewed during the pest management decision-making process

100% of the orchards assessed used this practice

Not only it is important to monitor for pests but it is also important to keep records of this monitoring to review later.

10. If pest management recommendations from a PCA were relied upon, they were reviewed and discussed with farm management staff before making a decision to take a management action

100% of orchards assessed used this practice and 0% assessed it as N/A

Good pest management requires good communications among all those involved in pest management decision making and actions. Since this 0% of the orchards assessed selected the Not Applicable option, PCAs are involved in the pest management decision making of all the orchards assessed.

11. Farm crew supervisors and farm managers are encouraged to report any pest problem that was out of the ordinary (e.g. pests they have never seen before) and report it to the appropriate person

100% of the orchards assessed used this practice

The more people looking out for and reporting potential pest problems in orchards the better.

12. Pictures of important exotic pests, (pests accidently introduced to California) that might affect cherries were posted in convenient places so employees could monitor for their presence and inform management if seen

27% of the orchards assessed used this practice

Early detection of an exotic pest may offer the option of eradication. One way to make workers aware of pests to look for is to post pictures of exotic pests along with other postings like worker health and safety rules. The results of this assessment indicates this is an opportunity for some growers to be more proactive in educating their workforce on potential exotic pests.

Pesticide Management

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20. Pesticide applications were NOT made when wind speeds exceed 7mph or in dead calm (e.g., when a temperature inversion exists) or when the wind was blowing toward a sensitive area to avoid pesticide drift

100% of orchards assessed used this practice

21. Sprayer nozzles were shutoff at row ends near environmentally sensitive areas

100% of orchards assessed used this practice

22. Pesticide mixing and loading was done using a closed system or with water soluble pesticide packets when appropriate for the pesticide being applied

Completely for 73% of orchards assessed, Somewhat for 27% and Not at All 0%

Using a closed mixing and loading system or water soluble pesticide packets minimizes the risk of exposure of workers to pesticide residue and volatile organic compounds (VOCs) from the pesticide formulation.

23. Spray mixing, loading and calibration were planned so that the tank was empty at the end of the spray job

Completely for 95% of the orchards assessed, Somewhat for 5% and Not at All 0%

Having an empty spray tank at the end of the spray job avoids having to deal with a partial load in the sprayer.

24. The following safe pesticide storage practices were followed: dry pesticides stored above liquids, pesticides are stored more than 300 feet from nearest well, storage area has impermeable floor and sump to contain leaks, and only undamaged containers are stored

Completely for 100% of the orchards assessed

This assessment result indicates how important cherry growers consider pesticide storage safety.

25. An emergency response plan for pesticide and fertilizer spills and exposure was posted in the appropriate places and workers were trained to follow them

89% of the orchards assessed used this practice

26. A pesticide risk model such as PRiME, NRCS™'s WIN PST, or UC IPM™'s Water Tox was used when considering which pesticides to apply

Completely for 7% of orchards assessed, Somewhat for 27% and Not at All for 67%

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Knowledge of the existence of pesticide risk models in the grower community is not very high. They are relatively new, some are not easy to use, and the benefits of using them are not appreciated by many growers and other farming stakeholders. The value of using a pesticide risk model to help in deciding what pesticides to use, is that they take into account not only pesticide toxicity but also the risk of exposure of the pesticide to non-target organisms. If the risk of exposure to a pesticide is low then the risk of using this pesticide is low, too. In other words, risk models take into account the safety measures growers' use when they apply pesticides. This is a more realistic measure than using only a measure of a pesticides toxicity.

Biological Control

27. Conservation of pest natural enemies, particularly mite predators, was considered when choosing a pesticide to use in the orchard

Completely for 72% of orchards assessed, Somewhat for 28% and Not at All for 0%

Effects of Pesticides on Non-Target Sites, Bees and Other Organisms

28. Effects of a pesticide on pollinators were considered when selecting the material to apply

Completely for 74% of orchards assessed, Somewhat for 26% and Not at All for 0%

29. Pesticides were NOT applied in the orchard block when pollen was available AND bees were foraging OR pesticides were applied at night

Completely for 87% of orchards assessed, Somewhat for 13% and Not at All for 0%

30. Effects of a pesticide on non-target organisms existing on my farm, such as birds and small mammals, were considered when selecting the material to apply

Completely for 95% of orchards assessed, Somewhat for 5% and Not at All for 0%

Energy Management Module

1. The total amount (e.g. gallons) of fuel used annually on the farm was recorded and year to year comparisons made to better manage fuel use. Each fuel type is recorded separately, if possible

Completely for 2% of orchards assessed, Somewhat for 79% and Not at All for 20%

2. Annual fuel consumption and/or electrical use for irrigation pumps were recorded and comparisons made from year-to-year to better manage energy use for irrigation

34% of orchards assessed used this practice

3. Electrical use for office(s), shop(s), and outdoor security lighting was tracked using energy bills and year-to-year comparisons made to better manage energy use in the offices and shop

Completely for 5% of orchards assessed, Somewhat for 75% and Not at All for 20%

4. A process was in place to ensure the most appropriate piece of equipment was used for a given job (e.g., the most appropriate horse power engine for the job)

Completely for 60% of orchards assessed, Somewhat for 35% and Not at All for 5%

5. One or more solar energy systems were on the property and generated electricity

16% of the orchards assessed used this practice

6. One or more wind generators were on the property and generated electricity

0% of orchards assessed used this practice

7. Engines (stationary and mobile) and motors were maintained on a regular schedule to achieve optimum efficiency

Completely for 88% of orchards assessed, Somewhat for 0% and Not at All for 12%

8. Light switches were fitted with motion detectors or photo cells to reduce time of use

Completely for 18% of orchards assessed, Somewhat for 54% and Not at All for 28%

9. Office and shop lights were fitted with low energy consumption compact florescent bulbs or LED lights

Completely for 12% of orchards assessed, Somewhat for 87% and Not at All for 2%

10. An energy audit for the farm was done to identify the areas of farm management that require the most energy and which can therefore become the targets for optimizing energy use

3% of orchards assessed have used this practice

Food Safety Management Module

Food Safety Management Planning

1. The farm participated in a third party food safety certification program (e.g., Agriculture Marketing Service GAP Certified, Primus, SQF, Global GAP) or a food safety plan approved by the farm's packing/shipping company

100% of orchards assessed used this practice

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If the farm that assesses an orchard is participating in a third party food safety certification program then the rest of the practices in this module are skipped and not assessed. Since all the orchards that were assessed used this practice, the results of the assessment for the remaining questions are not reported.

Air Quality Management Module

In and Around the Orchard

1. Orchard prunings were chipped or shredded rather than burned

100% of orchards assessed used this practice

Burning releases ash, volatile organic compounds, and CO_2 into the air. All of which negatively impact air quality. Shredding or chipping orchard prunings not only benefits air quality, it also adds organic matter to the soil, improving aeration, water infiltration, and water storage.

2. Burning was restricted and only done when necessary, such as when taking out an old orchard or for pest or disease control, and was done in strict accordance with the law

97% of orchards assessed used this practice

3. Vehicle speed was restricted to 5 mph on dirt roads around orchards during the dry parts of the growing season to minimize airborne dust

Completely for 87% of orchards assessed for this practice; Somewhat for 13%

Dust kicked up from vehicles traveling on dirt roads around the orchard contributes to air quality reduction. It also becomes deposited on tree foliage adjacent to the road which can increase the likelihood of mite outbreaks.

4. Dirt roads were treated with an anti-dust agent that met the 50% PM10 (PM 10 = particulate matter 10 microns or less in diameter) control for a Fugitive PM10 Management Plan

Completely for 16% of orchards assessed; Somewhat for 30% and Not at All for 54%

Treating dirt roads with an anti-dust agent is one of the most effect ways to reduce dust kicked up by vehicles. However, it does add cost to the orchard management.

5. Dirt roads were graveled, watered, chipped, mulched (crop residues), sanded or seeded with cover crop

Completely for 47% of orchards assessed, Somewhat for 37% and Not at All for 16%

6. Heavily used roads were paved (e.g. main thoroughfares on farm)

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Completely for 15% of orchards assessed; Somewhat for 44% and Not at All for 41%

Paving dirt roads would be the most effective method for eliminating dust kicked up from vehicles but is by far the most expensive practice to reduce dirt road dust.

Engines and Fuel Consumption

7. Vehicles were equipped with engines able to use alternative fuels with lower emissions (e.g., compressed natural gas, flex fuel, biodiesel, propane)

Completely for 2% or orchards assessed; Somewhat for 26% and Not at All for 72%

8. Some off-road farm vehicles were battery powered

3% of orchards assessed used this practice

9. Vehicle miles were tracked on an annual basis and year to year comparisons made to better manage vehicle usage

2% of orchards assessed used this practice

10. Stationary diesel engines were replaced (or retrofitted) to Tier 3 or better

Completely for 8% of orchards assessed; Somewhat for 59%; and Not at All 33%

11. Stationary diesel engines were replaced (or retrofitted) with technology relying on cleaner burning fuel (e.g. propane, natural gas, biodiesel) or replaced with electric pumps

Completely for 5% of orchards assessed; Somewhat for 2%; and Not at All 93%

12. Selection of vehicle power plants and stationary engines is in part determined by lower emissions ratings

80% of orchards assessed used this practice

Pesticide Management and Air Quality

13. Soil fumigants were used only when necessary and applied appropriately (e.g. pre-planting where soil sampling has identified a significant pest problem, proper soil moisture conditions exist and that all regulations have been met)

92% of orchards assessed used this practice

14. The VOC (volatile organic compound) footprint of pesticides or plant growth regulators was considered when deciding which pesticides to apply

Completely for 80% of orchards assessed; Somewhat for 7%; and Not at All for 13%

Waste Management Module

Waste Management practices pertain to the entire farming enterprise and not the individual orchards. Therefore the sample size of 25 growers having done the assessment is too small to say with confidence that the percentage of orchards using these practices is representative of the cherry industry as a whole.

1. The farm had an established recycling program for metal, cardboard, plastics, paper and glass

Completely for 59% of orchards assessed; Somewhat for 39%; and Not at All for 2%

2. Unused or worn out equipment such as appliances, tractors, ATVs, electrical equipment, were taken to the proper recycling centers

Completely for 82% of orchards assessed; Somewhat for 16%; and Not at All for 2%

3. Employees were trained on the proper handling and disposal of hazardous materials (e.g. solvents, cleaning materials, explosives, compressed gases, fuel, acids, and lubricants)

100% of the orchards assessed used this practice

4. Employees were trained on legal requirements related to cleaning of farm equipment with water or steam cleaners and the resulting runoff

66% of the orchards assessed used this practice

5. Hazardous materials that are no longer used, as well as their containers, were disposed of according to legal requirements

100% of the orchards assessed used this practice

6. The farm participated in a pesticide container recycling program

100% of orchards assessed used this practice

7. Dumpsters and/or recycling containers were on cement pads to contain spills

Completely for 12% of orchards assessed; Somewhat for 72%; and Not at All for 16%

8. Dumpsters and/or recycling containers were covered to keep rain out

Completely for 72% of orchards assessed; Somewhat for 25%; and Not at All for 2%

9. Dumpsters and/or recycling containers were periodically inspected for leaks, spills, and litter. Problems noticed were corrected

85% or orchards assessed used this practice

Ecosystem Management Module

Ecosystem Management practices pertain to the entire farming enterprise and not the individual orchards. Therefore the sample size of 25 growers having done the assessment is too small to say with confidence that the percentage of orchards using these practices is representative of the cherry industry as a whole.

1. Vegetation such as grasses, trees or shrubs that are known to benefit desired wildlife or pest natural enemies were planted, or existing vegetation maintained along orchard edges, roadsides, ditch-banks and headlands

Completely for 56% of orchards assessed; Somewhat for 38%; and Not at All for 7%

2. Vernal pools or swales were preserved and managed with setbacks to reduce probability of soil disturbance and protect plant and animal species associated with them

Completely for 49% of orchards assessed; Somewhat for 2%; and Not at All for 0%

3. Nesting boxes for owls were placed around the farm, outside the orchard proper to avoid food safety issues

85% of orchards assessed used this practice

4. Water courses (e.g., creeks, streams), either seasonal or year-round, were present on the farm

31% or the farms on which orchards were assessed had water courses on the property and 69% of them did not

5. Setbacks were in place to minimize disturbance to the water course

Completely for 40% of orchards assessed; Somewhat for 8%; and Not at All for 52%

6. Resident vegetation was maintained on the banks of the water course

Completely for 48% of orchards assessed; Somewhat for 0%; and Not at All for 52%

7. Water course banks were vegetated with a mix of grasses, trees and shrubs

Completely for 16% of orchards assessed; Somewhat for 84%; and Not at All for 0%

8. The natural areas of the farm were protected by a conservation easement

Completely for 0% of orchards assessed; Somewhat for 26%; and Not at All for 74%

9. The farm was protected by an agricultural easement program

Completely for 0% of orchards assessed; Somewhat for 26%; and Not at All for 74%

10. The farm was managed to optimize ecosystem services such as nutrient cycling, carbon sequestration, healthy soils and plants, that are provided by groups such as plants, wildlife, pollinators, soil microbes, and/or arthropod natural enemies and to increase biodiversity

Completely for 53% of orchards assessed; Somewhat for 30%; and Not at All for 18%

11. Indicators of biodiversity on the farm were monitored and recorded, such as animal and plant populations, pollinators, or arthropod natural enemies

3% or orchards assessed used this practice

Financial Management Module

Financial Management practices pertain to the entire farming enterprise and not the individual orchards. Therefore the sample size of 25 growers having done the assessment is too small to say with confidence that the percentage of orchards using these practices is representative of the cherry industry as a whole.

Planning and Risk Management

1. A marketing and production plan was developed for the farm and seasonal outcomes compared to the plan

80% of orchards assessed used this practice

2. A succession plan was in place for the farm

95% of orchards assessed used this practice

3. A written will and estate plan was in place for the farm

98% of orchards assessed used this practice

4. A business continuation plan (disaster management plan) was in place for the farm

90% of orchards assessed used this practice

5. Key personnel in the company had health insurance

100% of orchards assessed used this practice

6. Key personnel in the company had disability insurance

82% of orchards assessed used this practice

7. Key personnel had life or accidental death insurance

98% of orchards used this practice

Accounting and Financial Analyses

8. A financial accounting system to track and report farm finances was used to make decisions about the farm's operation

97% of orchards used this practice

9. A financial advisor was met with in the last 12 months

98% of orchards used this practice

10. Financial profitability analyses for investments were done if investments were made

77% of orchards assessed used this practice; this practice was not applicable to 5% of orchards assessed

11. Production costs and revenue were tracked for each production block (orchard) in financial management reports to better track and improve profitability

93% or orchards assessed used this practice

12. Costs and returns were tracked for all important farming practices to help identify practices that are paying for themselves and those that are not

Completely for 92% of orchards assessed; Somewhat for 5%; and Not at All for 3%

13. Costs and returns were tracked for newly implemented sustainability practices and compared to costs and returns of practices they replaced

Completely for 26% of orchards assessed; Somewhat for 7%; and Not at All for 67%

14. Sensitivity analysis, i.e. change in crop prices over time, was used to analyze financial risk over time

79% of orchards assessed used this practice

Purchasing and Borrowing

15. More than one quote was obtained for major input purchases such as pesticides and fertilizers

93% of orchards assessed used this practice

16. Interest rates and services from more than one lending institution were compared before borrowing a significant amount of money

97% of orchards assessed used this practice

Workplace and Community Module

Practices that relate to Workplace and Community pertain to the entire farming enterprise and not the individual orchards. Therefore the sample size of 25 growers having done the assessment is too small to say with confidence that the percentage of orchards where these practices are used is representative of the cherry industry as a whole.

Staffing and Recruiting Strategy

1. A job description existed for each type of job and was given to the employee and their supervisor when the employee was hired

Completely for 7% of the orchards assessed; Somewhat for 87%; and Not at All for 7%

2. Job descriptions were reviewed and updated at least once every two years

Completely for 7% of the orchards assessed; Somewhat for 24%; and Not at All for 69%

Employee Orientation, Safety Training, and Career Development

3. An orientation program was provided for new non-seasonal employees

79% of orchards assessed used this practice

4. Every non-seasonal employee was provided an employee handbook in an appropriate language that included, at a minimum, the company's work standards and policies and an overview of benefits

76% of orchards assessed used this practice

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5. Safety training was done and documented according to Cal OSHA regulations, i.e. when employee begins a new job assignment, or any new process, procedure or use of a substance or equipment that creates a new hazard

98% of orchards assessed used this practice

6. If labor was contracted, a check was made to ensure the contract labor company adhered to all relevant Cal OSHA safety regulations

86% of orchards assessed used this practice; 14% of orchards assessed did not use contract labor

7. Safety failure statistics such as procedure violations, equipment malfunctions, and frequency of accidents were documented, tracked, and retained for at least two years, and root causes were determined and actions were taken to improve safety performance and training

Completely for 18% of orchards assessed; Somewhat for 81%; and Not at All for 2%

8. Employees were provided the opportunity to enhance their workplace knowledge, skills, and competencies through in-house or external company sponsored training or education at least once in the last 12 months (e.g. SpraySafe)

87% or orchards used this practice

9. An employee meeting was held at least once in the past 12 months to discuss company goals and to exchange ideas

95% or orchards assessed used this practice

10. A meeting of top management was held in the last 12 months discuss company goals and exchange ideas

94% of orchards assessed used this practice

Industry Awareness

11. Trade journals/literature (relevant to worker and safety issues, Farm Bureau and trade association activities, etc.) were reviewed by the farm management team (FMT) to identify opportunities to improve the workplace

Completely for 89% of orchards assessed; Somewhat for 11%; and Not at All for 0%

12. The company was a member and one (or more) staff participated in a local grower association(s) to stay informed about, internally communicate, and affect local issues relevant to the sustainable production of cherries, human resources, and neighbors and community

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95% of orchards assessed used this practice

13. In the last 12 months, the one (or more) farm staff attended regional and/or statewide industry meetings (Irrigation District, Farm Bureau, Water Coalition, etc.), trade shows, and/or seminars to stay informed about and internally communicate relevant information/knowledge gained about socially important issues

100% of orchards assessed used this practice

14. In the last 12 months one (or more) farm staff took a leadership role in local, regional, and/or statewide industry associations to influence business and social issues that impact the farm

86% of orchards assessed used this practice

Performance, discipline, grievance process, and employee recognition

15. A job performance process was in place and was linked to pay and promotions

77% of orchards assessed used this practice

16. A process was in place to evaluate and improve overall employee satisfaction

76% of orchards assessed used this practice

17. A grievance process was in place

79% of orchards assessed used this practice

18. At least one grievance was filed by an employee in the last 12 months, was recorded and processed in a timely manner

2% of orchards assessed used this practice; 95% of orchards assessed did not have a grievance filed

19. A process was used to receive, evaluate, respond to, and apply employee suggestions for improvements in company practices, working environment, and other areas

79% of orchards assessed used this practice

Health benefits, paid time off, and other benefits

20. Basic health benefits were provided to non-seasonal employees (Yes/No)

39% of orchards assessed used this practice

21. Non-seasonal employees had paid holidays and vacation time

41% of orchards assessed used this practice

22. Employees were provided paid sick leave and/or personal days (Yes/No)

97% of orchards assessed used this practice

23. Non-seasonal employees were provided access to a formal pension plan or a company 401k

33% of orchards assessed used this practice

Community Support

24. Within the last 12 months one (or more) farm staff was involved in regional land use planning

75% of orchards assessed used this practice

25. Within the last 12 months the company made one or more charitable contributions (products, money, and/or time) to recognized organizations committed to community wellbeing

95% of orchards assessed used this practice

26. Within the last 12 months one (or more) farm staff protected water quality by working with regional water quality coalitions, irrigation districts, and/or committees affecting ground water use or irrigated lands waiver planning

97% of orchards assessed used this practice

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Effects of Deficit Irrigation on Insect Communities in California Mature Green Tomato Cropping Systems

Introduction

Drought is the major obstacle for farmers in California and water scarcity is predicted to become more severe with progressing climate change. Climate simulations for California by Global Climate Models (GCM) show that mean annual temperature will rise by 1 to 3°C (1.8 to 5.4°F) by 2050 and that heat wave days will increase two to three-fold (Diffenbaugh et al. 2015). Precipitation is likely to decrease toward the end of the century, depending on the assumptions of each GCM but hydrological changes suggest that drought is already increasing and will become more severe and variable with time (Barnett et al. 2008; Cayan et al. 2010). Irrigation demand and groundwater pumping are expected to be substantial under a projected warmer and drier climate and the area's water district is likely to face more frequent years with water supply problems, e.g. years where water deliveries are either below full allocation and/or no-allocation (Jackson et al. in press-now published ?). California is leading state for fresh market vegetable production, accounting for 50% of annual production in the US and 55% ($6.1 billion) farm value. In 2016 Californian farmers produced 2366.8 million pounds of fresh market tomatoes. However production declined by 10% since 2015 due to severe water restrictions (USDA 2017). Management practices are aimed to reduce water input and maximize water use efficiency while maintaining high yields and growers already have moved to more efficient water management strategies like drip irrigation. Deficit irrigation was found to be a valuable tool to respond to limited water availability as water shortage may allow plants to use water more efficiently (Costa, Chaves & Ortu 2007; Barrios-masias & Jackson 2016).

Water deficits will not only affect plant growth but also may alter plant chemistry with consequences for insect herbivory. The relationship between insect communities and plant water status is complex, though. According to the plant stress theory, water deficits increase insect herbivory because water-stressed plants become nutritiously more attractive (White 1984). This theory finds support in other

studies showing that water-stressed plants are more susceptible to herbivore damage compared to unstressed plants (Cockfield & Potter 1986) and that water-stressed plants are less defensive (Rhoades 1979,1983) due to drought induced changes in plant defensive chemicals. Further, drought affected plants may offer a more suitable physical environment for insect herbivores (Begon 1983) by increased leaf temperatures due to stomatal closure as response to drought. In contrast, the plant vigor hypothesis argues that plants under stress, which can be caused by a variety of factors are less attractive to some herbivores (Price 1991) with examples of galling insects showing preferences for more vigorous plant modules at within plant species variation in woody plants (Larsson 1989). Most likely the relationship between drought and herbivory is a continuum with some herbivore groups or species being more attracted to drought stressed plants whereas others are favored by unstressed plants and probably some herbivores that prefer the average plant in the population. Feeding guild was found to influence preferences of insects for drought-stressed or well-watered plants with major differences between sap feeding and leaf chewing and gall-forming insects with sap feeding and gall-forming insects being more negatively affected by drought than leaf chewing insects (Larsson 1989; Huberty & Denno 2004). However, even within feeding guild, variability can exist. For example, specialist lepidopteran species preferably consumed well-watered plants whereas as a generalist lepidopteran species preferred drought-stressed plants (Gutbrodt, Mody & Dorn 2011).

Changes in plant chemistry likely mediate insect feeding preferences in response to changes in water status. For example, plants grown under drought stress can have greater nitrogen (Mattson *et al.* 1987) and carbon concentrations and generally have reduced water contents. However, the effects of water stress on plant chemistry are not always linear nor are they always consistent. This is shown in a study by English-loeb et. al (1997) where total plant nitrogen in tomatoes increased with drought stress in one experiment but was unaffected in another. Similarly, Gutbrodt *et al.* (2011) found inconsistent responses of plant nitrogen to drought. The timing and intensity of water stress can also affect insect herbivores. While a continuous water stress has been thought to increase pests, intermediate water stress

may cause increases in plant nitrogen which favor the proliferation of sap feeding herbivorous insects (Huberty and Denno 2004). The intensity of water stress can also affect plant defenses. For example, carbohydrates used for defenses were found to accumulate at mild drought stress due to reduced growth rates whilst photosynthetic processes are maintained but decrease at severe drought stress (English-loeb *et al.* 1997). For most plant species, information on the effects of water stress on plant chemistry are lacking entirely, and field studies observing the effects of deficit irrigation on insect communities are rare (Huberty & Denno 2004). Previous studies on effects of drought on insect herbivory have in common that the focus is on certain herbivore groups under a single drought treatment. Often plants or leaf extracts are used to test for larval development or feeding preferences rather than analyzing naturally occurring insect communities in water-stressed and unstressed plants in the field directly.

This study assesses the effects of deficit irrigation on insect communities and yield in three on-farm experiments with mature green tomato varieties that were grown under different levels of water deficit. Specific objectives were: 1) To determine if insect community composition or individual groups varied with deficit irrigation treatment; 2) To determine if deficit irrigation influenced fruit yield, plant nutrients (C and N, stable isotopes ^{13}C and ^{15}N) and physiological traits (plant relative water content, CTD) and 3) To determine if insect abundances co-varied with any of the plant characteristics measured.

The outcome of our study may further our ability to predict whether some herbivores may be more problematic in dry years than others. This predictability would facilitate integrated pest management on Californian farms facing periods of drought.

Materials and methods

Site 1: Le Grand

Site description

The on-farm experiment was conducted on Live Oak Farms in Le Grand, California, USA (37°11'24.24"N, 120°17'02.11"W) during the 2016 growing season, in a field of 10 acres (4 ha). The soil

series was mapped as a Madera loam and is classified as a Fine, smectitic, thermic Abruptic Durixeralfs (Soil Survey Staff, Natural Resources Conservation Service, 2003) with pH. Labile carbon (POX) was taken at three depths (0-15, 15-45, and 45-75 cm) and measured to be 265.6, 263.5, and 219.5 mg C kg^{-1}, respectively. Particle size analysis showed 41.7% sand, 56.5% silt, and 1.8% clay, and was thus a silt loam soil. Total soil C and N were x and x. The mean nitrate and ammonium concentrations were 52.3 and 3 μg N g^{-1} soil in the 0-6 inch (0-15 cm) layer, 33.3 and 0.9 μg N g^{-1} soil in the 6-18 inch (15-45 cm) layer, and 19 and 0.4 μg N g^{-1} soil in the 18-30 inch (45-75 cm) layer (mean of pretreatment and harvest measurement).

From 5/23/16 to 8/10/16 (transplanting and harvest, respectively), mean temperatures were 93.6°F or 34.2°C (maximum) and 55.6°F or 13.1°C (minimum), with a maximum of 104°F or 40°C and minimum of 47°F or 8.3°C (University of California Agriculture and Natural Resources, 2016), based on data collected at the #148 Merced, San Joaquin County station. No precipitation events occurred during the length of the field season.

Experimental design

The randomized complete block design had six blocks. Each block consisted of three 60-inch wide beds, 100 ft long. The number of plants in each row was 75, with 16 inch spacing between plants. Water regime was managed at three levels. Control rows were irrigated 4.5-6 hours per day and received approximately x acre-inches or cm of water and the other two treatments rows received 15% or 30% less water. Rows with 15% deficit irrigation were not irrigated on Sundays and received approximately x of water and rows with 30% deficit irrigation were not irrigated Sundays and Mondays and received approximately x of water. Daily reference evapotranspiration (ET_o) was derived from the nearest weather station of the California Irrigation Management Information System (CIMIS) network (~5 mi (~8 km) southeast of the experimental site). The total ET_o for the growing season was 21.1 inches (53.6 cm) (CIMIS, California Department of Water Resources).

Fresh-market tomato cultivar "Valley Cat" was transplanted 5/23/16 and harvested on 8/10/15. Pre-plant irrigation consisted of 3.0 inches (7.5 cm) of sprinkler irrigation, and 1500 gallons $acre^{-1}$ (14031 L ha^{-1}) were also applied at transplanting. Then 6 inches (15 cm) of water was delivered by sprinkler irrigation. The drip tape was in the center of the bed directly below the plants, and was placed at 12 inches (30 cm) depth. Specifications of the drip tape were one emitter per ft and 0.13 gallons $hour^{-1}$ per emitter. The system was typically run for 4 to 6 hours per day.

Irrigation deficit treatments began approximately 6 weeks after transplanting (7/8/16) and continued until harvest. Battery operated valve controllers were installed in each plot by splicing into the buried drip tape approximately 125 ft (38 m) from the end of the field. The controllers were set to turn off water flow only on days when fertilizers were not being applied. For the 30% treatment, the initial cutback of water occurred by eliminating one drip irrigation event once per week (~xx% water reduction), then later to eliminating 2 to 3 events per week to increase plant stress. For the 15% treatment, the cutback was eliminating two (~xx% water reduction), then 3 to 4 events per week. The total amount of water applied in the three treatments was estimated at xx, xx, and xx acre-inches (xx, xx, and xx cm), respectively.

Applied fertilizer consisted of 1000 lbs $acre^{-1}$ (1120 kg N ha^{-1}) of 4-10-10 pre-plant incorporated, followed by 100 gallons $acre^{-1}$ (935 L ha^{-1}) of CAN 17 and 120 gallons $acre^{-1}$ (1122 L ha^{-1}) of KTS (potassium thiosulfate) through the drip system. This amounted to a total of 237 lbs N, 100 lbs P_2O_5, and 466 lbs K_2O $acre^{-1}$ during the entire crop period. There were no differences in the amount of fertilizer applied in the different water treatments. The drip tape had been installed in the spring of 2014, and the field was bedded up in the fall of 2014.

For pest management, Admire and Platinum were applied through the drip system, followed by ground sprays for thrips and worms every two weeks (Radiant and Corrigen, synthetic pyrethroids). Treflan and Dual PPI were applied for weed control. Additional weed management included two post-transplanting mechanical cultivations, and one hand-hoeing pass.

Site 2: Merced station

Site description

The second experiment was conducted at Merced Community College in Merced, California, USA (37°20'37.48"N, 120°28'11.88"W) during the 2016 growing season. The 1-acre (0.40-ha) experimental site was at the agricultural facility on campus. The soil series was mapped as a Marguerite silty clay loam, deep over hardpan, and is a consociation with minor inclusions of Burchell, Wyman, and Yolo series. Regardless of the mapped inclusions, Marguerite is a classified as a fine-loamy, mixed, thermic Typic Xerochrept (Soil Survey Staff, Natural Resources Conservation Service, 2014). pH was determined to be x. Labile carbon (POX) was taken at three depths (0-15, 15-45, and 45-75 cm) and measured to be 296.7, 202.9, and 90.7 mg C kg^{-1}, respectively. Particle size analysis showed 38.6% sand, 57.8% silt, and 3.5% clay, and was thus a silt loam soil. Total soil C and N were x and x. The mean nitrate and ammonium concentrations were 24.5 and 1.2 μg N g^{-1} soil in the 0-6 inch (0-15 cm) layer, 9.8 and 0.3 μg N g^{-1} soil in the 6-18 inch (15-45 cm) layer, and 3.5 and 0.06 μg N g^{-1} soil in the 18-30 inch (45-75 cm) layer (mean of mid season and harvest measurement).

From 6/15/16 to 9/20/16 (transplanting and harvest, respectively), mean temperatures were 93.8°F or 34.3°C (maximum) and 54.8°F or 12.6°C (minimum), with a maximum of 104°F or 40°C and minimum of 24.4°F or 5.6°C (University of California Agriculture and Natural Resources, 2016), based on data collected at the #148 Merced, San Joaquin County station. The only precipitation event >1 mm occurred on 9/18/16 (0.25mm).

Experimental design

The randomized complete block design had four blocks. Each block consisted of four 60-inch wide beds, xx ft long. The number of plants in each row was xx, with xx inch spacing between plants. Water regime was the main plot with four levels (control (x acre-inches or x cm) with 90%, 80%, and 70% of the control treatment's water applied in the three other treatments, respectively). Irrigation scheduling in the control treatment used the same guidelines replacing crop evapotranspiration as described above. Daily

reference ET_o was derived from the same weather station as above. Here, the total for the ET_o for the growing season was 23.66 inches (60 cm) (CIMIS, California Department of Water Resources).

The "Q27" cultivar of fresh-market tomato was transplanted 6/15/16 and harvested 9/20/16. Pre-plant irrigation consisted of xx inches of sprinkler irrigation, and xx was also applied at transplanting. Installation of manifolds and meters for drip irrigation allowed for separate management of each row. The drip tape was in the center of the bed directly below the plants, and was placed at xx inches depth. Specifications of the drip tape were xx emitters/ft and xx gallons $hour^{-1}$ per emitter. Irrigation treatments did not begin until about 6 weeks after transplanting (7/24/15) and continued until harvest. The total amount of water applied in the four treatments was 17.6, 14.7, 13.6, and 10.3 acre-inches respectively.

Fertilizer was applied at which times? What fertilizers? This amounted to a total of xx lbs N $acre^{-1}$ and yy lbs P $acre^{-1}$ (xx kg N ha^{-1} and xx kg P ha^{-1}, respectively) during the entire crop period. There were no differences in the amount of fertilizer applied in the different water treatments.

For pest management, plants were sprayed with xx…. All weed management was done prior to xx date, and included xx post-transplanting mechanical cultivations, and xx hand-hoeing passes. During the experiment, weeds were mainly x.

Site 3: UC Davis station

Site description

The third trial was conducted at Armstrong Ranch at the University of California Davis Plant pathology field station in Davis, California, USA (38°31'21.5"N, 121°45'35.0"W). The experimental site was 0.17 acres in size and the soil was mapped as a 5% Reiff, 5% Sycamore, 5% Brentwood, silty clay loam, Yolo series (https://casoilresource.lawr.ucdavis.edu/gmap/). The soil pH was determined to be . We took soil samples and determined labile carbon (POX) at three depths (0-15, 15-45, and 45-75 cm) which were measured to be x, x, and x mg C kg^{-1}, respectively. Particle size analysis showed 40.2% sand, 55.3% silt, and 4.4% clay, and was thus a silt loam soil. Total soil C and N were x and x. The mean nitrate and ammonium concentrations were 17.6 and 4.3 μg N g^{-1} soil in the 0-6 inch (0-15 cm) layer, 13.7 and 3.4

174 µg N g^{-1} soil in the 6-18 inch (15-45 cm) layer, and 5.2 and 1 µg N g^{-1} soil in the 18-30 inch (45-75 cm)
175 layer (mean of mid season and harvest measurement). For references to soil testing methods, see Bowles
176 et al. (2015).
177 From 6/20/16 to 9/27/16 (transplanting and harvest, respectively), mean temperatures were 91.1°F or
178 32.8°C (maximum) and 55.5°F or 13°C (minimum), with a maximum of 103°F or 39.4°C and minimum
179 of 46°F or 7.8°C (University of California Agriculture and Natural Resources, 2016), based on data
180 collected at the CIMIS #6 Davis.A station. Precipitation occurred on three dates adding up to 1mm during
181 the season.

182 *Experimental design*

183 The randomized complete block design had two blocks. Each block consisted of six 60-inch wide beds,
184 each 40 ft long. Each row had 30 plants approximately 16 inches apart. We had two irrigation treatments,
185 a control and a 30% deficit irrigation treatment. Irrigation was based on replacing crop evapotranspiration
186 as described. Daily reference evapotranspiration (ET_o) was derived from the nearest weather station of the
187 California Irrigation Management Information System (CIMIS) network (proximity to site?). The total for
188 the ET_o for the growing season was 23.34 inches (56.7 cm) (CIMIS, California Department of Water
189 Resources).

190 In this trial we used the fresh-market tomato variety "Q27" which we transplanted 6/20/16 and
191 harvested 9/27/16. Beds were prepared on 4/27/16 and just before transplanting on 6/16/16 beds were
192 reshaped. At planting the site was irrigated with 50gal/row followed by 0.8 inches of precipitation on
193 6/21/16. The amount of water applied to each row could be managed separately and drip tapes were
194 installed in the center of each bed directly below the plants, at 10-12 inches. The drip tape had 1 emitter/ft
195 and an irrigation rate 0.25 gallons $hour^{-1}$ per emitter. Irrigation treatments began 5 weeks after
196 transplanting (7/25/16) and continued until harvest. The total amount of water applied in the control and
197 deficit irrigation treatment was 3.31 and 2.31 acre-inches, respectively.

UAN32 and KTS Fertilizer was applied at 5 dates during the season This amounted to a total of 19 lbs N $acre^{-1}$, 13.8 lbs K $acre^{-1}$ and 11.8 lbs S $acre^{-1}$ (21.3 kg N ha^{-1}, 15.5 kg K ha^{-1} and 13.2 kg N ha^{-1} respectively) during the entire crop period. The amount of applied fertilizer did not differ between irrigation treatments.

Sampling at all three sites

Aboveground biomass

Aboveground biomass was measured once at harvest of the crop. A 10 foot linear transect was chosen within each row, and all plants from this area were cut at the base and all fruit were picked and sorted into different categories. Biomass of all fruits and a subsample of four shoots were weighed in the field (fresh weight) and then shoot subsamples were dried at 60°C and weighed, as was a subsample of marketable fruit. Categories included minis with tomatoes smaller than 2 inches (5.08cm) in diameter, small (S) with tomatoes 2 to 2.25 inches (5.08 to 5.72cm) in diameter, medium (M) with tomatoes 2.25 to 2.5 inches (5.72 to 6.35 cm) in diameter, large (L) with tomatoes 2.5 to 3 inches (6.35 to 7.62 cm) in diameter, and extra-large (XL) with tomatoes 3 inches (7.62 cm) and larger in diameter. Marketable yield included only tomatoes from categories M, L and XL whereas total yield included all harvested fruit including small sizes and culls. Culls included fruit with symptoms of blossom end rot, cat facing, flecking or spotting, mildew, sunburn or worm damage and are described as fraction of the total yield. We further quantified red tomatoes.

Leaf nutrients and water status

For each site we sampled leaves at three dates. Before treatments began (6/17/16, 7/22/16 and 7/19/16 for Le Grand, Merced station and UC Davis station respectively), mid of the season (7/21/16, 8/9/16 and 8/16/16) and at harvest (8/10/16, 9/20/16 and 9/27/16). Three fully expanded leaflets, from the top of the canopy, were collected per plot for analysis of relative water content (RWC), total C, total N and $\delta^{13}C$.

Leaf RWC was calculated for all dates according to (Turner, 1986). Briefly, leaf samples were weighed fresh from the field and rehydrated overnight in double-distilled (dd) H_2O at 4 °C. Then the leaves were re-weighed before being oven dried for 48 h at 60 °C, weighed again, and the relative difference in water content calculated.

Canopy temperature depression (CTD) was measured on up to five dates during the season for all sites. Measurements were taken in the field using a dual laser video infrared thermometer (model VIR50, Omega Engineering Inc., Stamford, CT, USA).

Soil sampling

For each site the soil was sampled before the beginning of deficit irrigation treatments, mid of the growing season and at harvest at three depths: the 0-6 inch (0-15 cm) layer, the 6-18 inch (15-45 cm) layer, and the 18-30 inch (45-75 cm) layer. Two 2.5-inch (6.3 cm) diameter soil cores per plot were taken approximately 12 inches (30 cm) from the plant row and composited. At the Merced station trial the sample from the 18-30 inch layer could not be taken at the last sampling date because the soil was too compacted. Gravimetric water content (GWC) was measured on all samples by drying a subsample at 70°C for a minimum of 72 hours.

Inorganic N was measured on fresh soil samples using 2 M KCl extraction of 40 g soil and colorimetric analysis of nitrate and ammonium (Keeney and Nelson, 1982).

Soil particle sizes of soil samples from each plot in each site were determined by laser diffraction on a Beckman-Coulter LS-230 Particle Size Analyzer (Eshel et al. 2004).

A subsample of ground soil from all plots and sites was analyzed for labile carbon (POXC) following Culman et al. (2012). Briefly, triplicate samples of 2.50 g soil were oxidized with 0.02 mol l^{-1} $KMnO_4$ with 2 min shaking followed by 10 min incubation and non-reduced Mn^{7+} quantified by colorimetry. Further dried soil samples were analyzed for total N and C content on a Europe Hydra 20/20 isotope ratio mass spectrometer (Crewe, UK) at the University of California Davis Stable Isotope Facility.

246 *Herbivore surveys*

247 Two plants from each plot were randomly selected and surveyed on one side of the field row.
248 Insects that fell into collection containers from leaves, stems or near the canopy after shaking stems for
249 one minute were counted and identified under a microscope. At each date we collected flowers that were
250 scored for thrip damage and installed sticky traps in each row and counted and identified captured insect
251 communities after they have remained in the field for one week.

252 ## *Statistical analysis*

253 We tested for effects of deficit irrigation on gravimetric soil moisture, leaf nutrients, rwc, CTD
254 and aboveground biomass and fruit yield using ANOVA (aov function of R 3.2.2; http://www.r-
255 project.org). The data was analyzed for each sampling date and models contained irrigation treatment and
256 soil depth if testing for effects at different soil layers. We accounted for experimental blocks as error and
257 data were log transformed if necessary to meet requirements of normal and homoscedastic residual
258 distribution. For multilevel comparisons we used Tukey's range test (TukeyHSD function).

259 # Results

260 ## *Soil properties, crop yield and leaf nutrients*

261 *Le Grand*

262 Gravimetric soil moisture at Le Grand changed over time and was affected by the irrigation
263 treatment. Deficit irrigation reduced soil moisture at 15-45 cm depth ($P = 0.06$, $F_{2,14} = 11.08$) and also at
264 45-75 cm depth interval ($P = 0.001$, $F_{2,14} = 11.08$) compared to plots irrigated according to grower
265 standards (Fig. 1). Gravimetric soil moisture increased significantly with soil depth for all three irrigation
266 regimes. Further, soil water was lower at harvest in August compared to June ($P < 0.01$, $F_{1,88} = 118.94$)
267 before irrigation treatments were implemented illustrating the depletion of soil water during the growing
268 season.

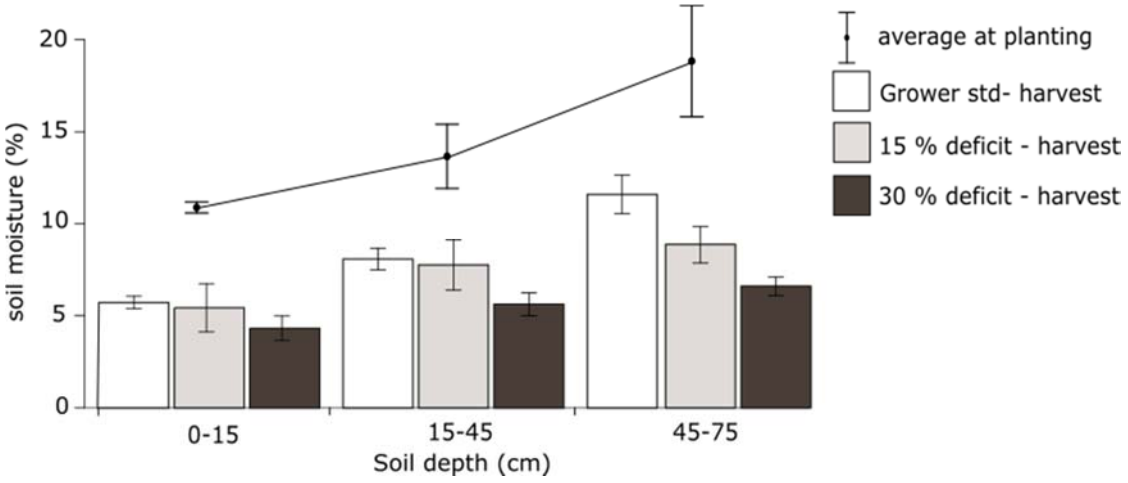


Figure 1. Gravimetric soil moisture at Le Grand measured at three depths before planting and at harvest. Bars illustrate mean values for each irrigation treatment and error bars show standard error of the mean.

Soil ammonium and nitrate decreased significantly with depth measured at planting ($P < 0.01$, $F_{2,43}$=13.56, $P < 0.01$, $F_{2,43} = 25.47$) and at harvest ($P < 0.01$, $F_{2,43} = 19.7$, $P < 0.01$, $F_{2,43} = 18.73$). At harvest, there were no differences in soil ammonium or nitrate content between deficit irrigated and control plots (Fig. 2).

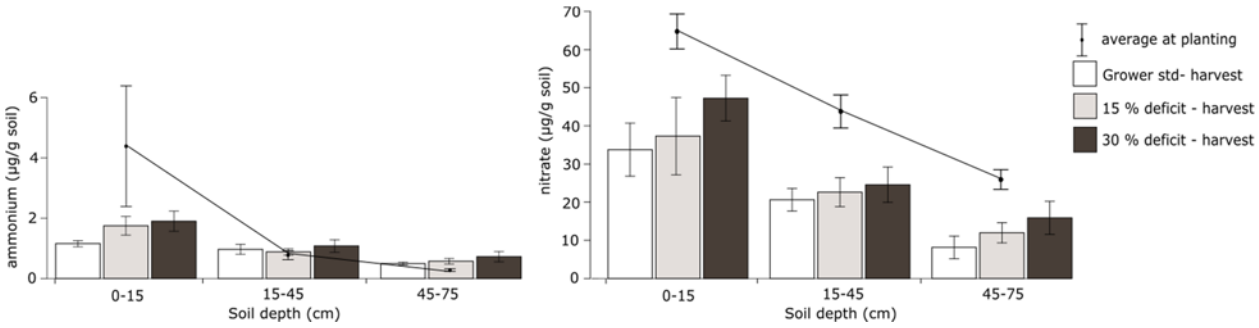


Figure 2. Soil ammonium and nitrate at Le Grand measured at three depths before planting and at harvest. Bars illustrate mean values for each irrigation treatment and error bars show standard error of the mean.

Total yield (Marketable fruit yield (sizes M, L, XL)) tended to be lower in rows with 15% deficit irrigation ($P = 0.06$, $F_{1,9} = 4.4$) and was significantly lower in 30% deficit irrigated rows compared to standard irrigation ($P = 0.01$, $F_{1,9} = 9.8$) (Table 1). Similarly, aboveground biomass harvested from rows with 30% deficit irrigation was significantly lower compared to rows with standard irrigation ($P = 0.02$, $F_{1,9} = 8.6$) but not affected by an irrigation reduction of 15%. Deficit irrigated plots had relatively more

red tomatoes than standard irrigated plots for both the 15 % deficit ($P = 0.02$, $F_{1,9} = 7.4$) and 30% deficit ($P = 0.07$, $F_{1,9} = 4.0$) and fruit with sunburn symptoms ($P = 0.06$, $F_{1,9} = 4.6$) and small sized tomatoes ($P = 0.03$, $F_{1,9} = 7.1$) tended to me more with 30% deficit irrigation. The relative amount of culls harvested from rows was not affected by deficit irrigation, though (Table 1).

*Table 1. Yield components at all three sites and for each irrigation treatment. Values show mean and standard errors. (*) = P < 0.1, * = P < 0.05.*

					Culls (% of Total yield)			
Site	**Irrigation treatment**	**Total yield (kg/ha)**	**TMY (kg/ha)**	**WUE**	**Total Culls**	**Too small**	**Sunburn**	**Reds**
Le Grand	Grower std	117418 ± 9326	75011 ± 5582		17 ± 1.7	18.9 ± 2.1	0.8 ± 0.2	0.6 ± 0.3
	15% deficit	94522 ± 7957	55752 ± 7694		16.1 ± 1.7	26.1 ± 3.4	1.1 ± 0.6	2.3 ± 0.5
	30 %deficit	73215 ± 11451 *	41059 ± 10321 *		15.1 ± 1.4	33 ± 5.6 (*)	2.4 ± 0.7 (*)	2.9 ± 0.9 *
Merced station	Grower std	69722 ± 11878	30278 ± 7747		82.3 ± 9.1	38.1 ± 6.8	0.2 ± 0.2	24.1 ± 6
	10% deficit	68833 ± 3062	26333 ± 1541		92 ± 3.1	49.7 ± 0.9	1.1 ± 0.3	30.3 ± 3.9
	20% deficit	57528 ± 5904	24278 ± 1684		89.2 ± 7.2	43.4 ± 4	1 ± 0.5	32.1 ± 6.8
	30% deficit	62500 ± 12608	21333 ± 5181		95.5 ± 3.6	51 ± 2.2	1.1 ± 0.4	28.5 ± 5.6
UC Davis station	Grower std	63074 ± 3276	41222 ± 3351		68.9 ± 2.7	17.4 ± 1.4	0.2 ± 0.2	33.8 ± 4
	30% deficit	68630 ± 10047	46037 ± 7623		58.7 ± 1.4 *	15.1 ± 2	0.2 ± 0.2	25 ± 1.6 (*)

Deficit irrigation treatments at Le Grand affected indicators of leaf water status such as leaf relative water content, CTD and $\delta^{13}C$. Leaf relative water contents (rwc) at harvest were significantly reduced in plants that had grown under deficit irrigation ($P = 0.05$, $F_{2,14}$=3.8, THSD 30%def: 0.05, 15%def: 0.08) (Table 2a). Plants that were irrigated with 30% or 15% less water had lower leaf rwc (70.1% and 70.9% respectively) compared to plants watered according to grower standard (78.2%). Mean canopy temperature depression across all sampling dates also tended to be lower in rows that were irrigated with 30% deficit irrigation compared to rows with standard irrigation ($P = 0.09$, $F_{1,5} = 4.3$, KW: $P = 0.05$). Canopy temperatures were 9.1, 8.1 and 7.3-degree Celsius cooler than atmospheric temperature in standard irrigated, 15% deficit and 30% deficit irrigated rows, respectively.

Leaflet $\delta^{13}C$ values from plants grown under 15% ($P = 0.02$, $F_{1,9} = 8.3$) and 30% ($P < 0.01$, $F_{1,9} = 21.7$) deficit irrigation were significantly less negative at harvest compared to standard irrigated plants indicating greater water use efficiency with deficit irrigation (Table 2a). As the season progressed, $\delta^{13}C$ increased over time ($P < 0.001$, $F_{2,44} = 69.0$), along with leaflet C contents ($P < 0.001$, $F_{2,44} = 69.3$), while

304 leaflet N contents decreased ($P < 0.001$, $F_{2,44} = 144.4$). However, deficit treatments, directly, had no effect
305 on Leaf C or N contents.

306 *Table 2. Leaf traits of plants at a) Le Grand b) Merced station and c) UC Davis station at three sampling dates and for each*
307 *irrigation treatment. Values show mean and standard errors. (*) = P < 0.1, * = P < 0.05.*

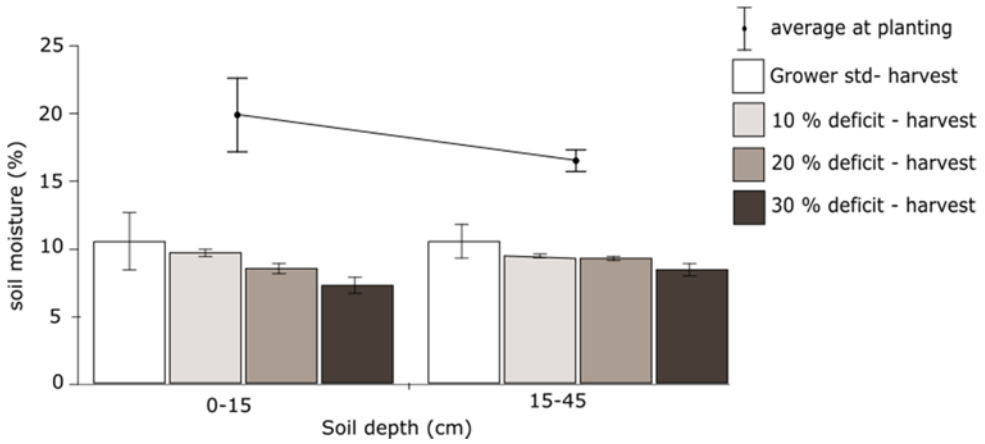
a) Le Grand

Date	Irrigation treatment	rwc	C	N	δ13C	δ15N
Planting	Grower std	85.1 ± 3.2	38.9 ± 0.3	5.2 ± 0.1	-28.7 ± 0.1	1.5 ± 0.3
	15% deficit	84.3 ± 2.1	38.7 ± 0.3	5.2 ± 0.1	-28.9 ± 0.2	1.9 ± 0.2
	30% deficit	85.7 ± 2.4	38.7 ± 0.3	5.2 ± 0.1	-28.8 ± 0.2	1.7 ± 0.3
Midseason	Grower std	70.6 ± 4.0	40.4 ± 0.5	4.4 ± 0.1	-27.9 ± 0.2	3.6 ± 0.3
	15% deficit	69.9 ± 2.4	40.5 ± 0.2	4.2 ± 0.2	-27.6 ± 0.2	3.2 ± 0.3
	30% deficit	69.3 ± 1.2	40.2 ± 0.5	4.2 ± 0.1	-27.5 ± 0.2	2.8 ± 0.2
Harvest	Grower std	78.2 ± 3.4	42.2 ± 0.3	3.4 ± 0.2	-27.6 ± 0.1	3.3 ± 0.2
	15% deficit	70.9 ± 1.1 (*)	41.9 ± 0.2	3.5 ± 0.1	-27.1 ± 0.2 *	3.2 ± 0.2
	30% deficit	70.1 ± 1.3 *	42.0 ± 0.2	3.6 ± 0.1	-26.9 ± 0.1 *	3.5 ± 0.2

308

309 *Merced station*

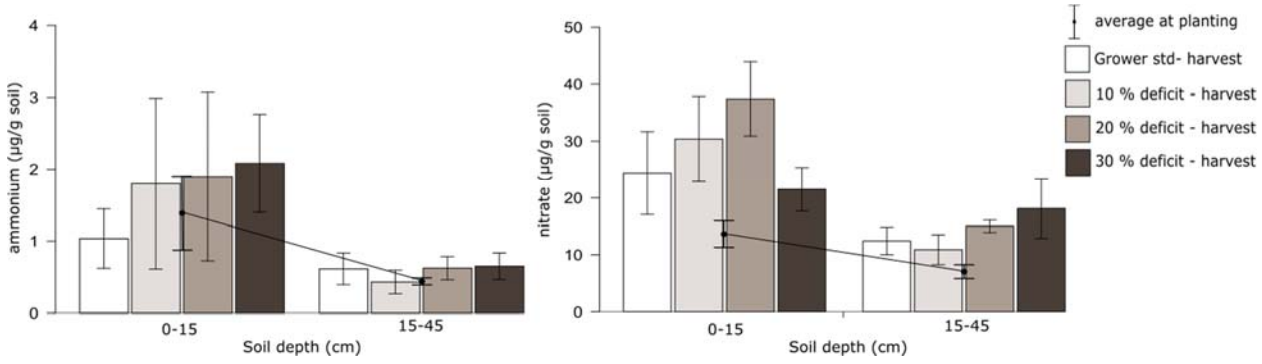
310 At Merced station, soil factors varied with sampling depth and changed over time, although only
311 soil moisture was affected by the irrigation treatment. Gravimetric soil moisture at harvest tended to be
312 lower with deficit irrigation in the top soil layer (0-15 cm) compared with plots with grower standard
313 irrigation (Kruskal $P = 0.09$, n.s. with Anova incl block error) but soil moisture was not affected by the
314 irrigation treatment in the 15-45cm deep soil layer (Fig. 3). At harvest, soil moisture did not change with
315 soil depth. Soil water was depleted over the season with significantly greater gravimetric soil moisture on
316 7/22/17 than at harvest on 9/20/17 ($P < 0.01$, $F_{1,59} = 113.5$).



317

318 *Figure 3. Gravimetric soil moisture at Merced station measured at two depths before planting and at harvest. Bars illustrate*
319 *mean values for each irrigation treatment and error bars show standard error of the mean.*

320 Soil ammonium and nitrate decreased significantly with depth at planting ($P < 0.01$, $F_{1,22}$=8.43, P
321 = 0.07, $F_{1,23}$ = 3.6) and at harvest (P = 0.01, $F_{1,23}$=8.0, $P < 0.01$, $F_{1,23}$ = 14.3) (Fig. 4). Both soil ammonium
322 and nitrate were unaffected by the irrigation treatment.



323

324 *Figure 4. Soil ammonium and nitrate at Merced station measured at two depths before planting and at harvest. Bars illustrate*
325 *mean values for each irrigation treatment and error bars show standard error of the mean.*

326 The total yield and amount of marketable fruit harvested from rows were not affected by the
327 deficit irrigation treatment (Table 1). Aboveground biomass was unaffected by irrigation treatment and
328 there were no differences in culls harvested from differently irrigated rows.

329 At Merced station, leaf rwc at harvest tended to be lower in plants with 30 % deficit irrigation
330 compared to plants from plots with control irrigation (P = 0.08, $F_{1,5}$ = 4.8) and 10% deficit irrigated plots
331 (P = 0.06, $F_{1,5}$ = 5.8) (Table 2b). Average rwc was 77.6% in control plants, 79.4% in 10% deficit

irrigated plants and 67.5% in plants with 30% deficit irrigation. Canopy temperature depression was unaffected by the irrigation treatment at all measurement dates.

Leaflet C contents increased significantly over time ($P < 0.001$, $F_{2,35} = 47.6$) while leaflet N contents decreased ($P < 0.001$, $F_{2,35} = 109.8$). Both C and N concentrations in leaves were unaffected by the irrigation treatment at all dates (Table 2b).

Table 3. Leaf traits of plants at a) Le Grand b) Merced station and c) UC Davis station at three sampling dates and for each irrigation treatment. Values show mean and standard errors. (*) = P < 0.1, * = P < 0.05.

b) Merced station

Date	Irrigation Treatment	rwc	C	N	δ13C	δ15N
Planting	Grower std	75.8 ± 2.1	39.3 ± 0.3	5.1 ± 0.1	-29.4 ± 0.1	5.6 ± 0.6
	10% deficit	82.6 ± 4.1	39.3 ± 0.2	4.7 ± 0.1	-28.9 ± 0.3	3.6 ± 0.2
	20% deficit	82.5 ± 1.6	38.2 ± 1.0	4.8 ± 0.1	-29.0 ± 0.1	4.1 ± 0.1
	30% deficit	80.7 ± 2.0	39.4 ± 0.3	5.0 ±0.1	-28.6 ± 0.1	3.8 ± 0.5
Midseason	Grower std	78.9 ± 2.0	41.8 ± 0.1	4.6 ± 0.1	-28.9 ± 0.2	2.4 ± 0.7
	10% deficit	77.6 ± 1.2	42.1 ± 0.2	4.7 ± 0.1	-28.6 ± 0.1	1.0 ± 0.4
	20% deficit	75.7 ± 1.7	42.1 ± 0.1	4.7 ± 0.1	-28.9 ± 0.2	2.4 ± 0.4
	30% deficit	78.2 ± 0.9	41.8 ± 0.2	4.8 ± 0.1	-28.8 ± 0.2	1.1 ± 0.3
Harvest	Grower std	77.6 ± 2.4	40.9 ± 0.5	3.9 ± 0.1	-27.9 ± 0.1	0.2 ± 0.5
	10% deficit	79.4 ± 2.8	41.2 ±0.3	3.6 ± 0.2	-28.0 ± 0.1	-0.3 ± 0.7
	20% deficit	76.6 ± 1.7	40.8 ± 0.4	3.5 ± 0.1	-27.7 ± 0.3	-0.9 ± 0.4
	30% deficit	67.5 ± 3.6 (*)	41.2 ± 0.4	3.8 ± 0.1	-27.8 ± 0.3	-0.1 ± 0.4

UC Davis station

Gravimetric soil moisture at the UC Davis station trial tended to be lower with deficit irrigation in the top soil layer compared with plots irrigated according to grower standard ($P = 0.05$, $F_{1,9} = 5.1$) but deeper soil layers were not affected by the irrigation treatment (Fig. 5). Soil moisture at harvest increased significantly with depth ($P < 0.01$, $F_{2,29} = 35.9$). In contrast to the other two sites soil moisture at the UC Davis station trial was not significantly different between early season and harvest.

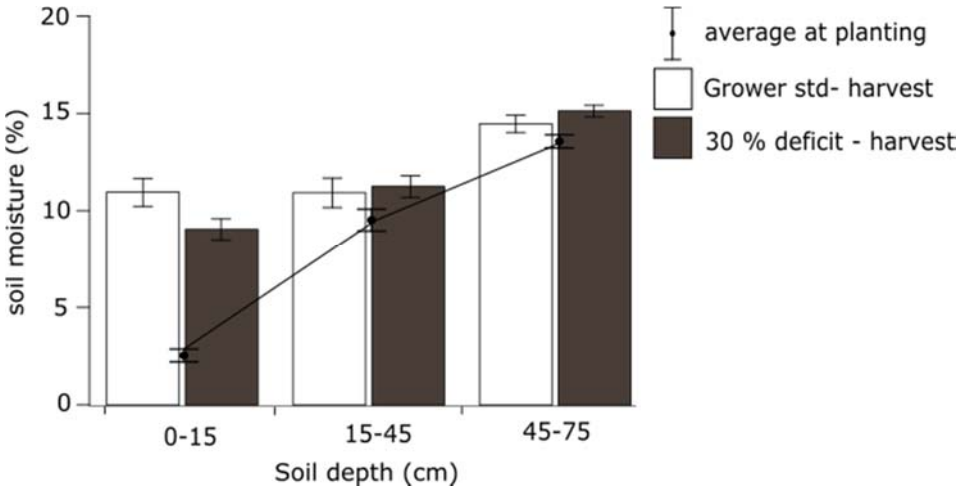


Figure 5. Gravimetric soil moisture at UC Davis station measured at three depths before planting and at harvest. Bars illustrate mean values for each irrigation treatment and error bars show standard error of the mean.

Soil ammonium was significantly depleted over the season ($P < 0.01$, $F_{2,88} = 33.2$) and decreased significantly with depth measured at planting ($P < 0.01$, $F_{2,30} = 70.0$) but remained stable across depths at harvest (Fig. 6). Soil nitrate decreased with depth at planting ($P < 0.01$, $F_{2,28} = 46.3$) and harvest ($P < 0.01$, $F_{2,29} = 24.6$). At harvest, there were no differences in soil ammonium or nitrate content between deficit irrigated and control plots.

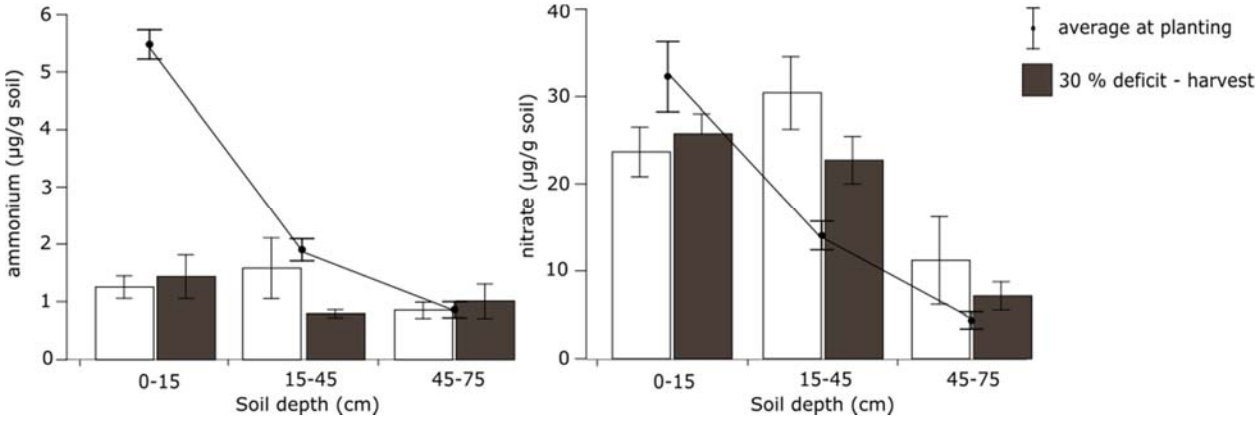


Figure 6. Soil ammonium and nitrate at UC Davis station measured at three depths before planting and at harvest. Bars illustrate mean values for each irrigation treatment and error bars show standard error of the mean.

At the UC Davis station trial total yield as well as marketable yield and aboveground biomass were not affected by deficit irrigation (Table 1). However, the amount of culls relative to the total yield was significantly reduced with deficit irrigation ($P = 0.01$, $F_{1,9} = 9.97$) and, in contrast to Le Grand, there tended to be less red tomatoes in plots with deficit irrigation ($P = 0.08$, $F_{1,9} = 3.78$).

At UC Davis station deficit irrigation had no effect on leaf rwc or CTD. Further leaflet δ13C, leaf C and N concentrations were unaffected by the irrigation treatment (Table 2c). Leaf N concentrations decreased over time ($P < 0.001$, $F_{2,29} = 36.3$) although leaf N concentrations increased between midseason and harvest.

*Table 4. Leaf traits of plants at a) Le Grand b) Merced station and c) UC Davis station at three sampling dates and for each irrigation treatment. Values show mean and standard errors. (*) = P < 0.1, * = P < 0.05.*

c) UC Davis station

Date	Irrigation treatment	rwc	C	N	δ13C	δ15N
Planting	Grower std	77.7 ± 1.0	39.0 ± 0.2	4.1 ± 0.2	28.3 ± 0.2	3.0 ± 0.3
	30 % deficit	79.5 ± 0.6	39.0 ± 0.3	4.5 ± 0.1	-28.4 ± 0.2	3.4 ± 0.2
Midseason	Grower std	80.0 ± 0.7	39.1 ± 0.2	3.2 ± 0.2	-29.2 ± 0.1	3.4 ± 0.4
	30 % deficit	80.6 ± 0.8	39.3 ± 0.1	3.0 ± 0.2	29.2 ± 0.1	3.3 ± 0.2
Harvest	Grower std	78.4 ± 1.2	39.6 ± 0.1	3.8 ± 0.1	-28.4 ± 0.2	1.6 ± 0.3
	30 % deficit	77.8 ± 0.6	39.6 ± 0.3	3.8 ± 0.1	-28.1 ± 0.1	1.4 ± 0.2

Discussion

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398

β-Glucosidase Engineering for the Degradation of Oleuropein

Introduction

There is current industrial need to replace the lye-curing process that is used by the California table olive industry to de-bitter olives. The current process is undesirable because it uses copious amounts of water, generates caustic, toxic waste, and destroys nutritional content of the olive.(ref) Use of enzyme processing in place of lye would greatly mitigate these unwanted side effects. Specific degradation of the compound oleuropein, which is primarily responsible for bitterness,(ref) would accomplish the goal of de-bittering the olive while retaining the nutritional content of the fruit. Furthermore, using an enzyme in place of lye will greatly reduce the amount of water used and render the wastewater non-toxic.

Endogenous olive β-glucosidases and esterases contained in the fruit are known to degrade oleuropein when the fruit is damaged or when it starts to ripen.(ref1) The purported reactions that take place are shown in **Figure 1** (could occur in either order), wherein a β-glucosidase cleaves the sugar moiety, resulting in oleuropein aglycone and glucose; oleuropein aglycone is hydrolyzed to the non-bitter elenolic acid and hydroxytyrosol via esterase cleavage.(ref)

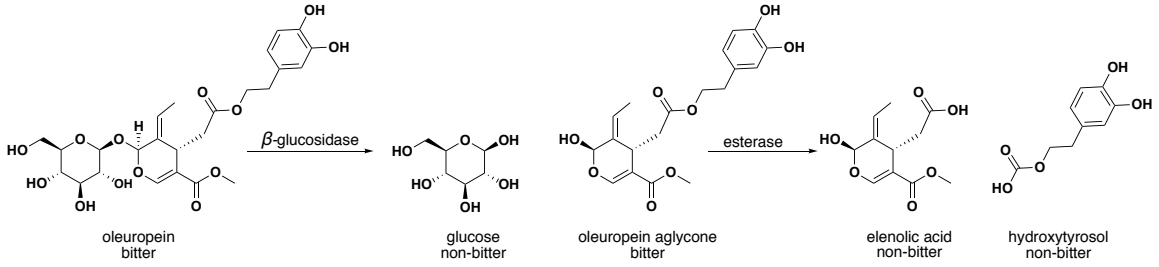


Figure 1. Oleuropein is converted to the non-bitter glucose, elenolic acid, and hydroxytyrosol via endogenous β-glucosidases and esterases.

The need for industrial oleuropein processing remains, due to the latent and incomplete degradation from the naturally occurring reaction sequence.(ref) Therefore, we hypothesized that enzyme treatment introduced during olive processing in place of lye, could degrade oleuropein specifically, while retaining other nutritional content in the fruit that would otherwise be destroyed. Using an enzyme to de-bitter olives is not a novel idea and has been considered,(ref) however, there is no precedence of an enzyme being developed for this substrate and application specifically. Furthermore, there is need for improvement upon enzyme efficiency and thermostability of current candidates,(ref) which can be accomplished through engineering a thermostable enzyme. This would both speed up the processing event and prevent denaturing of the enzyme during some of the less than ideal processing conditions (pH and temperature variations). In this work, we identify an enzyme capable of complete degradation of oleuropein to its non-bitter components and perform computationally guided engineering to improve efficiency.

Results and Discussion

Inspired by the natural degradation pathway, we chose to select a panel of enzymes from the β-glucosidase enzyme class (E.C. 3.2.1.21) for initial oleuropein degradation screening. The chemistry performed by this enzyme class consists of cleavage of a terminal, non-reducing, β-D-glucosyl residue with the release of β-D-glucose from a wide variety β-D-glucosides(ref) (i.e. oleuropein). Twenty-two β-glucosidases were chosen from a pool of 177 family 1 glycosyl hydrolases (GH1's) gifted by the Joint Genome Institute (GH1's are characterized based on their canonical eight-fold α/β barrel motif).(ref) This panel was chosen based on β-glucosidase activity on cellobiose and soluble expression levels in *Escherichia coli* according to experimental data provided by JGI. **Figure 2a** depicts the phylogenetic tree that was built based on sequence similarity containing all 177 GH1's in the pool. The 22 β-glucosidases that were tested are indicated on the tree and have a pairwise sequence identity of 32%. Of the 22, eight enzymes (**Figure 2a-b** indicated in green, having a pairwise sequence identity of 41%) were found to degrade oleuropein to hydroxytyrosol in significant amounts (>50 μM hydroxytyrosol formation by high performance liquid chromatography analysis) after a 24 hour, room temperature incubation. Surprisingly, the oleuropein aglycone, formed in situ following glycosyl cleavage, spontaneously degrades to hydroxytyrosol without the need of further treatment with an esterase.

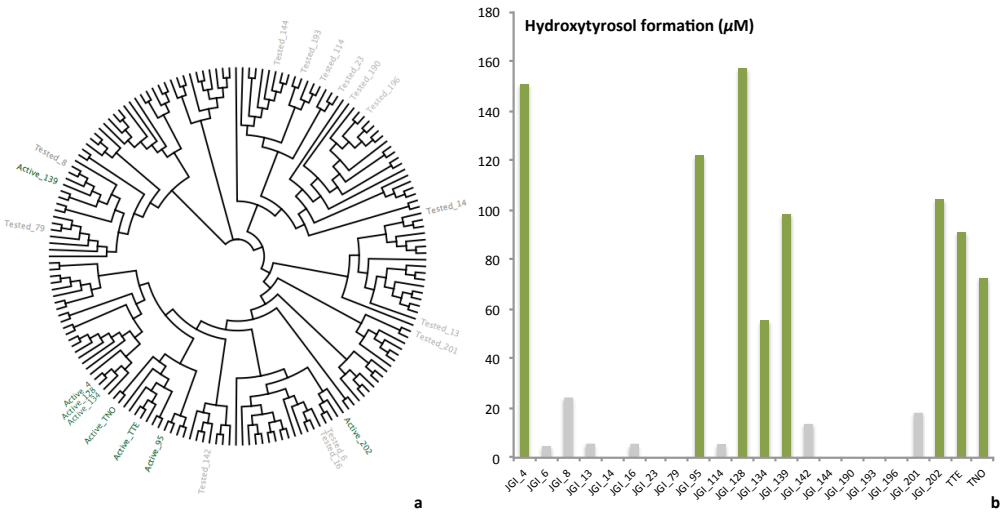


Figure 2a. Phylogenetic tree based on sequence similarity indicating 22 GH1's tested. **2b.** Specific activity shown by hydroxytyrosol formation. The eight β-glucosidases showing significant activity are highlighted in green (forming >50 μM hydroxytyrosol after 24 hour incubation at room temperature).

Following the initial screening, a time-point study of these eight candidates was conducted in order to identify the enzymes that produced hydroxytyrosol from oleuropein at a relatively faster rate. **Figure 3a** shows the production of hydroxytyrosol at three time points (2, 6, and 24 hrs) for each selected candidate. It is also important to note that hydroxytyrosol, once cleaved from oleuropein, degrades over time, most likely due to

oxidation and further polymerization of the catechol moiety[(ref)] (see **Figure 3a** product standard series). Based on this time-point study and also considering availability of structural data (facilitating the modeling process), the *β*-glucosidase from *Streptomyces sp.* (labeled JGI 4) was chosen as a starting point for engineering (PDB accession code 1GNX, uniprotKB AC Q59976) which degraded 84% of oleuropein in 24 hours.

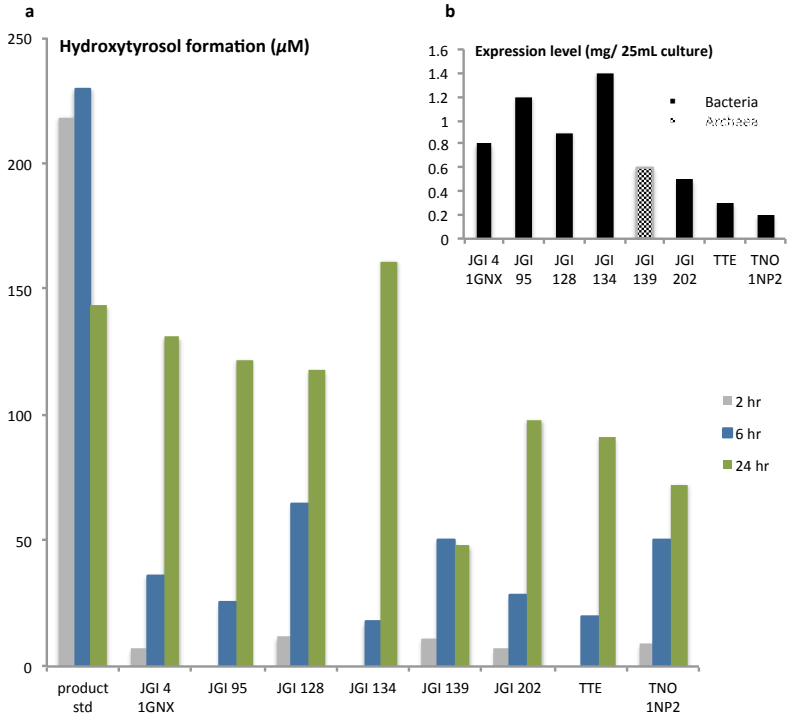


Figure 3a. Time-point study of hydroxytyrosol formation (*μ*M; PDB accession codes are indicated below enzyme label if structural information is available). Product standard data shows hydroxytyrosol degradation over time. **3b.** Indicates expression level of candidates chosen for time-point study and also kingdom of gene source.

Following this lead candidate, computational modeling was performed using the Rosetta Molecular Modeling Suite to guide our engineering efforts to enhance activity of this enzyme. The catalytic triad of 1GNX was identified by aligning the crystal structure with another *β*-glucosidase, PDB 2JIE (BglB), which is in complex with a covalently bound inhibitor (2-deoxy-2-fluoro-*α*-D-glucopyranose) and has catalytic residues elucidated.[(ref)] The oleuropein ligand was constrained in the active site according to known *β*-glucosidase chemistry.[(ref)] The purported catalytic mechanism performed on oleuropein is show in **Figure 4a** and is initiated as GLU353 nucleophilically attacks the anomeric carbon of the *β*-D-glucosyl residue, displacing the oleuropein aglycone in an S_N2 fashion. GLU164 works as an acid/base conduit, protonating the leaving group (oleuropein aglycone) and subsequently deprotonating a water molecule, creating a hydroxide nucleophile that displaces GLU353 and releases *β*-D-glucose with retention of stereochemistry. TYR295 is thought to orient the nucleophilic GLU353 and pre-organize the active site for attack.[(ref)] Conformers of oleuropein, containing a transition state-like geometry at the anomeric carbon of the rate-limiting initial S_N2 attack, were built and minimized using Spartan. This conformational library was then used in Rosetta's docking

and design protocol with functional constraints defined. The electrophilic carbon was constrained as the center of a trigonal bipyramidal geometry wherein the attacking and leaving group oxygen atoms would be placed at the two apexes, giving an angle between these three atoms of 180^0 ($O_{nucleophile}$–$C_{electrophile}$–$O_{leaving}$: 180^0). The constraints were further defined to include distances, angles, and dihedrals between the catalytic residues and the oleuropein substrate and also between catalytic residues in an intramolecular fashion (detailed constraint and modeling files are included in supplementary information). **Figure 4b** shows an example of one Rosetta result docking oleuropein in the active site with constraints implemented.

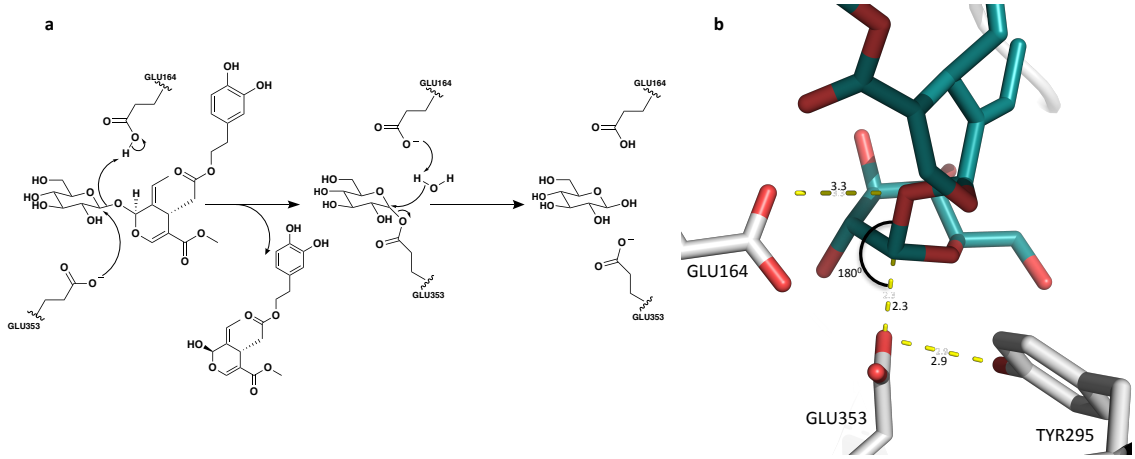


Figure 4a. Mechanistic depiction of the hydrolysis of oleuropein to oleuropein aglycone and *β*-D-glucose showing the catalytic roles of GLU353 and GLU164. **4b.** Example of a docking result with functional constraints implemented. The distances are shown in Å**.**

The results from Rosetta's design protocol were filtered based on Rosetta's energy output and constraint scores. The top 20 designs with the lowest Rosetta energy and constraint scores were visually inspected in order to discard mutations that did not appear to be chemically sound (i.e. those that did not seem to improve hydrophobic, electrostatic, or hydrogen bonding interactions or remove steric clashing). Eleven mutants (each with 1-2 mutations) were chosen, constructed, and tested for oleuropein degradation activity using the HPLC assay mentioned above. A time course study showing specific activity of each mutant at three time points is shown in **Figure 5a**. Through this, one mutant showed enhanced activity, degrading oleuropein about twice as fast as the wild type. **Figure 5b** depicts the HPLC trace showing this improvement.

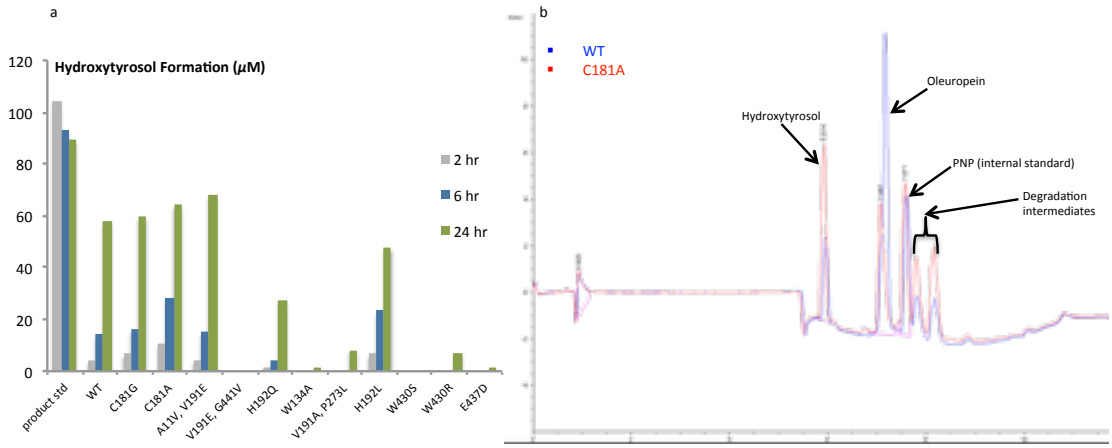
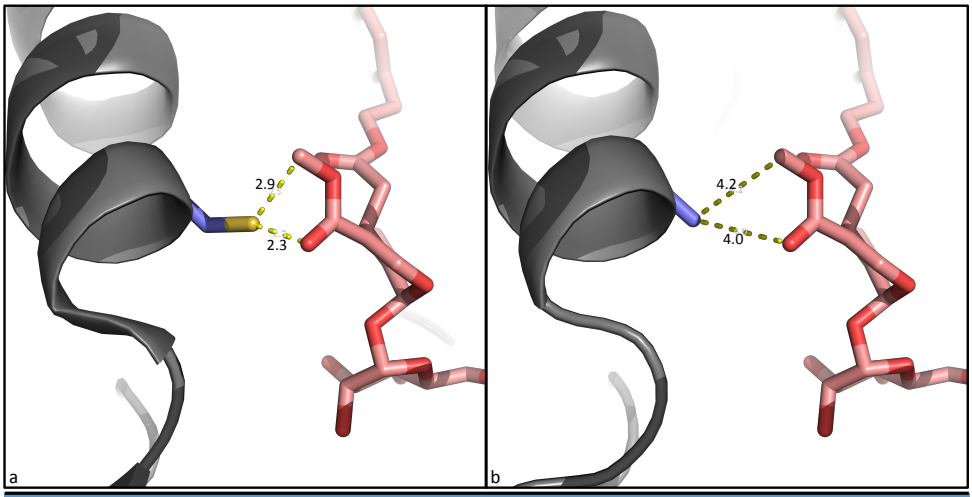


Figure 5a. Specific activity of wild type and mutant activity over time. **5b.** HPLC trace overlay of the product profiles of wild type and C181A at six hours showing a two-fold increase in product formation with mutant C181A.

This new enzyme has one cysteine to alanine mutation at amino acid position 181 and is depicted in **Figure 6b** in comparison to the wild-type (**6a**). Kinetic analysis was performed on both the wild-type and the C181A mutant. Interestingly enough, while k_{cat} was improved by about two-fold with the mutant, the pseudo-binding constant, K_m, increased by about four-fold (**Figure 6c**). This could be due to a loss of hydrogen bonding between cysteine and the carbonyl oxygen of the methyl ester in the substrate according to projected modeling. However, this loss in binding may be the reason the turnover rate has increased by improving the ease of release of product.



c

	Wild type	C181A
K_m(mM)	1.15	5.00
k_{cat}(min^{-1})	0.16	0.44

Figure 6a. Interaction of oleuropein substrate with C181 of wild-type depicting possible hydrogen bond between the thiol and carbonyl oxygen (distances show in Å). **6b**. Interaction of oleuropein with 181A of the mutant showing loss of interaction. **6c**. Kinetic analysis comparing wild-type and C181A mutant.

Figure **7a-c** depicts other examples of mutations made on wild-type 1GNX (**7a**), including H192Q (**7b**) and H192L (**7c**). Modeling suggests a new hydrogen bonding interaction in H192Q between the amide nitrogen and carbonyl oxygen of the hydroxytyrosol moiety of oleuropein, however, this mutant has a lower specific activity compared to wild-type according to the time point study (**Figure 5a**). Kinetic analysis was not performed on this mutant, however, one could speculate that the binding affinity might increase, inhibiting product release (if applying the previous hypothesis when discussing wild-type vs. C181A). Mutant H192L performs better than H192Q, and produces about 1.5x the amount of hydroxytyrosol at the six-hour time point as wild-type, however, does not perform as well at the 24 hour mark.

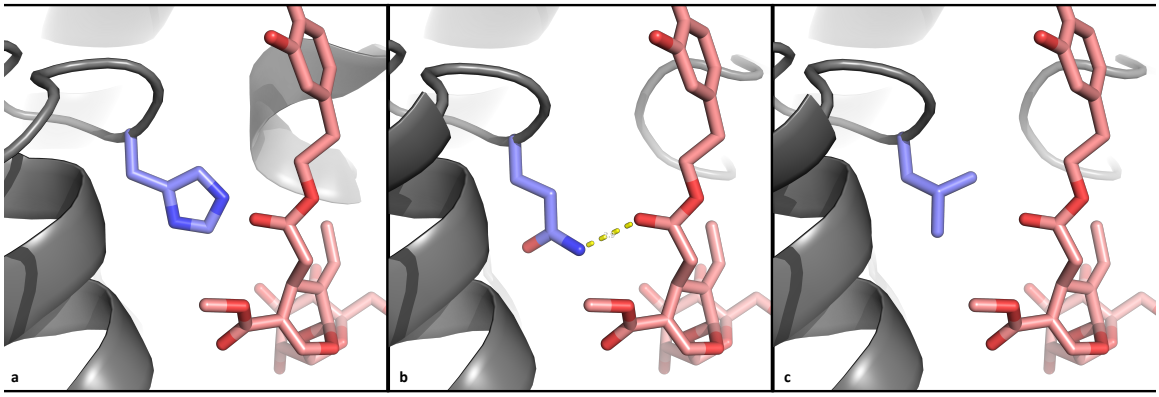


Figure 7a-c. Depicts wild-type, H192Q, and H192L, respectively.

Following these specific and kinetic activity analyses, we chose C181A to be our best candidate for assessing oleuropein degradation activity in olive tea leaf extract and whole ripe olives in order to investigate how our enzyme performs within a vegetative and fruit matrix. (**Data from Selina and Lauren**).

Methods

Mutagenesis and protein expression. The plasmids encoding the 22 *β*-glucosidase enzymes tested were gifted to us from the Joint Genome Institute. The mutant plasmids were constructed using site directed mutagenesis according to the Kunkel protocol.[(ref)] Oligonucleotides that were used in the Kunkel protocol were purchased from Eurofins MWG Operon (Louisville, KY). The mutations were confirmed by DNA sequencing. The wild-type and mutant plasmids were transformed into the BLR(DE3) strain of *E. coli* (New England Biolabs, Ipswich, MA). 2 mL of terrific broth containing 50 *μ*g/mL carbenicillin (Fischer Scientific, Hampton, NH) was inoculated with each transformant and was grown for 12 hours at 37°C while shaking at 300 rpm. This 2 mL culture was then expanded to 500 mL (terrific broth with 50 *μ*g/mL carbenicillin) and grown at 37°C while shaking at 300 rpm until the OD reached 0.7-0.9 (OD determined by measuring absorbance at 600 nm). Isopropyl *β*-D-1-thiogalactopyranoside (IPTG Fischer reagent) to induce protein expression was then added at a final concentration of 1M. The

cultures continued to grow for an additional 30 hours at 18°C while shaking at 300 rpm. At this point, the cultures were centrifuged at 4700 rpm and the media decanted. The cell pellet was resuspended in 30 mL 1X phosphate buffered saline (1XPBS) with 30 mM imidazole at pH 7.4. To lyse the cells, the suspension was sonicated on ice (with a Fischer Scientific Model 705 sonic dismembrator) for a total of 2 minutes: 30 seconds at an amplitude of 30 and a 30 second break, which is then repeated. The lysate was then clarified by centrifugation at 4700 rpm for 1 hour. The supernatant was passed over 1 mL of HisPur Ni-NTA (nickel ion affinity) resin 50% slurry (Fischer Scientific) in a gravity column. The resin was then washed with 10 mL of 1XPBS with 30 mM imidazole 6 times. The protein was eluted with 10 mL 1XPBS with 200 mM imidazole into Corning Spin-X UF concentrators with a 10 kD molecular weight cutoff. The concentrators were centrifuged at 4700 rpm until the volume reached about 1 mL. Protein concentration was detected by measuring the absorbance at 280 nm with a BioTek spectrophotometer. Protein purity was assessed with a Coomassie stained SDS-PAGE gel (NuPAGE bis-tris, Fischer Scientific) and assayed against oleuropein within 3 days of purification.

Assay Conditions and HPLC Method. Once the β-glucosidase wild-type and mutant enzymes were produced and verified via gel electrophoresis the assay against oleuropein was performed. The enzymes were normalized to a concentration of 0.1 mg/mL by dilution with 1XPBS up to 95 µL. 5 µL of 100 mM oleuropein in DMSO was added to initiate the reaction (5 mM final concentration of oleuropein). The reactions were incubated at room temperature for 5-24 hours and quenched by the addition of 300 μL acetonitrile. The resulting solutions were centrifuged at 15,000 g for 30 minutes and the supernatant was pipetted away from the pelleted protein and added to an HPLC vial. An Agilent 1100 series HPLC with variable wavelength UV detection was used to detect hydroxytyrosol, oleuropein, and intermediate products of the reaction at 280 nm. A Phenomenex C18 column (specifications: 2.6 μm C18 100 Å, LC column 50 x 4.6 mm) was used to separate these products with a gradient mobile phase of water/acetonitrile over a 15 minute method (specifically: 0-4 minutes at 100% water; 4-10 minute gradient increase of acetonitrile to 95%; 10-12 minutes held at 95% acetonitrile; 12-15 minute gradient decrease of acetonitrile back to 0%).

Table 1. Physical and chemical properties of wastewater from enzymatic and lye processing

Wastewater type		pH	COD (g/L)*	Turbidity (NTU)	Total solids (%)
Benchtop Experiment					
Treatment	Control	5.9 ± 0.7	9.5 ± 7.5	503 ± 19	1.0 ± 0.02
	Enzyme	6.0 ± 0.7	9.6 ± 4.7	549 ± 5.0	1.1 ± 0.03
	Lye	12.6 ± 0.5	1.8 ± 1.8	6.4 ± 1.2	0.7 ± 0.32
Rinse	Control	6.1 ± 0.6	1.2 ± 0.1	49.1 ± 34	n.d.
	Enzyme	6.1 ± 0.6	0.7 ± 0.5	23.5 ± 3.5	n.d.
	Lye	9.0 ± 0.6	2.3 ± 3.7	25.3 ± 4.8	n.d.
Neutralization	Lye	5.9 ± 1.0	2.2 ± 0.7	9.3 ± 3.9	0.2 ± 0.1
Industry wastewater					
Lye		13.2 ± 0.2	15.4 ± 3.3	659 ± 99	n.m.
Rinse 1		6.8 ± 0.1	3.9 ± 1.0	172 ± 9.1	n.m.
Rinse 2		9.4 ± 0.03	3.4 ± 0.3	27.2 ± 3.3	n.m.
Rinse 3		11.4 ± 0.01	6.0 ± 1.4	43.5 ± 4.9	n.m.
Neutralization		7.6	6.4	96.4	n.m.

*COD = chemical oxygen demand
n.d. = not detected
n.m. = not measured

Table 2. Phenolic composition (mg/kg) of whole, pitted and crushed olives following enzyme (0.1 mg/mL) or lye treatments

Sample type	Treatment	Oleuropein	Oleuropein aglycone	Hydroxytyrosol	Tyrosol	Hydroxytyrosol glucoside	Rutin	Caffeic acid	Total phenols
Unprocessed olives	n/a	1257 ± 74	256 ± 26	37.3 ± 1.6	13.2 ± 1.2	59.3 ± 0.9	78.1 ± 6.2	3.5 ± 0.3	n.m.
Whole olives	Control	1293 ± 192	148 ± 22	28..0 ± 1.3	11.2 ± 0.9	49.3 ± 4.1	85.0 ± 5.4	2.9 ± 0.6	284 ± 16
	Enzyme	1236 ± 48	205 ± 31	39.4 ± 1.1	14.9 ± 1.7	66.7 ± 8.6	138.7 ± 31	4.2 ± 0.8	350 ± 22
	Lye	943 ± 59	129 ± 86	44.9 ± 9.8	23.0 ± 14	38.9 ± 8.3	55.1 ± 36	2.3 ± 0.2	267 ± 86
Pitted olives	Control	786 ± 103	151 ± 17	33.1 ± 2.8	12.9 ± 0.6	45.6 ± 3.1	68.0 ± 10	3.4 ± 0.2	296 ± 14
	Enzyme	702 ± 145	175 ± 23	29.0 ± 1.6	9.7 ± 1.9	44.0 ± 5.7	84.4 ± 3.5	4.2 ± 0.7	263 ± 8.0
	Lye	155 ± 142	17 ± 12	9.2 ± 1.4	10.2 ± 6.8	9.5 ± 1.3	19.0 ± 10	1.1 ± 0.1	64.7 ± 26
Crushed olives	Control	64 ± 15	3.2 ± 1.5	8.1 ± 2.6	5.1 ± 0.5	8.5 ± 2.4	14.1 ± 3.7	1.6 ± 0.3	76.8 ± 8.7
	Enzyme	48 ± 25	2.4 ± 1.1	7.3 ± 0.4	4.6 ± 0.2	8.4 ± 1.0	25.6 ± 15	1.8 ± 0.1	77.0 ± 14
	Lye	n.d.	n.d.	3.2 ± 0.1	6.4 ± 5.6	4.1 ± 0.4	n.d.	n.d.	23.0 ± 0.7
Olive leaf extract	Control	587 ± 36	n.m.	30.5 ± 1.5	5.1 ± 0.3	50.6 ± 1.7	8.7 ± 4.2	13.9 ± 0.7	n.m.
	Enzyme	n.d.	n.m.	122 ± 2.6	12.2 ± 0.3	9.0 ± 0.1	4.1 ± 0.3	15.1 ± 0.03	

n.d. = not detected

n.m. = not measured

APPENDIX:

Final Performance Report

California Sustainable Winegrowing Alliance

SCB14038 - Accelerating Adoption of Innovation and Sustainable Best Management Practices

Appendix Contents:

- Sample of Educational Workshop Agendas
- Environmental compliance criterion and educational materials for the Code self-assessment workbook
    - Criterion and Educational Boxes
    - Vineyard Environmental Permits List & Questionnaire
    - Winery Environmental Permits List & Questionnaire
- Outreach Examples
    - Sample Case Study E-Newsletter and Announcement of Economic Tools
    - Sample Wine Institute News Brief Announcement of Economic Tools

CALIFORNIA
SUSTAINABLE WINEGROWING
ALLIANCE

The Economics of Sustainable Winegrowing Webinar

May 31, 2017
10:00am – 12:00 pm
Webinar

Agenda:

10:00	**Welcome and Introductions,** *Lisa Francioni-Hai, California Sustainable Winegrowing Alliance*
10:10	**New Economic Tools to Assess Costs and Benefits of Sustainable Winegrowing,** *Jodi Wilson and Lisa Francioni-Hai, California Sustainable Winegrowing Alliance*
10:30	**How to Identify Winery Water Hotspots with the New Water Efficiency Tool & the Solid Waste Audit Tool,** *Susanne Zechiel, Jackson Family Wines*
11:00	**Trunk Disease Management Online Tool,** *Jonathan Kaplan, Sacramento State*
11:30	**Dust Mitigation Methods and Sprayer Decision Tools,** *Michael McCulluogh, Cal Poly*
12:00	**End**

Register for the free webinar workshop at:
https://attendee.gotowebinar.com/register/40884608464970393

Learn more about that tools at: http://www.sustainablewinegrowing.org/economic-tools.php

Recovering Resources:
New Tools for Water Efficiency & Solid Waste Diversion

June 15, 2017
9:00am – 12:00 pm

Freemark Abbey Winery
N, 3022 St Helena Hwy, St Helena

Co-hosted by California Sustainable Winegrowing Alliance and Napa Green

Agenda:

9:00 **Welcome & Introductions**

9:10 **Economic Tools to Assess Costs and Benefits of Sustainable Winegrowing,** *Lisa Francioni-Hai, California Sustainable Winegrowing Alliance*

9:35 **How to Identify Winery Water Hotspots with the New Water Efficiency Tool,** *Susanne Zechiel, Jackson Family Wines*

10:10 **Overview of One-Stop Energy, Water, Waste Assessments in Napa County,** *Anna Brittain, ViewCraft*

10:30 **Break**

10:45 **Water Monitoring, Metric Baselines, and Efficiency Opportunities,** *Anna Brittain, ViewCraft*

- St. Supery case study on water savings**,** *Brooke Shenk, St. Supery Estate Vineyards & Winery*

11:15 **Increasing Waste Diversion**

- Cakebread Cellars Aims for Zero Waste, *Cynthia Sharp, Cakebread Cellars*
- Napa Recycling & Waste Services, *Tim Dewey-Mattia*
- Upper Valley Disposal Services, *Bryce Howard, General Manager*

11:50 **Lunch**

Thank you to the California Department of Food and Agriculture for the Specialty Crop Block Grant that made this workshop possible.

CALIFORNIA
SUSTAINABLE WINEGROWING
ALLIANCE

Sustainable Winegrowing Workshop

for Ag Professionals

Friday, June 16, 2017
Department of Viticulture and Enology, UC Davis
RMI Sensory Theater
9:00am-2:30pm *(Lunch provided and wine reception to follow)*

AGENDA

8:45 **Registration and Networking with coffee and pastries**

9:00 **Welcome and Update on California Sustainable Winegrowing Program**
Allison Jordan, California Sustainable Winegrowing Alliance

9:15 **Economic Tools for Assessing Sustainable Winegrowing Practices**
Lisa Francioni-Hai, California Sustainable Winegrowing Alliance

9:35 **Trunk Disease Prevention and Online Management Tool**
Dr. Jonathan Kaplan, CSUS

10:05 **Sustainable Vineyard Cost and Return Study**
Alicia Hoepfner, UC Davis Agricultural and Resource Economics

10:35 **Break**

10:45 **Climate Smart Agricultural Practices and Carbon Farm Planning**
Charles Schembre, Napa Resource Conservation District

11:15 **CDFA Healthy Soils Initiative and Funding Opportunities**
Dr. Geetika Joshi, CDFA Senior Environmental Scientist

11:35 **The North Coast Soil Health Hub**
Carol Mandel, Natural Resources Conservation Service (NRCS)

12:00 **Lunch** *(Buffet lunch will be served in Interaction Space)*

12:45 **Lightening Talks: Round up of Recent Viticulture & Enology Research**

- *Controlling Ice Nucleating Bacteria as a Frost Protection Strategy - Glenn McGourty, UC Cooperative Extension*
- *Using Winery Process Water for Irrigation - Dr. Anita Oberholster, UC Davis Department of Viticulture and Enology*
- Use of Wine Grape Pomace as Soil Amendments for Pest Control, *Dr. Chris Simmons, UC Davis Department of Food Science and Technology*

2:00 **Networking Wine and Cheese Reception**

2-2 Environmental Compliance Planning* *Vineyard & Winery*

Category 4	Category 3	Category 2	Category 1
The vineyard and/or winery operation had an established means or process for staying aware of environmental legal and regulatory requirements ***And*** The vineyard and/or winery operation had a compliance strategy that was reviewed at least annually to address legal and regulatory requirements that included a list of all relevant permits and licenses and a system for keeping abreast of permit renewal dates, any monitoring and reporting, and permit terms *** ***And*** All relevant employees were informed of the compliance requirements and understood the purpose of permits and knew which staff to contact when regulators visit the operation ***And*** We proactively interact with regulators affecting our business (e.g., submit public comments, participate in working groups, direct communication with regulators for permit clarification, etc.) ***And/Or*** We belong to an association that addressed regulatory and compliance issues.	The vineyard and/or winery operation had an established means or process for staying aware of environmental legal and regulatory requirements ***And*** The vineyard and/or winery operation had a compliance strategy that was reviewed at least annually to address legal and regulatory requirements that included a list of all relevant permits and licenses and a system for keeping abreast of permit renewal dates, any monitoring and reporting, and permit terms ***And*** All relevant employees were informed of the compliance requirements and understood the purpose of permits and knew which staff to contact when regulators visit the operation.	The vineyard and/or winery operation had an established means or process for staying aware of environmental legal and regulatory requirements ***And*** The vineyard and/or winery operation had a compliance strategy to address legal and regulatory requirements that included a list of all relevant permits and licenses and a system for keeping abreast of permit renewal dates, any monitoring and reporting, and permit terms.***	The vineyard and/or winery operation had an established means or process for staying aware of environmental legal and regulatory requirements.**

*See **Chapter 14 Human Resources** for relevant sources and information about ensuring human resources compliance including **Criterion 14-1**.
Environmental legal and regulatory compliance requirements can include, but are not limited to, laws and regulations related to water quality, water supply, air quality, hazardous materials, hazardous wastes, etc. See **Box 2-E and **Box 2-F** for more information.
***A list of permits and licenses can be as simple as a list with expiration dates, renewal dates, purpose of permit and costs, and a system for keeping informed of renewal dates can vary from calendar reminders to compliance software systems. See **Box 2-F** for a template and for more information about the environmental permits that are commonly applicable to a winery or a vineyard. A list of permits, information on the applicable regulatory program area, legislation, and relevant regulatory agencies, and a simplified self-assessment form are available.

BOX 2-E LEGAL AND REGULATORY COMPLIANCE PLANNING

Throughout the California Code of Sustainable Winegrowing, compliance is assumed for all practices where legal and regulatory requirements exist. As appropriate, Category 1 is intended to meet or exceed legal requirements (at the time of print); while Categories 2, 3 and 4 reflect practices that move beyond compliance on a continuum towards increased sustainability.

The United States of America has stringent environmental and social laws and regulations. The Clean Water Act, the Clean Air Act, the Endangered Species Act, and the National Environmental Quality Act are examples of some of the foundational laws for US environmental regulation; while the Fair Labor Standards Act, the National Labor Relations Act, the Civil Rights Act of 1964 and the Occupational Safety and Health Act are among the foundational US labor laws. These federal laws result in numerous compliance requirements for vineyards and wineries.

In addition to the federal requirements, California has an even stronger regulatory framework for both environmental (including land use, water use and quality, air quality, hazardous materials), and human resources (including employer requirements and worker health and safety). California's Environmental Quality Act, the California Air Resources Act, Health and Safety, the Porter-Cologne Water Quality Control Act, and Hazardous Materials Inventory and Reporting Requirements are some of the state-specific laws that form the basis for state and regional environmental regulations and ordinances. The Ag Labor Relations Act guarantees certain rights to California farmworkers and applies to all; while California's Division of Occupational Safety and Health (Cal/Osha) sets and enforces standards, issues permits/licenses/certifications/registrations/approvals, and provides outreach and education to protect and improve worker health and safety.

While the Code addresses legal requirements within 72 relevant criteria and educational content, the complex tapestry of federal, state and local laws, regulations and ordinances – which are only strengthening in stringency over time – requires planning to ensure on-going compliance. Criterion 2-2 and 14-1 lay out a continuum of practices to become more efficient and action-oriented in addressing these issues. See below for a list of resources and best practices, and a template for tracking permits and licenses.

Resources and Best Practices

- See the Code's Chapter 14 for laws and regulations, as well as best practices, related to Human Resources and health and safety.
- California Environmental Protection Agency - http://www.calepa.ca.gov/
- Local Agricultural Commissioner - https://www.cdfa.ca.gov/exec/county/countymap/
- Local Farm Advisors - http://wineserver.ucdavis.edu/people/farm-advisors.html

- A Handbook on the California Agricultural Labor Relations Law – https://www.alrb.ca.gov/content/pdfs/formspublications/handbook/handbook0207.pdf
- Winegrape, wine and agricultural associations:
  - California Association of Winegrape Growers – www.cawg.org
  - Wine Institute – www.wineinstitute.org
  - California Farm Bureau Federation – www.cfbf.com
  - California Farm Labor Contractor Association – www.calflca.org
  - CalChamber - https://www.calchamber.com/Pages/default.aspx and local Chambers of Commerce
- Safety, health and human resources training:
  - Farm Employers Labor Service - http://www.fels.net/1/labor-safety.html
  - AgSafe - http://www.agsafe.org/index.php/en/
- Find your local Chamber of Commerce at: http://advocacy.calchamber.com/resources/local-chambers/
- Local Ag Commissioner Offices can be found at: https://www.cdfa.ca.gov/exec/county/countymap/

BOX 2-F ENVIRONMENTAL PERMITS FOR VINEYARDS AND WINERIES

California vineyards and wineries must comply with a myriad of environmental legal and regulatory requirements. They can cover areas such as water quality, water supply, air quality, hazardous materials, and hazardous wastes. Keeping a single list with all of the permits and licenses needed to remain in compliance is a simple way to keep track of expiration and renewal dates (see below for a list template). Understanding which permits apply to the vineyard and/or winery is also essential for staying in compliance. CSWA has worked with experts to develop a list of the environmental permits that are commonly applicable to a California winery or vineyard that includes information about the applicable regulatory program area, legislation, and relevant regulatory agencies. A simplified questionnaire for determining which permits may be relevant is also provided. To see the latest list and questionnaire visit: add URL on CSWA website.

Example Template for List of Permits and Licenses

Permit/License	Expiration Date	Renewal Date	Purpose of Permit	Cost	Person Responsible

Vineyard Environmental Permits List and Questionnaire

California vineyards and wineries must comply with a myriad of environmental legal and regulatory requirements. They can cover areas such as water quality, water supply, air quality, hazardous materials, and hazardous wastes. Keeping a single list with all of the permits and licenses needed to remain in compliance is a simple way to keep track of expiration and renewal dates. Understanding which permits apply to the vineyard and/or winery is also essential for staying in compliance.

The California Sustainable Winegrowing Alliance has worked with experts to develop the following list of the environmental permits that are commonly applicable to a California vineyard that includes information about the applicable regulatory program area, legislation, and relevant regulatory agencies. The list is not necessarily exhaustive and it is the responsibility of the individual vineyard to remain in compliance with all applicable laws and regulations. A simplified questionnaire for determining which permits may be relevant is also provided below.

Environmental Permits List

See tables below for detailed information about each permit.

Does not include permits and regulations administered by Plant Health and Pest Prevention Services - https://www.cdfa.ca.gov/plant/permitsandregs.html

WATER SUPPLY

- Appropriative Water Rights
- Riparian Statement of Use
- Dam Safety
- Groundwater Registration and Reporting

WATER QUALITY

- Waste Discharge Requirements (WDR) Permit
- Water Quality Certifications & Nationwide Permits
- Erosion Control
- General WDRs and/or General Conditional Waiver of WDRs (Irrigated Lands Program)

RIPARIAN HABITAT

- Streambed Alteration Permits

AIR QUALITY

- Stationary Diesel /Internal Combustion Engines
- Portable Engines Registrations
- Gasoline Dispensing Facilities
- Burn permits
- Dust Control

HAZARDOUS MATERIALS and HAZARDOUS WASTES

- Conditionally Exempt Small Quantity Generators (CESQG)
- Pressure Vessels permits to operate
- Restricted Materials Permits / Pesticide Use Registrations

- Certified Unified Program Agencies (CUPA) programs and EPCRA reporting requirements - hazardous materials, solid and hazardous wastes, petroleum storage tanks, etc.
    - Hazardous Materials Business Plan/Inventory Statement
    - Aboveground Petroleum Storage Tank Registration
    - California Accidental Release Prevention Program
    - SPCC requirements
    - Underground Storage Tank Registration
    - Hazardous Waste Generator

WATER SUPPLY and WATER QUALITY

Area	Relevant Legislation	Responsible Agency	Permit
Water Supply and Storage	• CA Water Code	California State Water Resources Control Board, Division of Water Rights.[i]	Appropriative water license or permit; Riparian Statement of Use
Dam Safety	• CA Water Code, Division 3; CA Code of Regulations; Title 23 Waters; and Current Practices (Supervision of Dams and Reservoirs)	California Department of Water Resources, Division of Safety of Dams	Jurisdictional Dam – approval to construct and operate
Groundwater permits	• Very location specific and in flux due to Sustainable Groundwater Management Act. • California Water Code, section 4999, et. seq. and the Coachella Groundwater Replenishment Program	California Department of Water Resources, State Water Resources Control Board, and various Adjudicated Water Basins. [ii] [iii] Districts. Also, some counties have special ordinances specific to managing groundwater and groundwater conservation.	Registrations vary. (Local entities are forming as required by the Sustainable Groundwater Management Act. These local agencies may eventually develop new requirements for facilities relying on groundwater.)
Water Quality Certifications & Nationwide Permits	• Federal Water Pollution Control Act of 1970 (aka Federal Clean Water Act), Sections 401 & 404 • California Fish and Wildlife Code, Section 1600	The local California Regional Water Quality Control Board and the the U.S. Army Corps of Engineers	Water Quality Certifications
Riparian Habitat	• California Fish and Wildlife Code, Section 1600	The CA Dept. of Fish and Wildlife	Streambed Alteration Permits
Discharges of waste associated with vineyards (Non Point Source Pollution Control Program NPS Policy)	• Porter-Cologne Act (aka California Water Code) • Irrigated Lands Program	The California Regional Water Quality Control Boards	General WDRs and/or General Conditional Waiver of WDRs
Erosion Control Non Point Source (NPS) pollution	• Porter-Cologne Act (aka California Water Code)[iv] • Federal Clean Water Act • Various erosion control ordinances [v]	Local agencies	Grading permits

AIR QUALITY

Area	Legislation	Agency	Permit
Stationary Diesel /Internal Combustion Engines greater than 50 horsepower (Standby Generators Engines, Firewater Pump Engines	• Air Toxic Control Measures (ATCM) • Title 17, California Code of Regulations section 93115 • Individual Air District Rules and Regulations	California Air Resources Control Board and the local Air District.	Diesel Engine permit to operate
Statewide Portable Equipment Registration Program (PERP)	• Air Toxic Control Measures (ATCM) • Title 17, California Code of Regulations section 93115	California Air Resources Control Board[vi]	Fleet Compliance Report
Gasoline Dispensing Facilities	• Title 17 of the California Code of Regulations (CCR)) and rules adopted by the California Air Resource Board • Various Rules and Regulations adopted by local Air Districts	California Air Resources Control Board and the local Air District.	Permit to Operate
Large Spark Ignition Mobile Engines	• California Code of Regulations, Title 13, section 2433	California Air Resources Control Board and the local Air District.	Average Fleet Emission Inventory
Smoke Management Program	• Title 17, California Code of Regulations, Sections 80100, • Various Rules and Regulations adopted by local Air Districts	California Air Resources Control Board and the local Air District.	Burn Permits
Fugitive Dust	• Ambient air quality standards (AAQS) for particulate matter (PM) as in established in the Federal Clean Air Act and Title 17, California Code of Regulations • Various Rules and Regulations adopted by local Air Districts	California Air Resources Control Board and the local Air District.	Conservation Management Plans Dust Control Plans

HAZARDOUS MATERIALS and WASTES

Area	Relevant Legislation	Responsible Agency	Permit
Certified Unified Program Agencies (CUPA) programs and EPCRA reporting requirements	Varies and includes[vii]: • Final Rule for the SPCC Plan Requirements, 40 CFR 112 • California Health and Safety Code, Division 20, Chapters 6.67 and 6.95 • CCR, Title 23, Division 3, Chapter 16 • Aboveground Petroleum Storage Act (AB 1130)	CUPA agency varies based on location. [viii] The California Department of Toxic Substance provides the CUPA agencies with technical support.	• Hazardous Materials Business Plan/Inventory Statement • Aboveground Petroleum Storage Tank Registration • California Accidental Release Prevention Program • SPCC requirements • Underground Storage Tank Registration • Hazardous Waste Generator
Small Quantity Generators (SQG)	• Part 262 of the Code of Federal Regulations (40 CFR Part 262) [ix]	California Department of Toxic Substance Control	California EPA Identification Number
Pressure Vessels – air compressors and liquid propane tanks, boilers	• Labor Code sections 7620-7771	California Department of Industrial Relations, Pressure Vessel Unit	Pressure Vessel Permit
Restricted Materials / Pesticide Use	• Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the regulations in the Code of Federal Regulations, Title 40. • California Food and Agricultural Code (FAC) Divisions 6, 7, and 13; the regulations are in Title 3, CCR Division 6.	California Department of Pesticide Regulations and local Agriculture Commissioner. [x]	Restricted Materials Permits / Pesticide Use Registrations / Pesticide Use Reporting / and Applicator License

Environmental Permits Questionnaire

Water Quality Permits

A. Waste Discharge Requirements (WDRs) Permit - Land that is irrigated to produce crops for commercial purposes is regulated under the Irrigated Lands Program.*

1. Are you in Region 3, 4, and 8?
   - If so, enroll in and comply with your Regional Board's Agricultural Order (No. R3-2012-0011, No R4-2015-0202, or No. R8-2016-0003
2. Are you in Region 5?
   - Join a third-party coalition group or obtain coverage (WDR) as an individual grower.
3. Are you in Region 1, 2, or 9
   - These regions are currently developing their programs to regulate discharges of waste associated with vineyards.

* Water discharges from agricultural operations include irrigation runoff, flows from tile drains, and storm water runoff. These discharges have the potential to carry sediment, nutrients, and agri-chemical to local surface water and groundwater resources.
http://www.swrcb.ca.gov/water_issues/programs/agriculture/

B. 404 Permits & 401 Certifications

1. Has surface waters (including wetlands) on your property been dredged or filled? This can include work in drainage ditches and stream crossings for transportation and water supply pipelines.

If 'yes', you may need:

- Certification from the state verifying that the activity will comply with state water quality standards (401 certification) and that discharges to the waters of the United States are appropriate (404 permits).
- Contact your Regional Water Quality Control Board and Army Corps of Engineers.

C. Grading

1. Have you recently planted new vineyards or recently replanted existing vineyards?
   - If yes, check with your local Building Department or Planning Department about relevant ordinances.

Water Supply Permits

A. Appropriative Water License

1. Do you take water from a lake, river, stream, or creek for use on your property?

   - If you answered 'yes', you may need to establish a water right with the State Water Resources Control Board. Individuals can hold riparian water rights, appropriative rights, and prescriptive water rights. Do not assume that you have a water right just because you have a water diversion or a dam on your property. You can check with the Division of Water Rights to determine if you have a water right permit, license, certificate or registration. If you can't find documentation that you have an established water right permit, license, certificate or registration contact an expert – lawyer or engineer – to assist you in assessing your water rights. You may need to begin the application process which will require significant documentation.

http://www.waterboards.ca.gov/waterrights/board_info/faqs.shtml

B. Jurisdictional Dams

1. Do you have a water reservoir with a dam height of 25-feet or greater (dam height is measured from the downstream toe to the maximum storage elevation/spillway)?
2. Do you have a water reservoir that has a storage capacity of more than 50 acre-feet?

- If you answered 'yes' to either questions 1 and 2, you may need to a permit from the CA Division of Safety of Dams. You should start by notifying the respective Area Engineer.

C. Groundwater Registrations & Reporting

- Local entities are forming as required by the Sustainable Groundwater Management Act. These local agencies may eventually develop new requirements for facilities relying on groundwater.
- There are few areas that have had groundwater registrations and reporting for decades, like the Coachella Valley.
- There are areas with Water Right Determinations: http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/judgments/docs/judgments_map.pdf
- Watermaster Service Area on the map: http://www.water.ca.gov/watermaster/ND_Watermasters/ServiceAreas/index2.cfm

Air Quality Permits

A. Permit to Operate – Stationary Diesel Engines

1. Do you have a diesel fired engine used to pump water or provide power for growing crops*?
2. Are any of the diesel engines 50 horsepower or greater?

- If you answered 'yes' to both questions, you likely require a permit from the local air district and need to comply with the State's Stationary Diesel Engine Air Toxic Control Measures. This may involve simply registering your engines.

***** agricultural wind machines or tractors or harvesters are excluded

B. Gasoline Dispensing Facilities

1. Does your facility maintain a fueling area that includes gasoline dispensing?
2. Do you use this gasoline facility to fuel vehicles others than farm equipment? This includes trucks and over-the-road vehicles that transport farm equipment.

- If you answered 'yes' to both questions, you should contact your local air district.

C. Mobile Emissions

1. Does the operation have four (4) or more forklifts, sweepers, scrubbers, or industrial tow tractors with large spark ignition (LSI) engines of 25 horsepower (19 kilowatt) or greater?*
2. Do you have several facilities, that together maintain 4 or more LSI engines of 25 horsepower or greater?

- If you answered "yes" to both questions, then you should follow the directions on the Air Resources Control Board's website to calculate a baseline inventory, determine if your LSI average fleet emissions is within the appropriate range: http://www.arb.ca.gov/msprog/offroad/orspark/orspark.htm

*Agricultural fleets are not required to comply with the fleet average, but must address all 1990 and newer uncontrolled forklifts.

D. Smoke Management Program

1. Is agricultural burning conducted to dispose of agriculture waste generated in the process of growing of crops?
2. Is land management burning conducted to dispose of woody waste cleared from ranch lands?

- If you answered 'yes' to both questions, you should contact your local air district for a burn permit which are allowed only on permissive burn days. Also, you may need to check with the local Fire District to make sure conditions are safe for burning and to obtain any required Fire District permits.

E. Fugitive Dust

- Your Local Air District may have Fugitive Dust Rules, which prohibits the transport of dust off your property and requires you to "take every reasonable precaution to minimize emissions." Other districts may use the State Nuisance law or the Visible Emissions/Opacity rule to regulate fugitive dust emissions. Some districts may attach dust control measures to your Permit to Operate and require Conservation Management Plans and Dust Control Plans.
- Check with your local air district for requirements.

Hazardous Materials and Wastes

A. Small Quantity Generators (SQG)

1. Does your facility generate less than 1,000 kg of hazardous waste per month, excluding universal wastes, and/or 1kg or less of acutely or extremely hazardous waste per month. This includes wastes from equipment maintenance and farm shop.

- If so, you are a Small Quantity Generators (SQGs). You need an EPA ID number and must comply with the appropriate requirements:
  - http://www.dtsc.ca.gov/IDManifest/index.cfm
  - http://www.dtsc.ca.gov/HazardousWaste/upload/California-Generator-Chart.pdf and
  - https://www.dtsc.ca.gov/HazardousWaste/upload/HWM_FS_Generator_Requirements.pdf

B. Pressure Vessels Permits

1. Does your facility have any boilers (pressure vessel used to generate steam pressure by the application of heat), air pressure tanks, or liquefied petroleum gases (LPG) tanks? For example, to run wind machines.
2. Are the air tanks or LPG propane storage tanks over 125 gallons?
3. Are the high pressure boilers over 15 psig steam.

- If you replied 'yes' to questions 1 and question 2 or 3, then permit is likely needed. Contact the Department of Industrial Relations, Pressure Vessel Unit: https://www.dir.ca.gov/dosh/pressure.html

C. Pesticide Use

1. Do you apply pesticides and/or restricted use materials on your vineyard?

- If 'yes', you need to ensure you are using a product that has been approved and registered, that a registered and license pesticide applicator is overseeing the use, and that appropriate reports are provided to the agricultural commissioner office.

D. Certified Unified Program Agencies (CUPA) program - the next six sections cover:

- Hazardous Materials Business Plan/Inventory Statement
- Aboveground Petroleum Storage Tank (AST) Registration
- California Accidental Release Prevention (CAL-ARP) Program
- SPCC requirements
- Underground Storage Tank (UST) Registration
- Hazardous Waste Generator

E. Hazardous Materials Business Plan / Inventory Statement

1. Does your vineyard or vineyard shop handle hazardous materials in quantities equal to or greater than:
   - 55 gallons of a liquid,
   - 500 pounds of a solid, or
   - 200 cubic feet of compressed gas,
   - or extremely hazardous substances above the threshold planning quantity,

- If 'yes', you need to submit a Hazardous Materials Business Plan (HMBP) electronically to the statewide information management system (California Environmental Reporting System, or CERS).
- For help in doing this, contact the local implementing agency (Certified Unified Program Agency or CUPA)

F. Spill, Prevention, Control and Countermeasure (SPCC) plan requirements

1. Does your vineyard property maintain aggregate aboveground petroleum storage capacities of 1,320 gallons or more? This includes aboveground storage containers or tanks with petroleum storage capacities of 55 gallons or greater and also includes portable tanks.
2. Does your facility maintain aggregate aboveground petroleum storage capacities above 10,000 gallons?

- If you responded 'yes' to question 1, you will need to register with the local CUPA agency, pay a fee, and develop and implement a SPCC plan
- If you responded 'yes' to question 2, your SPCC will need to be developed, signed, and stamped by a licensed Professional Engineer as well as register with the local CUPA agency and pay an annual fee.
- All regulated facilities must meet the federal SPCC rule requirements.

G. California Accidental Release Prevention (CAL-ARP) Program

1. Does your property have more than a threshold quantity of a regulated substance (listed in Tables 1-3, Title 19 § 2770.5 (note that Ammonia and Sulfur Dioxide have a threshold quantity of 500 lbs)

   - If yes, you may want to contact your CUPA agency for guidance. Or, try to reduce the regulated substance to below the threshold quantity. http://www.caloes.ca.gov/cal-oes-divisions/fire-rescue/hazardous-materials/california-accidental-release-prevention

H. Underground Storage Tank (UST) Registration

1. Does your facility maintain UST for activities other than sanitary waste?

   - If you replied 'yes', the UST should be registered with the SWRCB and/or the appropriate CUPA agency.

I. Aboveground Petroleum Storage Tank (AST) Registration

1. Does your facility maintain aggregate aboveground petroleum storage capacities of less than 1,320 gallons of petroleum, but has an underground storage tank?

   - If 'yes', the property is regulated under APSA (Aboveground Petroleum Storage Tank Act) and you should contact your local CUPA.

J. Hazardous Waste Generator

- See Small Quantity Generators (SQG) above.
- The local CUPA agency enforces the regulations associated with hazardous waste. This includes permits, inspections, and issuing violations.

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[i] SWRCB, Division of Water Rights home page: http://www.waterboards.ca.gov/waterrights/

[ii] Adjudicated Basin Reporting http://www.water.ca.gov/groundwater/sgm/adjudicated.cfm

[iii] Adjudicated Basins list - http://www.water.ca.gov/groundwater/docs/List%20of%20adjudicated%20basins%20and%20subbasins_01012014.pdf

[iv] SWRCB – Nonpoint Source Pollution and agriculture - http://www.waterboards.ca.gov/water_issues/programs/nps/docs/plans_policies/nps_iefs.pdf

[v] Napa County Erosion Control - file:///C:/Users/SusanneZ/Downloads/1On%20Line%20ECP.pdf and Sonoma County Ordinance http://www.sonoma-county.org/agcomm/vesco.htm

[vi] ARB Agricultural Engines home page - http://www.arb.ca.gov/diesel/statport.htm

[vii] CUPA regulations - http://www.calepa.ca.gov/CUPA/LawsRegs/

[viii] CUPA Directory - http://cersapps.calepa.ca.gov/Public/Directory/

[ix] CESQG - http://www.epa.gov/osw/hazard/generation/sqg/handbook/insert.pdf

[x] Pesticide Use Reporting - http://www.cdpr.ca.gov/docs/pur/purmain.htm

Winery Environmental Permits List and Questionnaire

California vineyards and wineries must comply with a myriad of environmental legal and regulatory requirements. They can cover areas such as water quality, water supply, air quality, hazardous materials, and hazardous wastes. Keeping a single list with all of the permits and licenses needed to remain in compliance is a simple way to keep track of expiration and renewal dates. Understanding which permits apply to the vineyard and/or winery is also essential for staying in compliance.

The California Sustainable Winegrowing Alliance has worked with experts to develop the following list of the environmental permits that are commonly applicable to a California winery that includes information about the applicable regulatory program area, legislation, and relevant regulatory agencies. The list is not necessarily exhaustive and it is the responsibility of the individual winery to remain in compliance with all applicable laws and regulations. A simplified questionnaire for determining which permits may be relevant is also provided below.

Environmental Permits List

See tables below for detailed information about each permit.

WATER SUPPLY

- Drinking Water Program permit
- Appropriative Right
- Groundwater Registration and Reporting

WATER QUALITY

- Wastewater Discharge Requirements Permit
- Industrial Stormwater Discharge Permit
- Onsite Waste Treatment System (OWTS) permit for domestic (sanitary) wastewater
- Water Quality Certifications & Nationwide Permits & Streambed Alteration Agreements

AIR QUALITY

- Title V Permit
- Permit to Operate Boilers and Steam Generators
- Stationary Diesel/Internal Combustion Engines
- Gasoline Dispensing Facilities
- Fermentation and Aging/Storage
- Refrigeration Management Program

HAZARDOUS MATERIALS and HAZARDOUS WASTES

- Conditionally Exempt Small Quantity Generators (CESQG)
- Pressure Vessels permits to operate
- Sulfur (SO2) product for use in barrel and cork sanitation
- Certified Unified Program Agencies (CUPA) programs and EPCRA reporting requirements -, including, hazardous materials, solid and hazardous wastes, petroleum storage tanks, etc.
    - Hazardous Materials Business Plan/Inventory Statement
    - Aboveground Petroleum Storage Tank Registration
    - California Accidental Release Prevention Program
    - SPCC requirements
    - Underground Storage Tank Registration
    - Hazardous Waste Generator

WATER SUPPLY and WATER QUALITY

Area	Relevant Legislation	Responsible Agency	Permit
Drinking Water Program permit	• Title 17 and Title 22 of the California Code of regulations (CCR). • Drinking Water Regulations also appear in the Corporations Code, Education Code, Food and Agricultural Code, Government Code, Health and Safety Code, Public Resources Code, and Water Code. • Potable water related statues - Title 22, CCR, Division 4, Chapter 15.	California State Water Resources Control Board, Division of Drinking Water with the exception of counties that have retained primacy. See Local Primacy Agency Counties map[i].	Drinking Water Permit
Water Supply	• Porter-Cologne Act (aka California Water Code, Division 2).	California State Water Resources Control Board, Division of Water Rights.[ii]	Appropriative water license
Groundwater permits	• Very Location Specific and in flux due to Sustainable Groundwater Management Act. • California Water Code, section 4999, et. seq. and the Coachella Groundwater Replenishment Program	California Department of Water Resources, State Water Resources Control Board, and various Adjudicated Water Basins. [iii] [iv] Districts. Also, some counties have special ordinances specific to managing groundwater and groundwater conservation.	Groundwater well registration. (Local entities are forming as required by the Sustainable Groundwater Management Act. These local agencies may eventually develop new requirements for facilities relying on groundwater.)
Water Quality Certifications & Nationwide Permits & Streambed Alteration Agreements	• Federal Water Pollution Control Act of 1970 (aka Federal Clean Water Act), Sections 401 & 404 • California Fish and Wildlife Code, Section 1600	The local California Regional Water Quality Control Board and the CA Fish and Wildlife agency.	Water Quality Certifications
Storm Water (National Pollution Discharge and Elimination System (NPDES) permits – INDUSTRIAL.)	• Porter-Cologne Act (aka California Water Code) Section 13020 et seq.	California State Water Resources Control Board, Division of Water Quality and your local California Regional Water Quality Control Board.[v]	Stormwater Permit (including Notice of Intent, Non-Exposure Certification, or Non-Applicability)

Onsite treatment and disposal of process wastewater	• Porter-Cologne Act (aka California Water Code)	The local California Regional Water Quality Control Board and Napa County.	Wastewater Discharge Regulations Permit (waiver, general, or individual)
Onsite disposal of septic wastewater			Onsite Wastewater Treatment System

AIR QUALITY

Area	Legislation	Agency	Permit
Title V	• Federal Clean Air Act, Major Facility Review Program (Title V)	US EPA and the local Air District.[vi]	Title V Permit
Boilers and Steam Generators	• Federal Clean Air Act • California Children's Environmental Health Protection Act (CEHPA, Senate Bill 25, Escutia, 1999). • CCR, Title 17, Div. 3 - Public Health • Individual Air Districts maintain rules specific to their air basins.	Administered by the local Air District.	Authority to Construct, Permit to Operate
Stationary Diesel /Internal Combustion Engines greater than 50 horsepower (Standby Generators Engines, Firewater Pump Engines	• Air Toxic Control Measures (ATCM) • Title 17 of the California Code of Regulations (CCR)) and various regulations adopted by the California Air Resource Board • Individual Air Districts maintain rules specific to their air basins.	Administered by the local Air District.	Diesel Engine permit to operate
Gasoline Dispensing Facilities	• Title 17 of the California Code of Regulations (CCR)) and rules adopted by the California Air Resource Board • Various rules adopted by local Air Districts.	Administered by the local Air District.	
Large Spark Ignition Mobile Engines	• California Code of Regulations, Title 13, section 2433	California Air Resources Control Board and the local Air District.	Average Fleet Emission Inventory

Fermentation and Aging/Storage	• Title 17 of the California Code of Regulations (CCR)) and rules adopted by the California Air Resource Board • Various Rules and Regulations adopted by local Air Districts	California Air Resources Control Board and the following local Air Districts: Monterey Air Pollution and Control District (APCD), Santa Barbara APCD, San Joaquin Valley APCD	
Refrigeration Management Program	• California Global Warming Solutions Act (AB 32) (compliments U.S. EPA Rule 608)	California Air Resources Control Board - facilities register and submit annual reports using the R3 tool.	Register refrigeration systems with more than 50 pounds of high 'global warming potential' refrigerant

HAZARDOUS MATERIALS and WASTES

Area	Relevant Legislation	Responsible Agency	Permit
Certified Unified Program Agencies (CUPA) programs and EPCRA reporting requirements	Varies and includes[vii]: • Final Rule for the SPCC Plan Requirements, 40 CFR 112 • California Health and Safety Code, Division 20, Chapters 6.67 and 6.95 • CCR, Title 23, Division 3, Chapter 16 • Aboveground Petroleum Storage Act (AB 1130)	CUPA agency varies based on location. [viii] The California Department of Toxic Substance provides the CUPA agencies with technical support.	• Hazardous Materials Business Plan/Inventory Statement • Aboveground Petroleum Storage Tank Registration • California Accidental Release Prevention Program • SPCC requirements • Underground Storage Tank Registration • Hazardous Waste Generator
Small Quantity Generators (SQG)	• Part 262 of the Code of Federal Regulations (40 CFR Part 262) [ix]	California Department of Toxic Substance Control	California EPA Identification Number
Pressure Vessels – air compressors and liquid propane tanks, boilers	• Labor Code sections 7620-7771	California Department of Industrial Relations, Pressure Vessel Unit	Pressure Vessel Permit
Sulfur (SO2) product for use in barrel and cork sanitation	• Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the regulations in the Code of Federal Regulations, Title 40. • California Food and Agricultural Code (FAC) Divisions 6, 7, and 13; the regulations are in Title 3, CCR Division 6.	California Department of Pesticide Regulations and local Agriculture Commissioner. [x]	Pesticide Use Reporting and Applicator License

Environmental Permits Questionnaire

Water Supply Permits

A. Drinking Water Permit

1. Is water to the bathrooms, break rooms, or tasting room supplied by an onsite groundwater well, spring, creek or stream?
2. Does the water system serve 25 people (employees, vendors, and visitors) per day at least 60 days per year?

➢ If you answered 'yes' to both question 1 and question 2, a drinking water permit may be needed. See the information here: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/publicwatersystems.shtml

B. Appropriative Water License

1. Do you take water from a lake, river, stream, or creek for use on your property?
2. Did your property begin using surface water or groundwater from a subterranean stream after 1914?

➢ If you answered 'yes' to both questions 1 and 2, you may need to establish a water right with the SWRCB. Individuals can hold riparian water rights, appropriative rights, and prescriptive water rights. Do not assume that you have a water right just because you have a water diversion or a dam on your property. You can check with the Division of Water Rights to determine if you have a water right permit, license, certificate or registration.

http://www.waterboards.ca.gov/waterrights/board_info/faqs.shtml

C. **Groundwater Registrations & Reporting**

- Local entities are forming as required by the Sustainable Groundwater Management Act. These local agencies may eventually develop new requirements for facilities relying on groundwater.
- There are few areas that have had groundwater registrations and reporting for decades, like the Coachella Valley.
- There are areas with Water Right Determinations: http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/judgments/docs/judgments_map.pdf
- Watermaster Service Area on the map: http://www.water.ca.gov/watermaster/ND_Watermasters/ServiceAreas/index2.cfm

Water Quality Permits

A. Wastewater Discharge Requirements (WDRs) Permit

1. Does your facility generate process wastewater*?
2. Is the process wastewater directed to a public sewer system or a publically owned treatments works (POTW)?

- If you answered 'yes' to the first question and 'no' to the second, contact your Regional Water Quality Control Board to determine if a waiver, general WDR, or individual WDR is needed.

* Process wastewater is water that has been used for cleaning, sanitation, and wash down activities. Process wastewater excludes domestic and sanitary wastes.

B. Industrial General Stormwater Permit (IGP)

When it rains, does stormwater:

1. Leave your property?
   - If not, you likely do not need coverage under the IGP. Consider registering a Notice of Non-Applicability (NONA) with the State Water Resources Control Board (SWRCB).

2. Come in contact with outdoor processing areas (grape receiving areas, crush pad, bulk wine transfer areas, etc.) and leave your property?
   - If so, you may need to file a Notice of Intent (NOI) to comply with the IGP with the SWRCB

3. Never come in contact with industrial activities. For example, all industrial activities occur inside?
   - If stormwater leaves your property, but never comes in contact with industrial activities, you may need to file a Non Exposure Certificate (NEC) with the SWRCB.

See: http://www.waterboards.ca.gov/water_issues/programs/stormwater/industrial.shtml

C. Onsite Wastewater Treatment System (OWTS) permit

1. Does your have kitchens, bathrooms, and break rooms that generate domestic and sanitary wastes?
2. Is the sanitary waste directed to a public sewer system or a publically owned treatments works (POTW)?

- If you answered 'yes' to the first question and 'no' to the second, contact your Regional Water Quality Control Board to determine if your OWTS permit is up to date with recent policy changes.

D. 404 Permits & 401 Certifications

3. Has surface waters (including wetlands) on your property been dredged or filled?

- If 'yes', you may need:
  - Certification from the state verifying that the activity will comply with state water quality standards (404 permits) and that discharges to the waters of the United States are appropriate (401 Certification).
  - Contact your Regional Water Quality Control Board.

Air Quality Permits

A. Major Facility Review Program (Title V) Permit

1. Is there a potential for your facility to emit:
   - 100 tons per year of a criteria air pollutant (NOx, SO2, Pb, VOC, CO or PM10)? *

- 10 tons per year of a Hazardous Air Pollutant (HAP)?; or
- 25 tons per year of any combination of HAPs?

➢ If you responded 'yes', contact your local air district.

* Most wineries will not emit 100 tons of a criteria air pollutant; this may impact the largest wineries.

B. Permit to Operate – Boilers and Steam Generators

1. Does your facility have an individual (or grouping of) boilers or large water heaters with a rated heat over 2.0 million BTUs per hour (MMBtu/hr)?
2. Is the boiler(s) or water heater(s) fired by natural gas or LPG?

➢ If you answered 'yes' to both questions, you need a permit from your local air district.

C. Permit to Operate – Stationary Diesel Engines

1. Do you have a diesel fired emergency standby generator engine; a diesel fired emergency firewater pump engine, or other diesel engine?
2. Are any of the diesel engines 50 horsepower or greater?

➢ If you answered 'yes' to both questions, you likely require a permit from the local air district and need to comply with the State's Stationary Diesel Engine Air Toxic Control Measures.

D. Gasoline Dispensing Facilities

1. Does your facility maintain a fueling area that includes gasoline dispensing?
2. Do you use this gasoline facility to fuel vehicles others than farm equipment? This includes trucks and over-the-road vehicles that transport farm equipment.

➢ If you answered 'yes' to both questions, you should contact your local air district.

E. Mobile Emissions

1. Does the operation have four (4) or more forklifts, sweepers, scrubbers, or industrial tow tractors with large spark ignition (LSI) engines of 25 horsepower (19 kilowatt) or greater?*
2. Do you have several facilities, that together maintain 4 or more LSI engines of 25 horsepower or greater?

➢ If you answered "yes" to both questions, then you should follow the directions on the Air Resources Control Board's website to calculate a baseline inventory, determine if your LSI average fleet emissions is within the appropriate range: http://www.arb.ca.gov/msprog/offroad/orspark/orspark.htm

F. Fermentation, Aging, Storage Permits

1. Is your facility located in the San Joaquin APCD, Monterey Bay APCD, Santa Barbara APCD, or South Coast AQMD?

➢ If you answered 'yes', these air districts require a permit for fermentation and storage tanks (including barrels).

G. Refrigeration Management Program

1. Does your facility maintain a stationary refrigeration system using more than 50 pounds of a high-global warming potential (high-GWP) refrigerant?* The 50-pound threshold applies to the largest refrigeration system; it is not based on the cumulative total charge of all refrigeration systems at the facility.

➢ If you answered 'yes', you likely need to register your system on the Air Resource's Board R3 tool and comply with the Refrigeration Management Program. http://www.arb.ca.gov/cc/rmp/rmp.htm

*High-GWP refrigerants include CFC, HCFC, and HFC refrigerants such as R-12, R-22, R-404A, R-407A, R-410A, R-507, etc. High-GWP refrigerants do not include ammonia and carbon dioxide.

Hazardous Materials and Wastes

A. Small Quantity Generators (SQG)

1. Does your facility generate less than 1,000 kg of hazardous waste per month, excluding universal wastes, and/or 1kg or less of acutely or extremely hazardous waste per month. This includes wastes from throughout the winery, including administration, cellar, maintenance, and lab.

➢ If so, you are a Small Quantity Generators (SQGs). You need an EPA ID number and must comply with the appropriate requirements:

a. http://www.dtsc.ca.gov/IDManifest/index.cfm
b. http://www.dtsc.ca.gov/HazardousWaste/upload/California-Generator-Chart.pdf and
c. https://www.dtsc.ca.gov/HazardousWaste/upload/HWM_FS_Generator_Requirements.pdf

B. Pressure Vessels Permits

1. Does your facility have any boilers (pressure vessel used to generate steam pressure by the application of heat), air pressure tanks, or liquefied petroleum gases (LPG) tanks?
2. Are the air tanks or LPG propane storage tanks over 125 gallons?
3. Are the high pressure boilers over 15 psig steam.

➢ If you replied 'yes' to questions 1 and question 2 or 3, then permit is likely needed. Contact the Department of Industrial Relations, Pressure Vessel Unit: https://www.dir.ca.gov/dosh/pressure.html

C. Pesticide Use

1. Does your facility use Sulfur product for barrel treatment (fumigation) or cork sanitation?

➢ If 'yes', you need to ensure you are using a product that has been approved and registered, that a registered and license pesticide applicator is overseeing the use, and that appropriate reports are provided to the agricultural commissioner office.

D. Certified Unified Program Agencies (CUPA) program- the next six sections cover:

- Hazardous Materials Business Plan/Inventory Statement
- Aboveground Petroleum Storage Tank (AST) Registration

- California Accidental Release Prevention (CAL-ARP) Program
- SPCC requirements
- Underground Storage Tank (UST) Registration
- Hazardous Waste Generator

…and applies to the entire facility including administration, winery cellars, maintenance, shops, and lab.

D. Hazardous Materials Business Plan / Inventory Statement

1. Does your vineyard or vineyard shop handle hazardous materials in quantities equal to or greater than:
   - 55 gallons of a liquid,
   - 500 pounds of a solid, or
   - 200 cubic feet of compressed gas,
   - or extremely hazardous substances above the threshold planning quantity,

   ➢ If 'yes', you need to submit a Hazardous Materials Business Plan (HMBP) electronically to the statewide information management system (California Environmental Reporting System, or CERS).
   ➢ For help in doing this, contact the local implementing agency (Certified Unified Program Agency or CUPA)

E. Spill, Prevention, Control and Countermeasure (SPCC) plan requirements

1. Does your winery maintain aggregate aboveground petroleum storage capacities of 1,320 gallons or more? This includes aboveground storage containers or tanks with petroleum storage capacities of 55 gallons or greater and also includes portable tanks.
2. Does your facility maintain aggregate aboveground petroleum storage capacities above 10,000 gallons?

   ➢ If you responded 'yes' to question 1, you will need to register with the local CUPA agency, pay a fee, and develop and implement a SPCC plan
   ➢ If you responded 'yes' to question 2, your SPCC will need to be developed, signed, and stamped by a licensed Professional Engineer as well as register with the local CUPA agency and pay an annual fee.
   ➢ All regulated facilities must meet the federal SPCC rule requirements.

F. California Accidental Release Prevention (CAL-ARP) Program

1. Does your winery (including cellars, lab, shops, wastewater systems, refrigeration, etc.) have more than a threshold quantity of a regulated substance (listed in Tables 1-3, Title 19 § 2770.5 (note that Ammonia and Sulfur Dioxide have a threshold quantity of 500 lbs)

   ➢ If yes, you may want to contact your CUPA agency for guidance. Or, try to reduce the regulated substance to below the threshold quantity. http://www.caloes.ca.gov/cal-oes-divisions/fire-rescue/hazardous-materials/california-accidental-release-prevention

G. Underground Storage Tank (UST) Registration

1. Does your facility maintain UST for activities other than sanitary waste?

   ➢ If you replied 'yes', the UST should be registered with the SWRCB and/or the appropriate CUPA agency.

H. Aboveground Petroleum Storage Tank (AST) Registration

1. Does your facility maintain aggregate aboveground petroleum storage capacities of less than 1,320 gallons of petroleum, but has an underground storage tank?

   - If 'yes', the winery is regulated under APSA (Aboveground Petroleum Storage Tank Act) and you should contact your local CUPA.

I. Hazardous Waste Generator

- See Small Quantity Generators (SQG) above.
- The local CUPA agency enforces the regulations associated with hazardous waste. This includes permits, inspections, and issuing violations.

---

[i] Map of Local Primacy Agency (LPAs) for Drinking Water: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/sws/sws_area_unit_map.pdf

[ii] SWRCB, Division of Water Rights home page: http://www.waterboards.ca.gov/waterrights/

[iii] Adjudicated Basin Reporting http://www.water.ca.gov/groundwater/sgm/adjudicated.cfm

[iv] Adjudicated Basins list - http://www.water.ca.gov/groundwater/docs/List%20of%20adjudicated%20basins%20and%20subbasins_01012014.pdf

[v] SWRCB Industrial Storm Water home page http://www.waterboards.ca.gov/water_issues/programs/stormwater/industrial.shtml and map of the Regional Water Quality Control Boards http://www.waterboards.ca.gov/waterboards_map.shtml

[vi] List of California Air Districts - http://www.arb.ca.gov/capcoa/roster.htm

[vii] CUPA regulations - http://www.calepa.ca.gov/CUPA/LawsRegs/

[viii] CUPA Directory - http://cersapps.calepa.ca.gov/Public/Directory/

[ix] CESQG - http://www.epa.gov/osw/hazard/generation/sqg/handbook/insert.pdf

[x] Pesticide Use Reporting - http://www.cdpr.ca.gov/docs/pur/purmain.htm

Lisa Francioni

From: California Wine Institute <communications=sustainablewinegrowing.org@mail85.atl71.mcdlv.net> on behalf of California Wine Institute <communications@sustainablewinegrowing.org>
Sent: Thursday, May 25, 2017 9:10 AM
To: lisa@sustainablewinegrowing.org
Subject: Winery efforts restore stream to good health

Spottswoode takes the natural approach View this email in your browser



Creek Restoration Pays Big Benefits

May 2017



Environmental leader: Beth Novak

The Novak family has owned St. Helena's historic Spottswoode Winery since 1972. St. Helena was a sleepy

What's New?

Economic Tools: CSWA has launched new economic tools to help growers assess costs and benefits of specific sustainable winegrowing practices. Read more **HERE**.

Green Medal Environment Award: Congratulations to Spottswoode Estate Vineyard & Winery for receiving our 2017 California Green Medal Sustainable Winegrowing Leadership Award in the Environment Category. Watch the video below to learn more about Spottswoode's environmental leadership.

town then, but the ensuing decade saw a lot of vineyard and home development in the area. Thirty years later, the Novaks realized that Spring Creek, the year-round stream on the southern border of their property, had deteriorated considerably.

In 2005, the winery launched an extensive creek-restoration project. Spottswoode President Beth Novak describes the endeavor, one of many that contributed to the winery's selection as the recipient of the 2017 Green Medal Environment Award.

What made you think Spring Creek needed restoration?

Our property has been in vineyards since the late 1800s, and until the mid-to-late 1970s, the area west of us was just open land. Then a subdivision was built right along Spring Creek. Because of the houses, the creek no longer flowed freely. Residents would blow leaves into the creek and dump debris. It had turned into something like a drainage ditch with non-native plantings like vinca and Himalayan blackberries. It was not a natural stream bed.

We've been farming organically since 1985, and I've had a strong environmental ethic ever since then. I took a look at that creek and thought, 'Is there something we could do?' We hired a bio-engineer who takes a natural approach to restoration. He studied the creek, and he knew how to work with government agencies to get funding. Then we began explaining to our neighbors what we wanted to do.



Wine-country creek returns to health

What did the work entail?

First, the removal of non-natives, which continues to this day, and replacement with native grasses, more oak trees and toyon. When people build on a creek, they see the creek erode away. So they put in a wall and the water bounces to



Seasonal Recipes

Enjoy our fresh, seasonal, easy-to-prepare recipes complete with California wine pairing suggestions **HERE**.



Grilled Skirt Steak Salad with Rice Vermicelli Noodles, Carrots, Cucumber and Chili-Lime Dressing

Did You Know?

91% of Growers allowed the growth of resident or native vegetation to protect local water bodies and positively affect the surrounding community.



Resources • Publications

the other side and starts eroding the other side. Where there had been some of this undercutting, the engineer stacked big rocks and wove willow into these sort of willow walls to protect the edge of the creek. You want the water to filter and flow through it. On the creek bottom, they put big rocks to slow down the flow and create pools where fish could exist. We continue to add grasses and other plantings. It's a cool ongoing project that we're really proud of.

And the impact?

It's much more natural now. It has minimized erosion and made it less of a scoured gully. The water doesn't go rushing through. There are natural slow-down points, with the brush and grasses hanging over and the shading you need for aquatic life. It's a beautiful, verdant environment with tons of frogs and a lot of bird life. I would say it has brought awareness to all the neighbors about the need to take care of this creek.

Did government agencies share the cost?

We did get cost-share from the government because it was a full conservation effort. Napa County Resource Conservation District worked with us on it. We got a grant from the state Department of Water Resources' Urban Streams Restoration Program. And we were out-of-pocket some ourselves. But it was great to be able to do it and we absolutely would do it again. The creek is so much healthier.

Did the restoration have any impact on your vineyards?

We pulled our vineyards back from the creek a teeny bit to make more space. But, yes, it has helped with promoting beneficial insects. Getting more native plants out there helps prevent any sharpshooters from taking hold and possibly spreading Pierce's Disease. The sharpshooters like vinca and blackberries.

Was this just a "right thing to do" project? Or does it pay off somehow in grape quality, vine health or profit?

It was just the right thing to do. We feel so invested in this community, and I'm here to carry forward this multi-generational family estate.

In 2007, we joined 1% for the Planet. The premise is that you donate one percent of gross revenue every year to causes that support the environment. In 10 years, we've donated $634,000. We all have to do what we can to be good stewards of our natural environment.

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Riparian Habitat Restoration Cost-Share:
Check your local NRCS office for financial assistance opportunities **HERE**.

Erosion problems or prevention needed in the vineyard? Contact your local Resource Conservation District (RCD) to learn about the free resources available to assist with erosion prevention. Find your local RCD **HERE**.

CSWA Webinars:
For webinars and workshops on sustainable winegrowing and certification and more visit our CSWA calendar **HERE**.

May 31 Economic Tools Webinar

June 13 Sustainable Winegrowing Certification Webinar

June 15 Winery Water & Solid Waste Workshop, Napa

June 16 Ag Professionals Workshop, UC Davis

California Code of Sustainable Winegrowing Workbook:
Download individual chapters or the entire workbook to learn more about sustainability in your vineyard or winery **HERE**.



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Lisa Francioni

From: Wine Institute <Wine_Institute@mail.vresp.com>
Sent: Friday, May 12, 2017 6:07 AM
To: Lisa Francioni
Subject: News Briefs: TTB Receives 5% Funding Increase in Omnibus Bill

Monterey & Temecula FSMA Workshops, North Dakota Direct-to-Consumer Excise Tax

NEWS BRIEFS

Volume 24, Number 18 | May 12, 2017

IN THIS ISSUE:

- Board Meeting June 11-13 San Diego
- FSMA Workshops in Monterey May 30 & Temecula June 1
- TTB Receives 5% Funding Increase
- DTC Shipping & Tax Webinar May 17
- California Legislative Update
- New North Dakota DTC Excise Tax
- CSWA Releases New Economic Tools
- California Wines Summit 2017
- 2016 Wine Sales Report
- Submit: Publicity for Winery Summer Experiences
- Apply: Leopold Conservation Award

MEMBER RELATIONS

Register for Wine Institute Annual Meeting of Members June 11-13, San Diego



Registration for the 83rd Annual Membership and Board of Directors Meeting at the Fairmont Grand Del Mar, June 11-13, 2017 is now open. To register for the meeting and additional events, click this link. To book a hotel room and receive the special Wine Institute rate of $325/night at Fairmont Grand Del Mar please click this link or call 855/314-2030 and reference the Wine Institute Group. Visit the members-only website for information: http://members.wineinstitute.org.

FEDERAL COMPLIANCE

Food Safety Modernization Act Workshops Set for Monterey & Temecula

Wine Institute is pleased to announce two additional hands-on training sessions in Monterey (May 30) and Temecula (June 1) on how wineries can meet Food Safety Modernization Act (FSMA) regulations. Following the success of the March workshops, Allen Sayler of EAS Consulting will be returning to conduct the upcoming training sessions. The format and content of the upcoming workshops will be consistent with the topics discussed at the March workshops.

Click here to view the workshop agenda.

Monterey, May 30, 9-4pm – click here to register

Temecula, June 1, 9-4pm – click here to register

FEDERAL RELATIONS

Congress Enacts Needed Funding Increase for TTB

Last week, the U.S. Congress completed action on FY2017 government funding which included a 5% increase for TTB's annual operating budget. This marks the second year in a row that Wine Institute has been successful in advocating for an increased budget for TTB. TTB used new funds in the FY2016 budget to hire 20 new, full-time staff to help address critical areas such as COLA and formula approvals. Increased staffing helped reduce to four days the average processing time for COLAs. TTB is expected to use new FY2017 funds to help address issues at its National Revenue Center where permit applications or amendments are experiencing significant delays. Wine Institute will continue advocating for appropriate funding levels for TTB in future fiscal years.

DIRECT-TO-CONSUMER SHIPPING

Sales Tax & DTC Shipping Webinar with Steve Gross

Join experts Steve Gross of Wine Institute and Charles Maniace and Lauren Whitney of Sovos for a discussion of the top sales tax issues that wineries face in the direct-to-consumer market. Learn what actions wineries should consider in order to grow their businesses while staying up to date on complex regulations. Webinar will be held May 17, 2017 at 10 am PDT. Read more here.

CALIFORNIA RELATIONS

California Legislative Update

Bottle Bill: As previously reported, SB 168 (Wieckowski, D-Fremont) is pending legislation that would significantly reform the current bottle bill program, and also potentially include wine and spirits. SB 168 is pending in the Senate Appropriations Committee, which must pass the bill by May 26 for it to move forward. Members can find their state senator here or contact Senator Wieckowski, whose contact information can be found here.

Excise Tax: AB 479 (Gonzalez Fletcher & Garcia) proposed to eliminate the imposition of sales tax upon diaper and feminine hygiene products and to mitigate the lost revenue with an over 30% increase

on the distilled spirits excise tax. Wine Institute opposed the measure due to the poor precedent it would set with regard to excise tax policy. Wine Institute advocated alongside colleagues in the spirits and hospitality industries to successfully defeat this legislation. The Assembly Revenue & Taxation Committee overwhelmingly defeated the measure on a 1-6 vote on May 9.

DIRECT-TO-CONSUMER SHIPPING

North Dakota Clarifies DTC Sales & Use Tax Requirements

North Dakota tax laws are being interpreted by the Office of State Tax Commissioner to require out-of-state direct shipper licensees to collect and remit local sales and use taxes on wine shipped to consumers in ND, in addition to the 7% state alcohol beverage gross receipts tax. A winery that has been issued a Direct Shipper license is required to collect local sales and use taxes even if the licensee does not have a business presence, such as employees or deliveries using the licensee's own vehicles, within the local taxing jurisdiction. The 7% state alcohol beverage gross receipts tax and local sales and use taxes are also imposed on the cost of shipping.

Prior to making shipments into North Dakota, a winery must obtain a Direct Shipper license and a Sales and Use Tax Permit. Taxpayers may choose to file paper sales and use tax returns or file online via the North Dakota Taxpayer Access Point (TAP). A return form will be mailed for all paper filers and an email reminder for all TAP filers based on the filing frequency assigned at the time of registration. A return must be filed for each reporting period even if no sales were made or no tax is due.

Direct Shippers are required to pay an annual $50 license fee, pay liquor tax on the total gallons of wine shipped to North Dakota consumers and file a direct shipper's annual tax report. More information on the direct shipper license and reporting requirements are available on the State Tax Commission website www.nd.gov/tax/user/businesses.

SUSTAINABILITY

CSWA Releases New Cost Benefit Tools

The California Sustainable Winegrowing Alliance (CSWA) recently released new economic tools to help growers and vintners assess costs and benefits of adopting specific sustainable winegrowing practices. Growers can use the Excel-based calculators to support decisions on different types of sprayers, compare dust mitigation methods and develop a sustainable water management strategy. They can also use a web-based tool to evaluate costs and potential savings from implementing different trunk disease prevention practices. Vintners can use the tools to evaluate winery water efficiency and identify hot spots, estimate the true cost of water, and conduct a solid waste audit. In addition, a certification cost benefit evaluation tool can be used by growers and vintners to evaluate the expected benefits and investments associated with the first year of certification.

The 2.5-year project was funded by a CDFA Specialty Crop Block Grant and involved an advisory group comprised of agricultural economists from Cal Poly, UC Davis, Fresno State and Sacramento State, regional association partners and other experts. The new Economic Tools and upcoming workshop information can be found at: www.sustainablewinegrowing.org/economic-tools.php.

INTERNATIONAL MARKETING

International California Wines Summit to Feature 500 Wines, 200 Vintners, 50 AVAs

Wine Institute's "California Wines Summit" taking place May 15-20, 2017 will host 30 key wine media and trade from 10 countries: Canada, United Kingdom, Hong Kong, Japan, China, Sweden, Mexico, the Netherlands, Switzerland and Ireland. The program will include presentations on the state of the California wine industry and sustainability as well as in-depth tastings led by top U.S. wine media and trade.

The 10 markets represented by the Summit guests account for more than 80 percent of the value of California wine exports. Read the complete press release here.

STATISTICS

2016 California Wine Sales Climb to $34.1 Billion



California wine shipments to the U.S. reached an estimated retail value of $34.1 billion in 2016. The state shipped an all-time high of 238 million cases within the U.S. in 2016, up 2% from the previous year.

California wine sales to all markets, both domestic and international, were 285 million cases in 2016, a record high. Read the complete press release.

COMMUNICATIONS

Submit Top Summer Experiences at Wineries for Upcoming News Release

Wine Institute is preparing a national news release on “Great Summer Winery Experiences in California” to kick off the summer travel season. Submit region or winery experiences that highlight summertime, such as summer concerts or festivals, unique winery tours, top picnic spots or any special summer activities by May 18. A selection of experiences from around the state will be included in the release, at www.discovercaliforniawines.com and in story pitches. Include with the submission:

- Winery or Region Experience Name
- Brief description
- Website for more info
- Photos for release to media

Email info to: communications@wineinstitute.org by May 18.

SUSTAINABLE WINEGROWING

California Leopold Conservation Award Seeking Nominees

The Leopold Conservation award recognizes California landowners committed to responsible stewardship and land management. The award is presented by Sand County Foundation in partnership with Sustainable Conservation and the California Farm Bureau Federation. Past recipients of this “Nobel Prize of Agriculture” include dairies, ranchers, and winegrowers. The deadline for nominations is July 8 and the grand prize of $10,000 and an Aldo Leopold crystal will be presented at the California Farm Bureau Federation's annual convention in December. Click here for more information or contact Sustainable Conservation at 415/977-0380 x317.

WINE INSTITUTE CALENDAR

2017	
May 17	DTC & Sales Tax Webinar, 10 am.
May 30	FSMA Workshop, 9 am-4 pm, Monterey.
May 31	Economic Tools for Sustainable Winegrowing Webinar, 10-12 noon. No charge.
June 1	FSMA Workshop, 9 am-4 pm, Temecula.
June 11-13	Wine Institute 83rd Annual Membership & Board Meeting, Fairmont Grand Del Mar, San Diego
June 13	Sustainability Self-Assessment & Certification Webinar, 10-11:30 am. No charge.

June 15	Economic Tools for Winery Water & Solid Waste Workshop, 9 am-12 noon, Napa.
June 16	Sustainable Winegrowing Workshop for Ag Professionals, 9 am-2:30 pm, UC Davis. No charge.
December 3-5	Wine Institute Winter Board Meeting, The Lodge at Pebble Beach

Wine Institute prohibits discrimination in its programs on the basis of race, color, national origin, sex, religion, age, disability and marital or familial status. Persons with disabilities who require alternative means of communication of program information (Braille, large print, audiotape, etc.) should contact communications@wineinstitute.org

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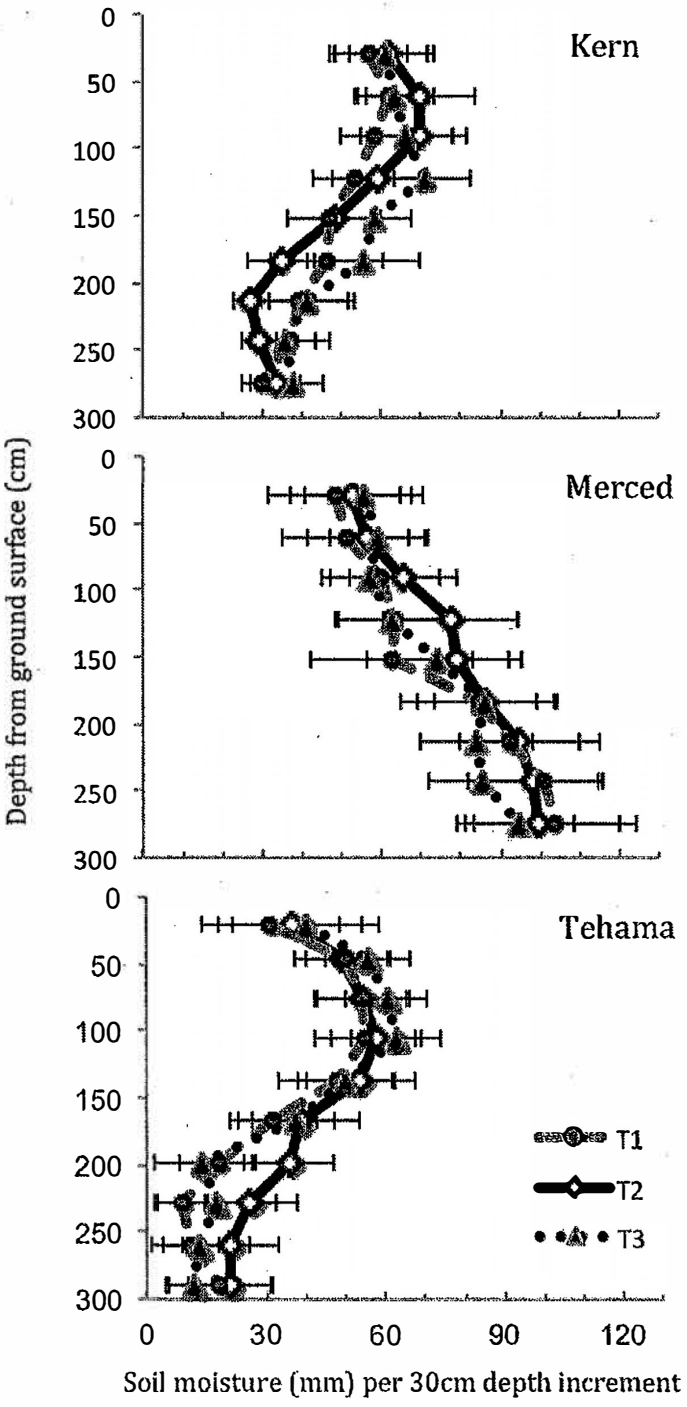


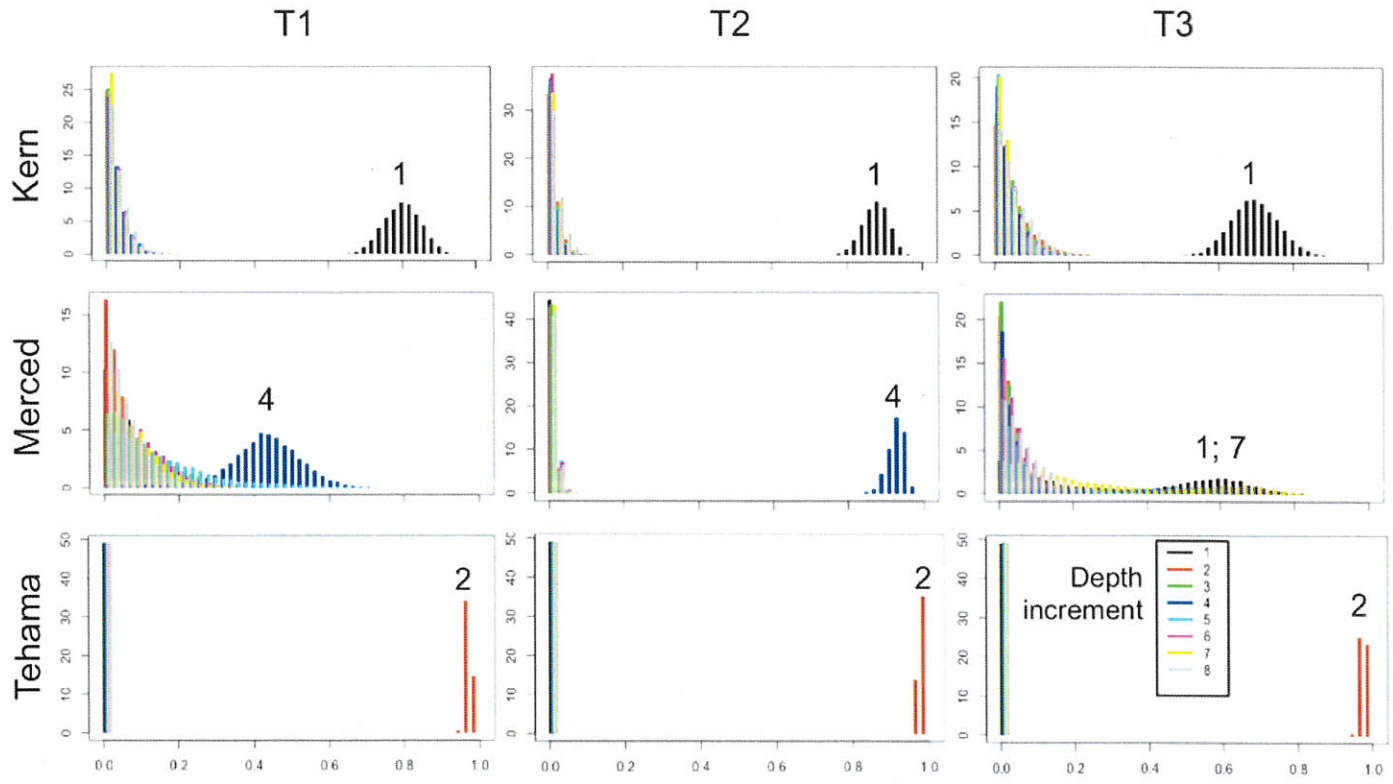
Figure 2.1. Soil moisture by depth for all three orchards. Error bars indicate standard deviation. Data were averaged to produce curves of average yearly soil moisture in 2016 by depth and temporally 'binned' to evaluate moisture conditions representative of early (Feb-Apr), mid (May-Jul), and late (Aug-Oct) season periods.

Table 2.3

Depth Increment	ıproximate Depth (cm)
1	8
2	23
3	38
4	53
5	70
6	90
7	110
8	130

Figure 2.3. Statistical likelihood presented in histogram format of the depth of water uptake source for tree xylem water by orchard and treatment for both May (I) and July (II). Depths of maximum likelihood are numbered on each graph.

I. May



II. July

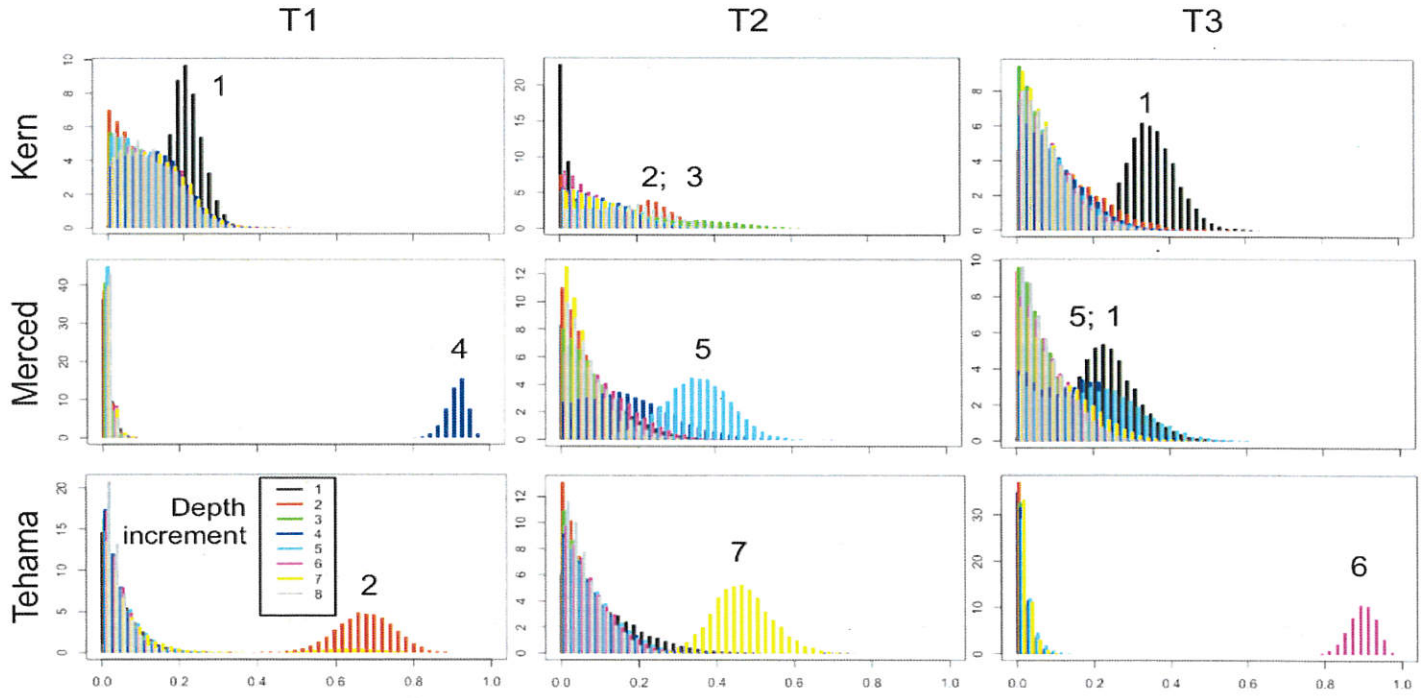

T1
T2
T3
Kern
Merced
Tehama
1
2; 3
1
4
5
5; 1
2
7
6
Depth increment
1
2
3
4
5
6
7
8

Figure 2.4. δ2H and δ18O isotopic signatures in soil water by depth for each orchard and treatment in May and July

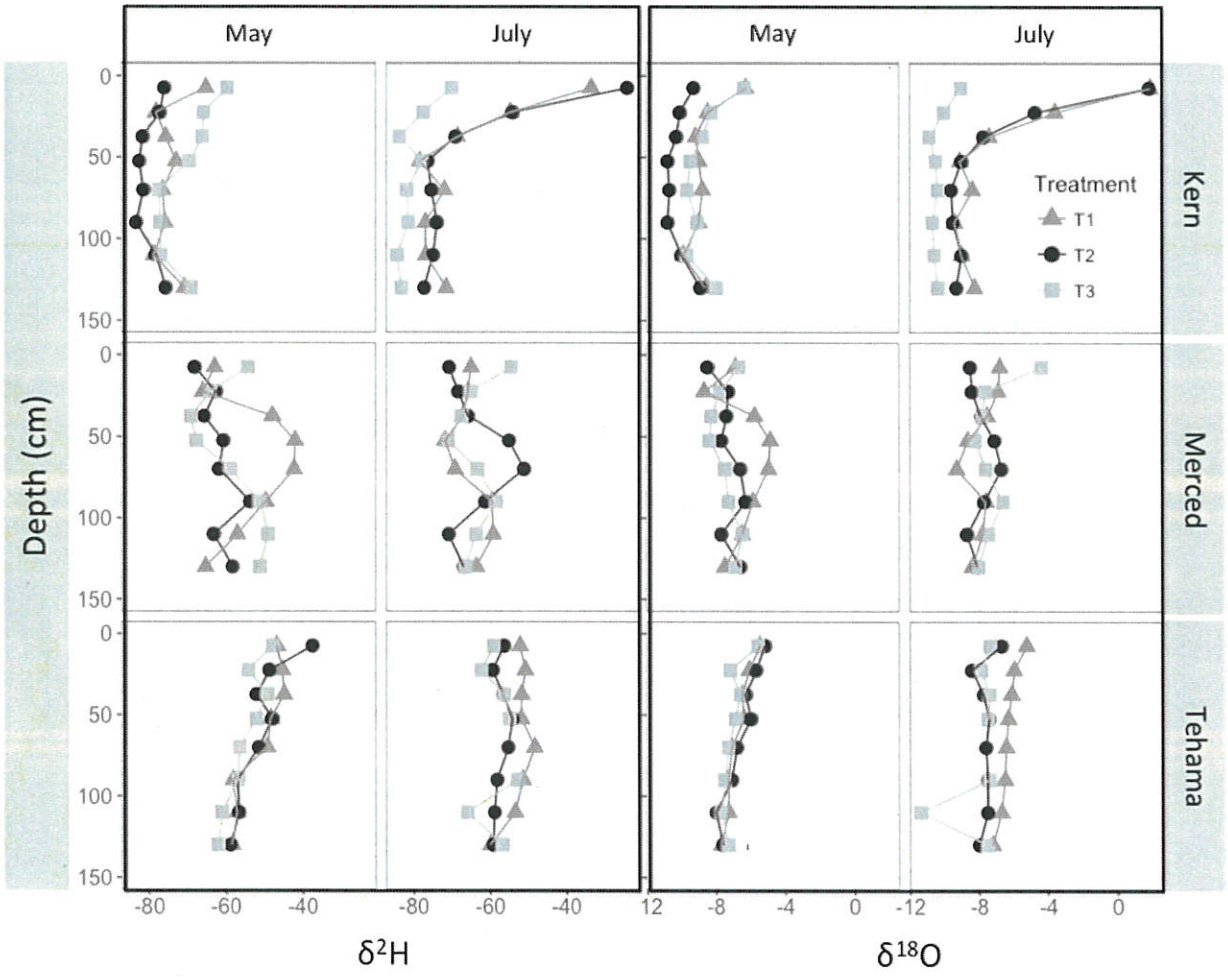
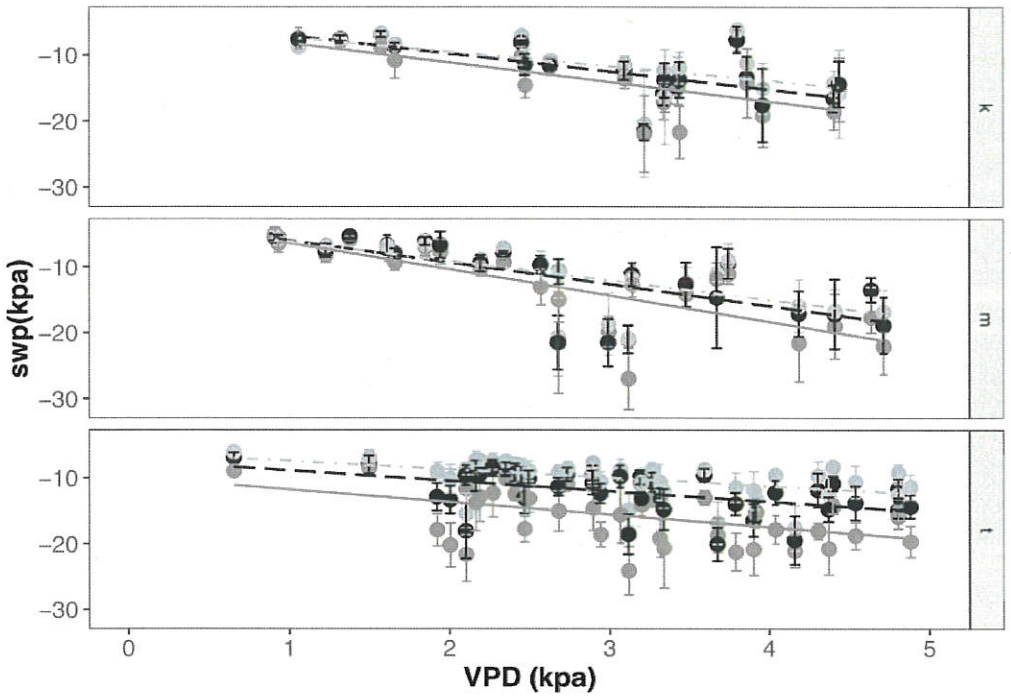
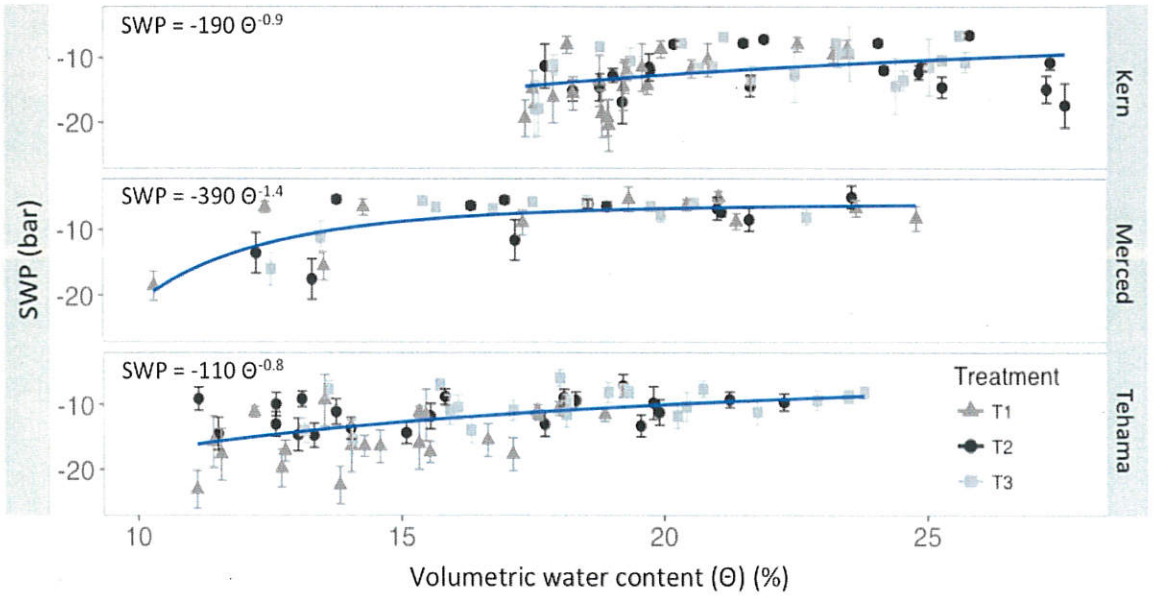


Figure 2.2. ET-driven stress measured as changes in stem water potential (SWP) in response to VPD (I) and volumetric water content (II) by orchard. Data is shaded by treatment. Lines of best fit in graph I are linear regressions for each orchard and treatment combination. Linear regression statistics are displayed by orchard for Kern and Merced and by treatment for Tehama, where treatment regressions are statistically different. Lines of best fit in graph II are power functions ($SWP = a\Theta^b$) and significance level is displayed for b coefficient.

I.

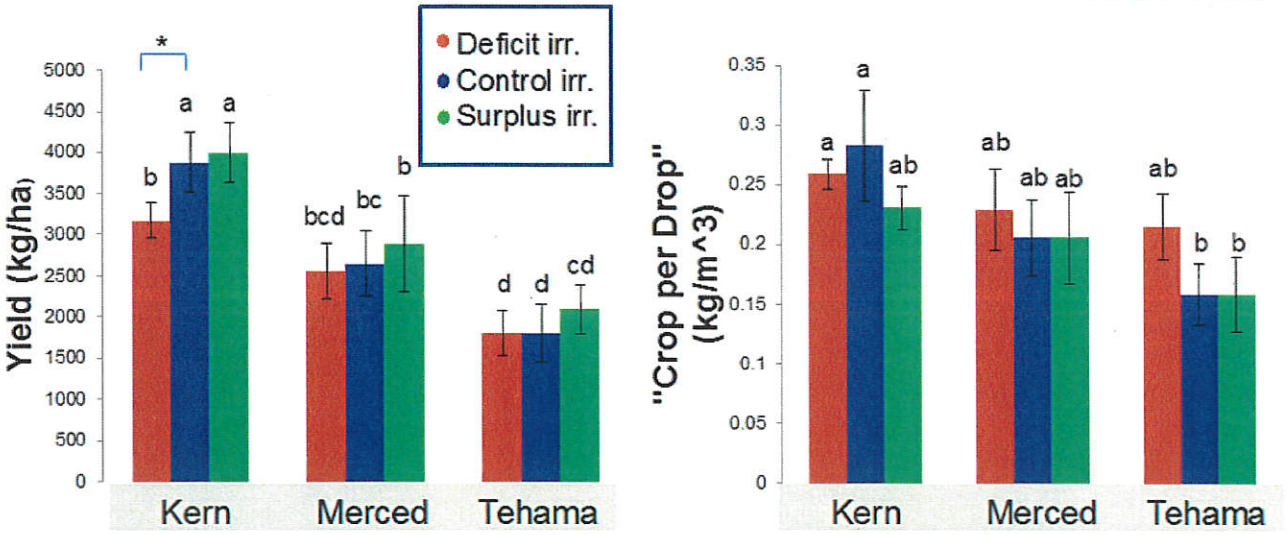


II.



SCB14040 Attachment 2

Orchard Level

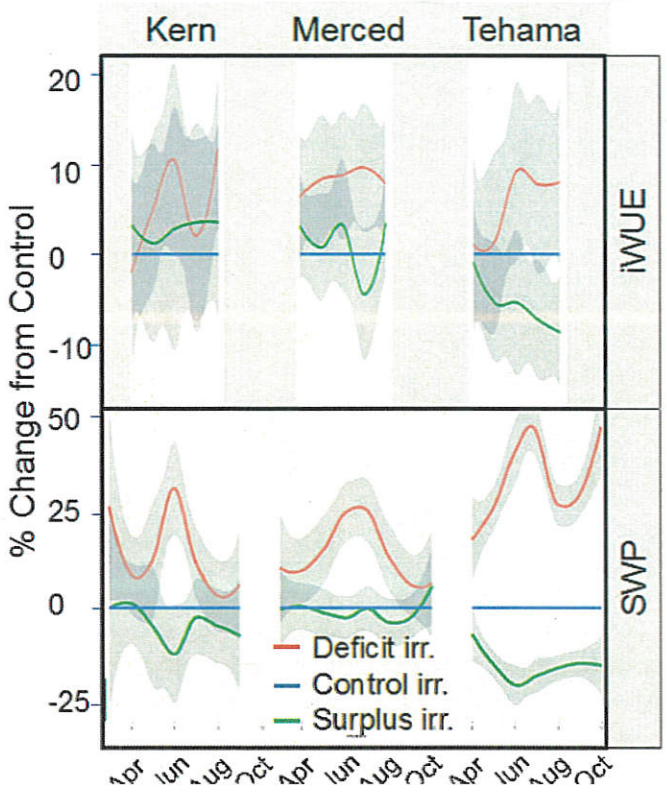


Significant differences based on Tukey HSD 95% confidence level

- Kern has the only significant decrease in yield due to deficit irrigation
- "Crop/drop" values aren't affected by irrigation treatment

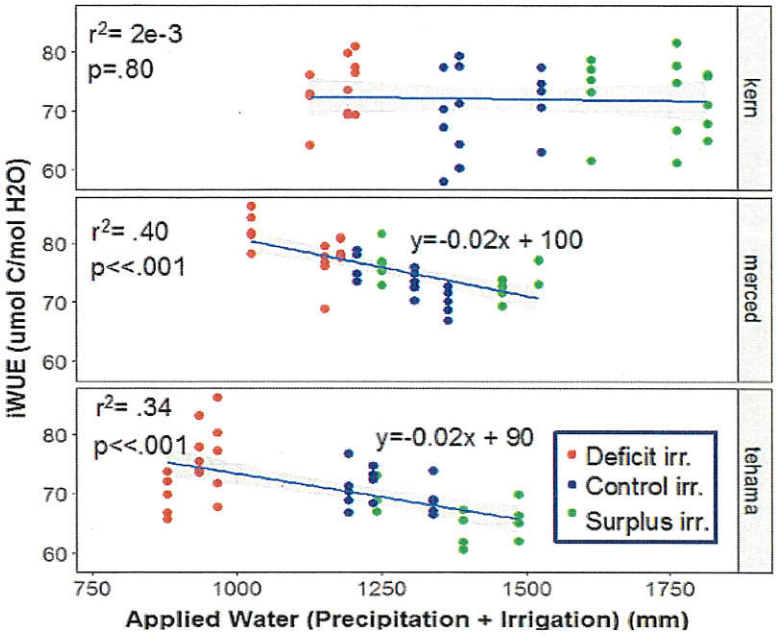
Physiological stress response fluctuates over growing season

Tree Level



- Deficit irrigated trees are more stressed relative to control
- Key Difference:
  - SWP is a "snapshot" of stress, useful for irrigation management
  - iWUE is an integration of stress over leaf-growth period, useful for growing-season response

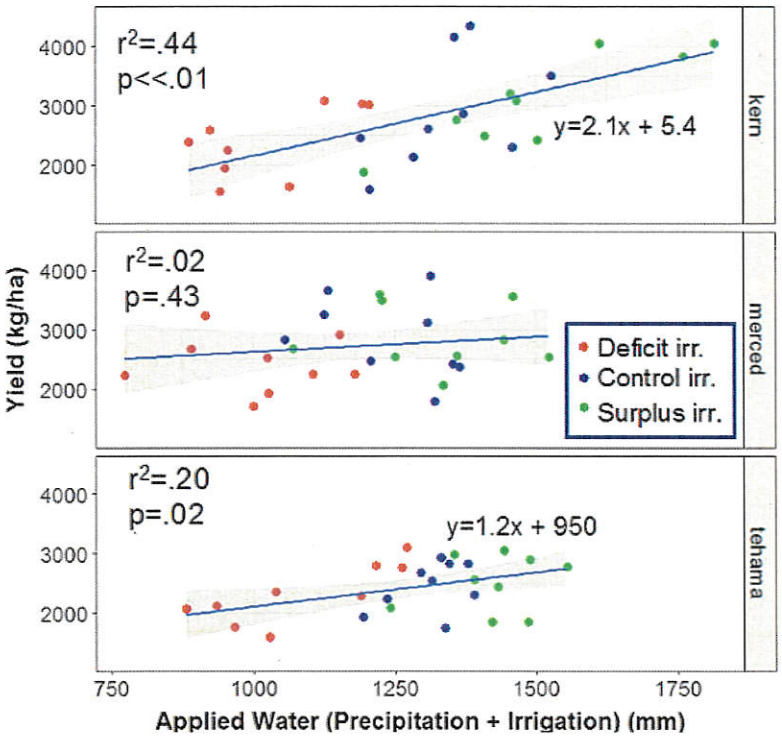
iWUE has orchard-specific relationship to water applied



- Kern has no relationship between iWUE and applied water
- Merced and Tehama have the expected relationship between iWUE and applied water

Yield has a contrasting, orchard-specific response to water applied

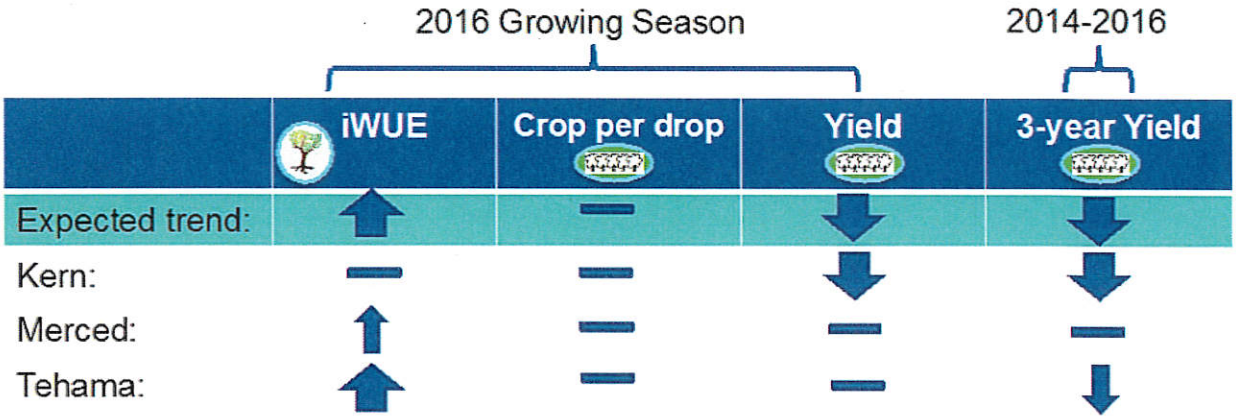
Orchard Level



- Compiled data from 2014-2016
- Kern has significant increase in yield with increased irrigation
- Merced has no relationship between yield and water amount
- Tehama has an upward trend, but smaller than Kern

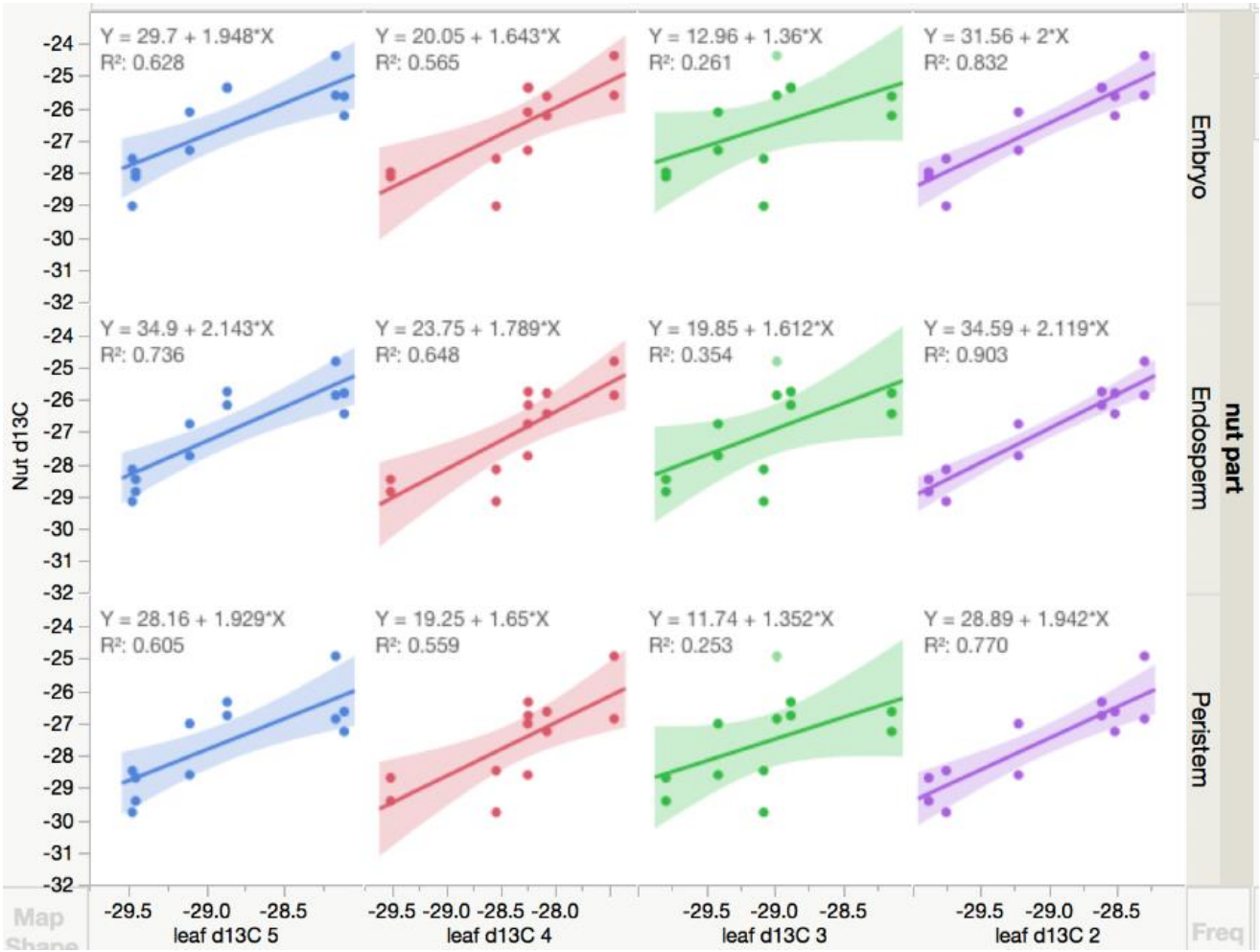
Summary: physiology and yield response to deficit irrigation

Tree & Orchard Levels



- **Kern**: reduction in yield, but not reflected in tree physiology
- **Merced**: physiology responds to water stress, yet tree productivity is maintained. **Ideal for deficit irrigation.**
- **Tehama**: trees sensitive to water stress, slight reduction in yield over time. Suitable for deficit irrigation.

SCB14040 - Attachment 3
Relationship between different parts of almond kernel and leaf d13C showing a strong connection between foliar carbon-water exchange and nut carbon isotope ratios. Decreasing d13C values indicate decreasing iWUE.



Average isotopic ratios of nitrogen (d15N) and d13C measured in different parts of almond kernels for each irrigation treatment across sites. Differences in d13C are statistically significant between deficit (70% replenishment) and excess irrigation (110% replenishment) treatments, showing that kernels preserve stress signals and integrate the effect of leaf iWUE (higher in Treat 70) throughout the season. Average differences in d15N values indicate higher N-use efficiency in Treat 110, which is attributed to larger and more productive canopies. No differences were found for kernel C/N ratios (data not shown).

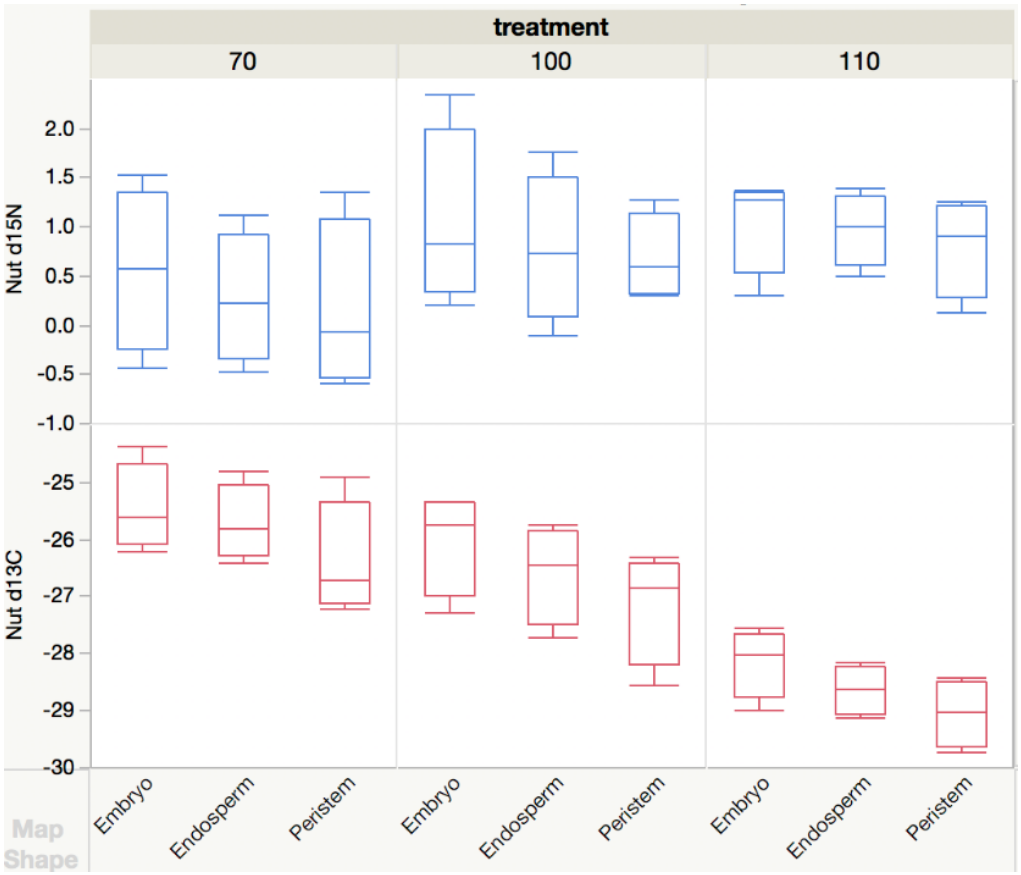

treatment
70
100
110
Nut d15N
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
Nut d13C
-25
-26
-27
-28
-29
-30
Embryo
Endosperm
Peristem
Map Shape

Table 1. Calculated (ETc) and reference (ETo) evapotraspiration losses and crop coefficients (Kc) at each study site from 2013 to 2015.

Site	Date	Week	Kc	Mean ETc	Stderr Etc	Mean Eto	Stderr Eto
Kern	2/18/15	7	0.430	0.961	0.061	2.236	0.142
Kern	2/25/15	8	0.490	1.113	0.058	2.271	0.119
Kern	6/4/14	9	0.500	1.338	0.070	2.679	0.126
Kern	6/11/14	10	0.565	2.063	0.062	3.678	0.098
Kern	6/18/14	11	0.630	2.489	0.081	3.958	0.115
Kern	6/25/14	12	0.685	2.966	0.095	4.319	0.116
Kern	7/2/14	13	0.725	3.122	0.129	4.276	0.144
Kern	7/9/14	14	0.760	3.411	0.112	4.513	0.169
Kern	7/16/14	15	0.795	4.190	0.075	5.270	0.082
Kern	7/23/14	16	0.825	4.347	0.144	5.272	0.174
Kern	7/30/14	17	0.860	5.563	0.142	6.470	0.160
Kern	8/6/14	18	0.895	4.884	0.166	5.456	0.178
Kern	8/13/14	19	0.925	5.599	0.204	6.086	0.247
Kern	8/20/14	20	0.960	5.535	0.170	5.786	0.197
Kern	8/27/14	21	0.985	6.583	0.114	6.688	0.121
Kern	9/3/14	22	1.010	7.435	0.122	7.366	0.128
Kern	9/10/14	23	1.030	7.445	0.252	7.239	0.253
Kern	9/17/14	24	1.055	7.929	0.100	7.511	0.073
Kern	9/24/14	25	1.070	7.946	0.117	7.425	0.101
Kern	10/1/14	26	1.090	8.441	0.158	7.747	0.149
Kern	10/8/14	27	1.100	8.429	0.151	7.665	0.142
Kern	10/15/14	28	1.105	8.361	0.117	7.566	0.106
Kern	10/22/14	29	1.110	8.006	0.160	7.213	0.144
Kern	10/29/14	30	1.110	8.188	0.153	7.376	0.137
Kern	11/5/14	31	1.110	7.500	0.161	6.757	0.145
Kern	11/12/14	32	1.110	7.785	0.077	7.014	0.069
Kern	11/19/14	33	1.110	7.815	0.115	7.040	0.103
Kern	11/26/14	34	1.105	7.217	0.053	6.532	0.051
Kern	2/13/15	35	1.097	6.538	0.066	5.957	0.057
Kern	3/11/15	36	1.080	6.260	0.078	5.799	0.077
Kern	3/18/15	37	1.057	5.379	0.099	5.086	0.086
Kern	3/25/15	38	1.030	5.210	0.097	5.073	0.108
Kern	3/1/15	39	0.997	4.589	0.069	4.616	0.087
Kern	1/7/15	40	0.970	3.703	0.124	3.811	0.116
Kern	1/14/15	41	0.935	3.238	0.100	3.461	0.100
Kern	1/21/15	42	0.890	2.619	0.078	2.933	0.072
Kern	1/31/15	43	0.848	2.316	0.061	2.739	0.075
Kern	3/6/15	44	0.777	1.733	0.092	2.219	0.103
Kern	3/13/15	45	0.720	1.387	0.084	1.903	0.087
Kern	3/20/15	46	0.647	1.020	0.031	1.588	0.048
Kern	3/27/15	47	0.573	0.928	0.060	1.624	0.102
Kern	3/22/15	48	0.503	0.722	0.038	1.442	0.068
Merced	2/18/15	7	0.430	0.680	0.068	1.581	0.158
Merced	2/25/15	8	0.490	1.014	0.076	2.070	0.154
Merced	9/3/14	9	0.500	1.199	0.073	2.393	0.106

Merced	3/12/14	10	0.520	1.701	0.072	3.285	0.102
Merced	3/19/14	11	0.583	2.184	0.093	3.739	0.109
Merced	3/26/14	12	0.647	2.332	0.132	3.585	0.158
Merced	4/2/14	13	0.697	2.550	0.178	3.612	0.200
Merced	4/9/14	14	0.737	3.109	0.105	4.251	0.170
Merced	4/16/14	15	0.773	4.002	0.103	5.174	0.117
Merced	4/23/14	16	0.803	3.944	0.173	4.929	0.232
Merced	4/30/14	17	0.837	5.058	0.126	6.060	0.166
Merced	5/7/14	18	0.873	4.342	0.158	4.978	0.181
Merced	5/14/14	19	0.903	5.429	0.224	6.042	0.275
Merced	5/21/14	20	0.937	5.374	0.181	5.768	0.227
Merced	5/28/14	21	0.967	6.514	0.203	6.743	0.215
Merced	6/4/14	22	0.993	6.950	0.136	7.010	0.163
Merced	6/11/14	23	1.017	7.202	0.228	7.084	0.221
Merced	6/18/14	24	1.040	7.633	0.150	7.334	0.121
Merced	6/25/14	25	1.057	7.627	0.320	7.205	0.291
Merced	7/2/14	26	1.077	8.361	0.121	7.766	0.108
Merced	7/9/14	27	1.093	7.749	0.196	7.090	0.182
Merced	7/16/14	28	1.100	7.780	0.108	7.073	0.098
Merced	7/23/14	29	1.107	7.747	0.131	7.000	0.118
Merced	7/30/14	30	1.110	8.046	0.159	7.249	0.143
Merced	8/6/14	31	1.110	6.778	0.219	6.106	0.197
Merced	8/13/14	32	1.110	7.426	0.067	6.690	0.060
Merced	8/20/14	33	1.110	7.060	0.137	6.360	0.124
Merced	8/27/14	34	1.107	6.916	0.125	6.251	0.117
Merced	9/3/14	35	1.103	6.121	0.104	5.549	0.095
Merced	9/10/14	36	1.093	6.016	0.153	5.505	0.144
Merced	9/17/14	37	1.077	5.247	0.188	4.869	0.164
Merced	9/24/14	38	1.057	4.736	0.184	4.502	0.197
Merced	10/1/14	39	1.027	3.855	0.132	3.750	0.119
Merced	10/8/14	40	0.993	3.656	0.159	3.684	0.157
Merced	10/15/14	41	0.960	3.212	0.105	3.354	0.116
Merced	10/22/14	42	0.917	2.580	0.062	2.815	0.058
Merced	9/18/14	43	0.884	2.193	0.103	2.494	0.128
Merced	11/6/13	44	0.900	2.017	0.225	2.241	0.250
Merced	11/13/13	45	0.850	1.670	0.069	1.964	0.081
Merced	11/20/13	46	0.800	0.959	0.046	1.199	0.058
Merced	11/27/13	47	0.740	0.843	0.038	1.139	0.051
Merced	12/4/13	48	0.680	0.832	0.054	1.223	0.079
Tehama	2/11/15	6	0.430	0.725	0.060	1.687	0.139
Tehama	2/19/14	7	0.460	1.071	0.084	2.330	0.177
Tehama	2/26/14	8	0.530	1.585	0.130	2.972	0.217
Tehama	3/5/14	9	0.605	1.727	0.102	2.849	0.157
Tehama	3/12/14	10	0.587	1.841	0.118	3.187	0.205
Tehama	3/19/14	11	0.637	2.246	0.144	3.590	0.221
Tehama	3/26/14	12	0.687	2.204	0.191	3.135	0.226
Tehama	4/2/14	13	0.730	2.388	0.214	3.205	0.248
Tehama	4/9/14	14	0.770	3.167	0.169	4.144	0.226
Tehama	4/16/14	15	0.807	4.151	0.112	5.143	0.107

Tehama	4/23/14	16	0.837	4.096	0.270	4.853	0.288
Tehama	4/30/14	17	0.870	5.583	0.291	6.391	0.302
Tehama	5/7/14	18	0.907	4.555	0.242	5.013	0.242
Tehama	5/14/14	19	0.937	5.217	0.130	5.606	0.183
Tehama	5/21/14	20	0.963	5.540	0.173	5.763	0.185
Tehama	5/28/14	21	0.990	6.251	0.234	6.330	0.246
Tehama	6/4/14	22	1.013	7.051	0.233	6.964	0.228
Tehama	6/11/14	23	1.040	7.371	0.291	7.096	0.286
Tehama	6/18/14	24	1.060	7.142	0.125	6.740	0.112
Tehama	6/25/14	25	1.073	6.939	0.326	6.464	0.296
Tehama	7/2/14	26	1.087	8.037	0.182	7.396	0.161
Tehama	7/9/14	27	1.100	7.216	0.214	6.562	0.197
Tehama	7/16/14	28	1.103	7.545	0.131	6.838	0.118
Tehama	7/23/14	29	1.107	7.432	0.147	6.715	0.131
Tehama	7/30/14	30	1.110	7.393	0.188	6.660	0.169
Tehama	8/6/14	31	1.110	6.021	0.263	5.425	0.237
Tehama	8/13/14	32	1.110	6.677	0.077	6.016	0.069
Tehama	8/20/14	33	1.107	6.275	0.112	5.670	0.101
Tehama	8/27/14	34	1.100	6.130	0.082	5.574	0.078
Tehama	9/3/14	35	1.090	5.830	0.192	5.347	0.171
Tehama	9/10/14	36	1.073	5.364	0.203	4.998	0.188
Tehama	9/17/14	37	1.050	4.519	0.276	4.283	0.244
Tehama	9/24/14	38	1.023	4.035	0.131	3.958	0.141
Tehama	10/1/14	39	0.990	3.976	0.221	4.024	0.226
Tehama	10/8/14	40	0.957	3.493	0.172	3.651	0.180
Tehama	10/15/14	41	0.920	3.040	0.202	3.314	0.209
Tehama	10/22/14	42	0.873	2.094	0.125	2.440	0.171
Tehama	10/28/14	43	0.818	1.689	0.098	2.098	0.144
Tehama	10/7/14	44	0.712	1.651	0.185	2.305	0.244
Tehama	11/13/13	45	0.680	1.422	0.164	2.091	0.242
Tehama	11/20/13	46	0.600	1.341	0.429	2.234	0.715
Tehama	11/27/13	47	0.520	0.646	0.051	1.241	0.098
Tehama	12/4/13	48	0.450	0.567	0.128	1.260	0.285

Table 2. Average kernel production and standard errors by site, year, and irrigation treatment.

Site	Year	ETc replenishment (%)	Kernel production (lb/ac)	Stderr
Kern	2013	70	2672.3	211.3
Kern	2013	80	3064.5	146.2
Kern	2013	90	3543.0	96.5
Kern	2013	100	3313.7	161.9
Kern	2013	110	3200.0	195.4
Kern	2014	70	1610.0	74.7
Kern	2014	80	1837.3	171.6
Kern	2014	90	1959.2	212.1
Kern	2014	100	1872.2	156.8
Kern	2014	110	1890.8	101.0
Kern	2015	70	2139.9	65.9
Kern	2015	80	2365.1	40.9
Kern	2015	90	2347.6	76.8
Kern	2015	100	2414.4	103.8
Kern	2015	110	2771.8	77.8
Merced	2013	70	2904.7	243.1
Merced	2013	80	2717.7	425.7
Merced	2013	90	2617.4	114.4
Merced	2013	100	3235.4	232.7
Merced	2013	110	3037.0	110.2
Merced	2014	70	2423.5	255.9
Merced	2014	80	2640.9	356.1
Merced	2014	90	2535.1	132.0
Merced	2014	100	2899.9	210.7
Merced	2014	110	2906.3	260.4
Merced	2015	70	1746.4	139.9
Merced	2015	80	1822.2	273.6
Merced	2015	90	2079.6	203.7
Merced	2015	100	2414.4	559.8
Merced	2015	110	2216.7	198.4
Tehama	2013	74	2208.9	113.0
Tehama	2013	86	2306.4	114.0
Tehama	2013	100	2150.6	63.0
Tehama	2013	116	2143.0	223.2
Tehama	2014	74	2343.0	126.6
Tehama	2014	86	2261.0	142.8
Tehama	2014	100	2314.9	79.5
Tehama	2014	116	2262.5	149.4
Tehama	2015	74	2169.8	160.6
Tehama	2015	86	2379.8	111.7
Tehama	2015	100	2234.5	132.7
Tehama	2015	116	2442.9	86.9

Figure 1. Cumulative calculated evapotranspiration (ETc) over time at each site. Red lines show average water loss. Crop coefficients and ETo used for the ETc calculation are shown in Table1.

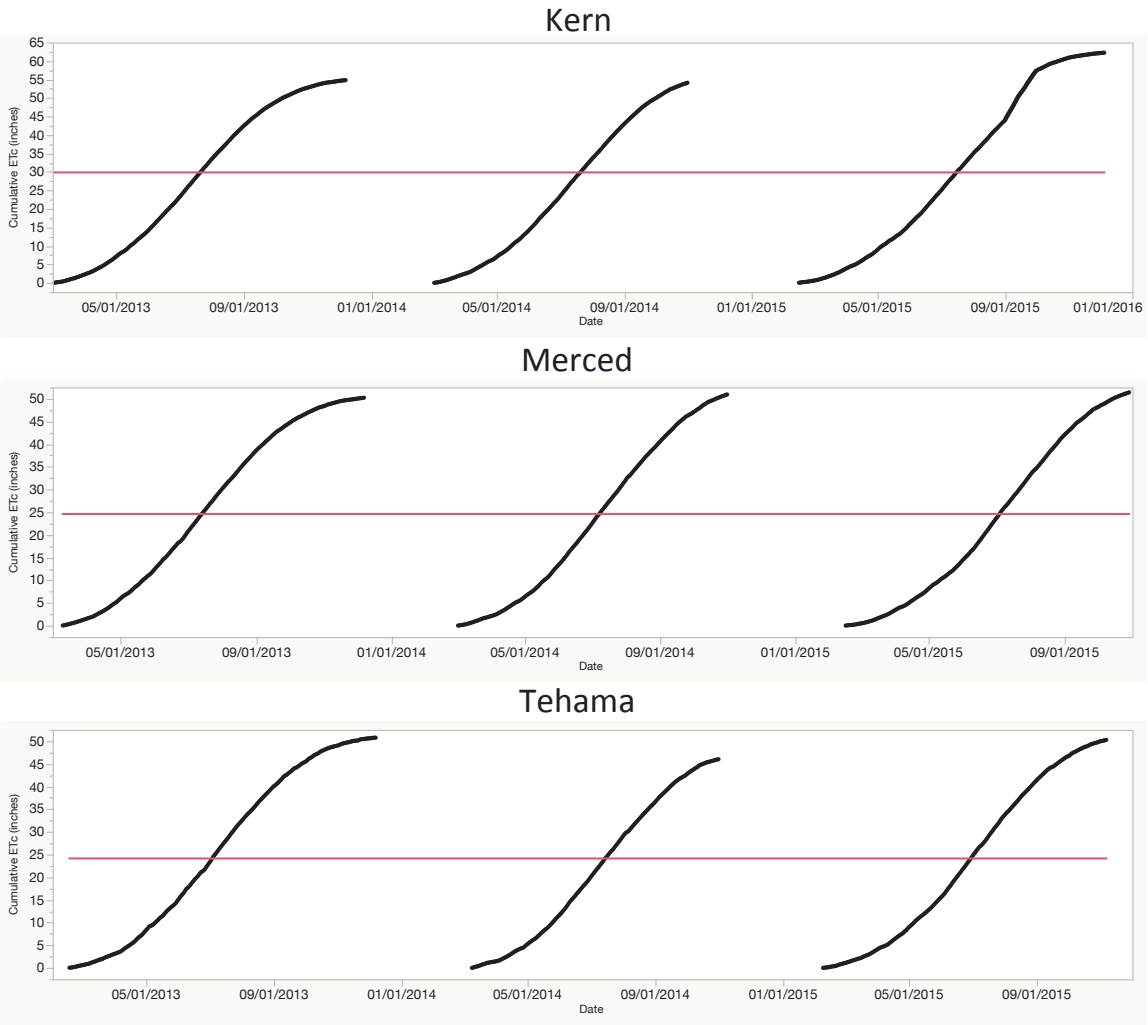
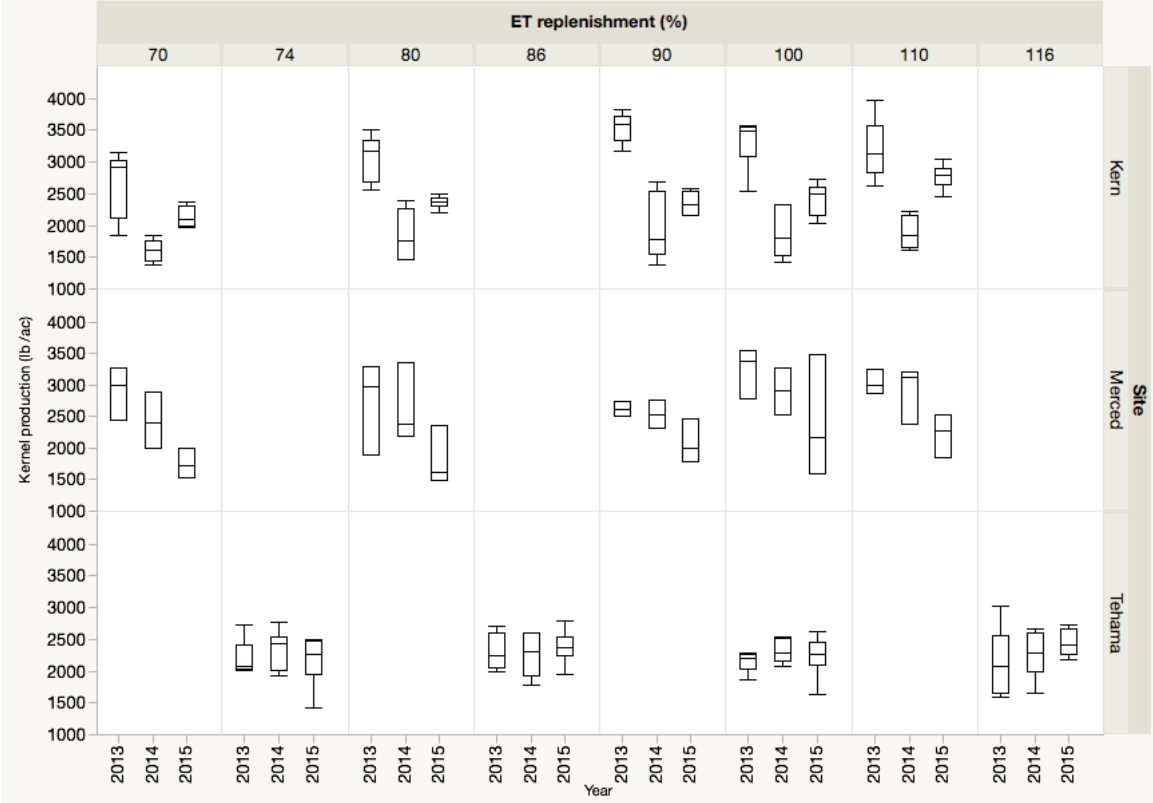


Figure 2. Summary of yield production by site, year, and irrigation treatments. Actual values and standard errors are shown in Table 2.



SCB14041: Attachment 1 - CASP BMP Educational Priorities

Ranked Educational Priorities by Management Area, Environmental or Grower Economic Impacts, and Assessment Results

Educational Priorities for Energy BMPs based on Environmental Impacts

BMP Short Name	BMP#	Rank	BMP Full Detail
Variable-Speed Drive Pumps	E26	1	Variable-speed drives were installed on pumps for systems experiencing variable loads (for electric pumps).
Regulated Deficit Irrigation	I62	2	I use Regulated Deficit Irrigation (RDI) where appropriate during the season.
Real-Time Crop Evapotranspiration (ETc)	I61	3	I irrigate following real-time evapotranspiration (ETc) data at least weekly and calculating the water volume leaving the plant and soil.
Variable-Rate Fertilization Technology	N9g	4	Plant tissue tests have been taken prior to the application of nutrients and maps of the testing results are used to guide precision fertilizer applications (variable rate technology).
Low-Emission Transportation	A31	5	Low-emission motorized vehicles (i.e., flex fuel, hybrids or biodiesel) were used by the business.
Computer-Controlled Irrigation	E27	6	The irrigation system was computer controlled (e.g., by a SCADA system) to allow users to monitor flow rates and/or other efficiency data about the system.

Educational Priorities for Energy BMPs based on Grower Economic Impacts

BMP Short Name	BMP#	Rank	BMP Full Detail
Real-Time Crop Evapotranspiration (ETc)	I61	1	I irrigate following real-time evapotranspiration (ETc) data at least weekly and calculating the water volume leaving the plant and soil.
Variable-Rate Fertilization Technology	N9g	2	Plant tissue tests have been taken prior to the application of nutrients and maps of the testing results are used to guide precision fertilizer applications (variable rate technology).
Regulated Deficit Irrigation	I62	3	I use Regulated Deficit Irrigation (RDI) where appropriate during the season.
Variable-Speed Drive Pumps	E26	4	Variable-speed drives were installed on pumps for systems experiencing variable loads (for electric pumps).
Nutrient Management plan	N18	5	In addition to the above practices, I have written a comprehensive nutrient management plan and budget for this orchard which guides my annual nutrient management.
Computer-Controlled Irrigation	E27	6	The irrigation system was computer controlled (e.g., by a SCADA system) to allow users to monitor flow rates and/or other efficiency data about the system.

Educational Priorities for Air BMPs based on Environmental Impacts

BMP Short Name	BMP#	Rank	BMP Full Detail
Reduced Diesel Engine Emissions	A34	1	Diesel engines have been replaced (or retrofitted) with technology relying on cleaner-burning fuel (e.g., propane, natural gas or biodiesel) or electricity.
Regulated Deficit Irrigation	I62	2	I use Regulated Deficit Irrigation (RDI) where appropriate during the season.
Variable-Speed Drive Pumps	E26	3	Variable-speed drives were installed on pumps for systems experiencing variable loads (for electric pumps).
Cover Cropping	A6	4	Cover cropping was used to stabilize and build soil (increase organic matter) while providing other benefits (reducing weeds, increasing natural enemies of pests, etc.).
Low-Emission Transportation	A31	5	Low-emission motorized vehicles (i.e., flex fuel, hybrids or biodiesel) were used by the business.
On-site Renewable Energy	A35	6	On-site renewable energy sources (e.g., solar or wind) supplied at least some electricity requirements.

Educational Priorities for Air BMPs based on Grower Economic Impacts

BMP Short Name	BMP#	Rank	BMP Full Detail
Real-Time Crop Evapotranspiration (ETc)	I61	1	I irrigate following real-time evapotranspiration (ETc) data at least weekly and calculating the water volume leaving the plant and soil.
Regulated Deficit Irrigation	I62	2	I use Regulated Deficit Irrigation (RDI) where appropriate during the season.
Variable-Speed Drive Pumps	E26	3	Variable-speed drives were installed on pumps for systems experiencing variable loads (for electric pumps).
Cover Cropping	A6	4	Cover cropping was used to stabilize and build soil (increase organic matter) while providing other benefits (reducing weeds, increasing natural enemies of pests, etc.).
Reduced Diesel Engine Emissions	A34	5	Diesel engines have been replaced (or retrofitted) with technology relying on cleaner-burning fuel (e.g., propane, natural gas or biodiesel) or electricity.
On-site Renewable Energy	A35	6	On-site renewable energy sources (e.g., solar or wind) supplied at least some electricity requirements.

Educational Priorities for Water Usage BMPs based on Environmental Impacts

BMP Short Name	BMP#	Rank	BMP Full Detail
Real-Time Crop Evapotranspiration (ETc)	I61	1	I irrigate following real-time evapotranspiration (ETc) data at least weekly and calculating the water volume leaving the plant and soil.
Regulated Deficit Irrigation	I62	2	I use Regulated Deficit Irrigation (RDI) where appropriate during the season.
Cover Cropping	A6	3	Cover cropping was used to stabilize and build soil (increase organic matter) while providing other benefits (reducing weeds, increasing natural enemies of pests, etc.).

Educational Priorities for Water Usage BMPs based on Grower Economic Impacts

BMP Short Name	BMP#	Rank	BMP Full Detail
Real-Time Crop Evapotranspiration (ETc)	I61	1	I irrigate following real-time evapotranspiration (ETc) data at least weekly and calculating the water volume leaving the plant and soil.
Regulated Deficit Irrigation	I62	3	I use Regulated Deficit Irrigation (RDI) where appropriate during the season.
Cover Cropping	A6	3	Cover cropping was used to stabilize and build soil (increase organic matter) while providing other benefits (reducing weeds, increasing natural enemies of pests, etc.).

Educational Priorities for Water Quality BMPs based on Environmental Impacts

BMP Short Name	BMP#	Rank	BMP Full Detail
Variable-Rate Fertilization Technology	N9g	1	Plant tissue tests have been taken prior to the application of nutrients and maps of the testing results are used to guide precision fertilizer applications (variable rate technology).
No Dormant Sprays in Last 5 Years	P105	2	How many times have dormant sprays been applied to this orchard in the past five years?**0**
Specialized Spray Equipment	P61	3	Ultra-low-volume spray equipment or target-sensing sprayers (e.g., SmartSpray® or WeedSeeker® technology) were used to reduce spray volumes or amounts of pesticides.

Educational Priorities for Water Quality BMPs based on Grower Economic Impacts

BMP Short Name	BMP#	Rank	BMP Full Detail
Variable-Rate Fertilization Technology	N9g	1	Plant tissue tests have been taken prior to the application of nutrients and maps of the testing results are used to guide precision fertilizer applications (variable rate technology).
No Dormant Sprays in Last 5 Years	P105	2	How many times have dormant sprays been applied to this orchard in the past five years?**0**
Specialized Spray Equipment	P61	3	Ultra-low-volume spray equipment or target-sensing sprayers (e.g., SmartSpray® or WeedSeeker® technology) were used to reduce spray volumes or amounts of pesticides.

Educational Priorities for Nutrient BMPs based on Environmental Impacts

BMP Short Name	BMP#	Rank	BMP Full Detail
Variable-Rate Fertilization Technology	N9g	1	Plant tissue tests have been taken prior to the application of nutrients and maps of the testing results are used to guide precision fertilizer applications (variable rate technology).
Vegetation in Unfarmed Areas	A7	2	Natural habitat has been maintained and/or perennial vegetation (hedgerows or trees) has been planted or retained in unfarmed areas within or surrounding the orchard.
Enhanced Infiltration via Tillage	I71h	3	My soil surface seals, and I use tillage to enhance water penetration.
Multiple-Source Nitrogen Calculations	N6	4	If compost, manure, or nitrogen-fixing cover crops were used, their nitrogen contribution to the crop was estimated and used in calculating the total nitrogen applied.
Retained Nutrients via Soil Enhancements	N17b	5	To reduce the likelihood of leaching or runoff, I use organic matter, filter strips, or cover crops.
Nitrogen-Fixing Cover Crops	N5d	6	In past year, the following source of nitrogen was utilized: nitrogen-fixing cover crops.

Educational Priorities for Nutrient BMPs based on Grower Economic Impacts

BMP Short Name	BMP#	Rank	BMP Full Detail
Variable-Rate Fertilization Technology	N9g	1	Plant tissue tests have been taken prior to the application of nutrients and maps of the testing results are used to guide precision fertilizer applications (variable rate technology).
Real-Time Crop Evapotranspiration (ETc)	I61	2	I irrigate following real-time evapotranspiration (ETc) data at least weekly and calculating the water volume leaving the plant and soil.
Nutrient Management Plan	N18	3	In addition to the above practices, I have written a comprehensive nutrient management plan and budget for this orchard which guides my annual nutrient management.
Enhanced Infiltration via Tillage	I71h	4	My soil surface seals, and I use tillage to enhance water penetration.
Retained Nutrients via Soil Enhancements	N17b	5	To reduce the likelihood of leaching or runoff, I use organic matter, filter strips, or cover crops.
Calculated Nitrate in Well Water	N7a	6	If the test (irrigation well water) indicates the water has nitrogen, the amount of nitrogen applied via irrigation over the season is calculated and used in calculating the total nitrogen applied.

Educational Priorities for Pest BMPs based on Environmental Impacts

BMP Short Name	BMP#	Rank	BMP Full Detail
No Dormant Sprays in Last 5 Years	P105	1	How many times have dormant sprays been applied to this orchard in the past five years?**0**
Specialized Spray Equipment	P61	2	Ultra-low-volume spray equipment or target-sensing sprayers (e.g., SmartSpray® or WeedSeeker® technology) were used to reduce spray volumes or amounts of pesticides.
Cover Cropping for Weed Suppression	P143	3	A between-row cover crop was selected, seeded and managed to outcompete weeds and prevent weed colonization of tree rows.
Equipment Cleaning to Reduce Weed Transfer	P145	4	To prevent transferring weeds among orchards, equipment was cleaned after working in weedy areas, especially if herbicide-resistant species were suspected or present.
Representative Orchard Monitoring for Pests	P36	5	Choose the option that best reflects the scouting method used:**C. Representative sampling of the orchard (e.g., by adopting university recommendations).**
Checked Spray Coverage for Accuracy	P57	6	Spray coverage was periodically checked using water-sensitive paper placed in the target zone.

Educational Priorities for Pest BMPs based on Grower Eonomic Impacts

BMP Short Name	BMP#	Rank	BMP Full Detail
No Dormant Sprays in Last 5 Years	P105	1	How many times have dormant sprays been applied to this orchard in the past five years?**0**
Specialized Spray Equipment	P61	2	Ultra-low-volume spray equipment or target-sensing sprayers (e.g., SmartSpray® or WeedSeeker® technology) were used to reduce spray volumes or amounts of pesticides.
Equipment Cleaning to Reduce Weed Transfer	P145	3	To prevent transferring weeds among orchards, equipment was cleaned after working in weedy areas, especially if herbicide-resistant species were suspected or present.
Checked Spray Coverage for Accuracy	P57	4	Spray coverage was periodically checked using water-sensitive paper placed in the target zone.
Representative Orchard Monitoring for Pests	P36	5	Choose the option that best reflects the scouting method used:**C. Representative sampling of the orchard (e.g., by adopting university recommendations).**
Monitoring Weeds Effectively	P151	6	Monitoring records included growth stages (seedling or mature) and potential herbicide resistance issues.

SCB14041: Attachment 2 – Workshop Agendas

Almond Board Workshop Series: Water & Nitrogen Management

Dates and Venues

Feb 26, 2015: Oroville (Butte County Farm Bureau; 2580 Feather River Blvd)
Feb 27, 2015: Woodland (Hampton Inn; 2060 Freeway Drive)
Mar 5, 2015: Modesto (Stanislaus County Ag Center; 3800 Cornucopia Way, Ste A)
Mar 10, 2015: Merced (Hampton Inn; 225 South Parsons Ave)
Mar 12, 2015: Visalia (Visalia Convention Center; 303 East Acequia Ave)
Mar 13, 2015: Bakersfield (Kern County UCCE office; 1031 South Mount Vernon Ave)

Agenda

8:00 Arrival, Sign-in and Refreshments

8:15 Almond Board Update
Almond Board of California

8:30 Almond Sustainability Program Highlights and Online Features
SureHarvest
- CASP overview and rationale for workshop topics
- *Online demo* of features pertinent to self-assess

9:15 Self-Assessment Activity (online/paper) – *New Module*
- Assess new module(s) (priority is Ecosystem Management)

10:00 Break

10:15 Irrigation Distribution Uniformity from Design to Maintenance – Why Care?
University of California Cooperative Extension
Alan Fulton, Katherine Pope, Blake Sanden and/or David Doll
- Spatial design for optimal irrigation
- Infrastructure maintenance
- Importance of and testing for distributional uniformity

10:45 Practical Irrigation Scheduling, Technology and Deficit Irrigation
University of California Cooperative Extension
Alan Fulton, Katherine Pope, Blake Sanden and/or David Doll
- Irrigation 101 elements (incl. ETo/ETc) similar to Almond Conference
- Technology fits = CIMIS, plant & soil moisture monitoring
- Managed deficit irrigation esp. given drought

11:15 Nitrogen Decision Support based on UC Modeling and Management Plans
SureHarvest and University of California
- Background re: nitrogen dynamics and management in almonds
- UC nitrogen modeling and incorporation in CASP online system
- *Online demo*

Noon Lunch and Informal Q&A

Almond Board Workshop Series: Pest & Honey Bee Management

Dates and Venues

Mar 18, 2015: Bakersfield (Kern County UCCE office; 1031 South Mount Vernon Ave)
Mar 19, 2015: Visalia (Visalia Convention Center; 303 East Acequia Ave)
Apr 6, 2015: Oroville (Butte County Farm Bureau; 2580 Feather River Blvd)
Apr 7, 2015: Woodland (UC Cooperative Extension, Norton Hall, 70 Cottonwood St)
Apr 9, 2015: Modesto (Stanislaus County Ag Center; 3800 Cornucopia Way, Ste A)
Apr 14, 2015: Merced (Hampton Inn; 225 South Parsons Ave)

Agenda

8:00 Arrival, Sign-in and Refreshments

8:15 Almond Board Update
Almond Board of California

8:30 Almond Sustainability Program Highlights and Online Features
SureHarvest
- CASP overview and rationale for workshop topics
- *Online demo* of features pertinent to self-assess and nitrogen budgeting and reporting

9:00 Crop Insurance Update via USDA Farm Service Agency

9:15 Self-Assessment Activity (online/paper) – *New Module*
- Assess new module(s) (priority is Financial Management)

10:00 Insects and Mites – Effective Monitoring and Decision Making
University of California Integrated Pest Management Program and Cooperative Extension
David Haviland, Emily Symmes, Katherine Pope, or Kris Tollerup
- NOW, mites, ants, leaffooted bug and PTB
- UC recs for cost-effective sampling, record keeping, resistance management, etc.
- Continue advocating not using dormant-season insecticide sprays

11:00 Break

11:15 Habitat Enhancement for Honey Bees
Paramount Farming
Gordon Wardell or
USDA Natural Resources Conservation Service
Priscilla Baker, Tom Moore or Jesse Bahm
- Forage enhancements for honey bees
- "Seeds for Bees" initiative (Project Apis m.)
- Relevant NRCS programs

Noon Lunch and Informal Q&A

Almond Board Workshop Series: Energy Stewardship & Air Quality

Dates and Venues

Apr 23, 2015: Bakersfield (Kern County UCCE office; 1031 South Mount Vernon Ave)
Apr 24, 2015: Visalia (Visalia Convention Center; 303 East Acequia Ave)
May 1, 2015: Woodland (UC Cooperative Extension; Norton Hall, 70 Cottonwood St)
May 6, 2015: Merced (Hampton Inn; 225 South Parsons Ave)
May 7, 2015: Modesto (Stanislaus County Ag Center; 3800 Cornucopia Way, Ste A)

Agenda

8:00 Arrival, Sign-in and Refreshments

8:15 Almond Board Update
Almond Board of California

8:30 Almond Sustainability Program Highlights and Online Features
SureHarvest
- CASP overview and rationale for workshop topics
- *Online demo* of features pertinent to self-assess and nitrogen budgeting and reporting

9:15 Self-Assessment Activity (online/paper) – *New Module*
- Assess new module(s) (priority is Workplace and Communities)

9:45 Energy Management Services and Incentives for Agriculture
Pacific Gas & Electric (contact is Dean Kunesh)
- Time-of-use financial plans
- Energy audits, irrigation pumping plant testing, etc.
- Equipment rebates (e.g., variable frequency drives for irrigation pumps)

10:15 Air Quality Regulatory Updates and Programs for Almond Growers
Ted Strauss, Johnnie Siliznoff or regional staff, USDA NRCS
- Current and pending regulations
- NRCS programs including technical support for developing air quality management plans, relevant EQIP cost-share opportunities, etc.

10:45 Break

11:00 Equipment and Operations for Reducing Harvest Dust
Doug Flora, Exact Corp
- Emphasis about harvest equipment technology and operations vs "making a sale"

11:30 On-Site Renewable Energy Systems (Solar) – Pros & Cons
Chad Cummings or Rich Borba, JKB Energy
- Emphasis about technology, costs, incentives, etc. vs "making a sale"

Noon Lunch and Informal Q&A

Almond Board Tools to Ease Irrigation and Nitrogen Budgeting and Compliance

Dates and Venues
Mar 15, 2016: (Tulare Agri-Center, Conference Dining Room, 4500 S. Laspina St., Tulare)
Mar 16, 2016: (Modesto Junior College Ag Pavilion – ACE 170, West Campus, Brink Ave., Modesto)
Mar 18, 2016: (Chico Masonic Center, 1110 W. East Ave., Chico)

8:00 **Arrival, Sign-in and Refreshments**

8:15 **Almond Board Update**
Almond Board of California

8:30 **Online Tools Overview (Assessment, Budgeting and Reporting)**
SureHarvest

- Brief verbal CASP overview then *online tour* emphasizing assessment elements but note access to irrigation, nitrogen & mapping tools (more per tool later)
- Include assessment of Ecosystem, Financial and/or Workplace & Communities modules

9:30 **Almond Board's Irrigation Continuum Standards – Where do you fit?**
Almond Board of California
Gabriele Ludwig or other ABC staff

- Description of consolidated irrigation continuum, details about 1.0, 2.0 and 3.0 standards and how to achieve (including online resources)
- Content here to set stage for following demo of ABC irrigation tool

10:00 **Demonstration: FREE Irrigation Budgeting Tool**
SureHarvest

10:20 **Break**

10:30 **Irrigated Lands Regulatory Program Update – Nitrogen Management Plans etc.**
Tulare: David Sholes, Central Valley Regional Water Quality Control Board
Modesto: Wayne Zipser, Stanislaus County Farm Bureau
Chico: Bruce Houdesheldt, Northern California Water Association

- Update on ILRP requirements (expectations, forms, certification, submission, records)

11:00 **Demonstration: FREE Nitrogen Budgeting, Farm Mapping and Reporting Tools**
SureHarvest

11:30 **Financial Assistance Programs for Efficient Water and Nutrient Use**
USDA Natural Resources Conservation Service
Eric Beardsley and local NRCS leads

- Funding opportunities & eligibility requirements (EQIP, CSP & other NRCS programs)
- Description & distribution of ABC incentives program handout (SWEEP, NRCS, etc.)

Noon **Lunch and Informal Q&A**

Almond Board "In-the-Orchard" Weed Identification and Management

Dates and Venues
May 10, 2016: Nickels Soil Lab, Green Bay Rd, Arbuckle (between Wildwood Rd & California Ave)
May 11, 2016: Genzoli Ranch, 1130 North Commons Rd, Turlock
May 12, 2016: Southern Star Ranch, 14400 Panama Ln, Bakersfield

8:30 Arrival, Sign-in and Refreshments

8:45 Almond Board Update
Almond Board of California

9:00 Sustainability Program Tools to Support Almond Growers
SureHarvest

- CASP overview about relevant tools and activities associated with ABC priorities - emphasizing assessment and educational/operational support via resource budgeting and compliance tools (irrigation, nitrogen, mapping)
- Include in-the-orchard assessment of Ecosystem, Financial and/or Workplace & Communities modules

9:45 Hands-On Identification of Weeds and Implications for Management
Kurt Hembree
University of California Cooperative Extension Weed Specialist

- Grower/PCA attendees devote ca. 30-45 minutes to identify live weed specimens in pots provided using answer sheet with choice options
- For balance on segment, Kurt will reveal the correct name and characteristics of each weed and interact with audience to discuss associated management options based on weed species, species complexes, and resistance status
- Handouts distributed to assist growers/PCAs with future identification and management decisions

11:30 Orchard Demonstration and Discussion: Weed Monitoring and Record-Keeping
Kurt Hembree
University of California Cooperative Extension Weed Specialist

- Kurt will lead orchard tour and discussion around recommended weed monitoring and record-keeping and why
- Handout(s) distributed to assist growers/PCAs with future weed monitoring and record-keeping

Noon Lunch

Almond Board "In-the-Orchard" Harvest Practices and Equipment Demo

Jul 7, 2016: Fresno State Orchard Field House, (Enter off of Chestnut Ave. ¼ mile north of Barstow Ave.),
Jul 8, 2016: Nickels Soil Lab, Green Bay Rd. (Between Wildwood Rd. and California Ave.), Arbuckle

8:30 **Arrival, Sign-in and Refreshments**

8:45 **Almond Board Update**
Almond Board of California

9:00 **Sustainability Program Tools to Support Almond Growers**
SureHarvest

- CASP overview about relevant tools and activities associated with ABC priorities - emphasizing assessment and educational/operational support via resource budgeting and compliance tools (nitrogen, mapping, irrigation)
- Include in-the-orchard assessment of Air Quality module

9:45 **Harvest Dust Reduction Strategies**
Gabriele Ludwig, ABC

- Overview of research-based strategies that tools are based on, show the two printed tools "tech guide and tool kit" (10 min. max)
- Show full dust video (8 min.)

10:10 **Incentive Funding for Low-Dust Harvest Equipment**
Alexcia Everhart (Yuba City Field Office) or Toney Tillman (Kern County Field Office), NRCS

10:25 **Walk to Orchard/Sweeper Adjustment Demo**
Farm manager/Equipment rep.

- Adjust Sweeper matching tips given in dust video

10:45 **Harvester Demos**
Farm manager/Equipment rep.

- Describe/show how to reduce dust with conventional harvesters
- Reps will talk through low-dust technology
- Demos of harvesters for dust emissions (two machines, not simultaneously)

11:30 **Lunch**

Almond Board "In-the-Orchard" Bee Health and Pollination

Dates and Venues

Jan 17, 2017: Livingston (Butte/Padre Orchard, 10029 West Olive Ave, Livingston)
Grower-cooperator: Ralf Sauter (209) 585-8616
Jan 18, 2017: Woodland (Bullseye Farms, intersection of County Roads 97 and 25A, Woodland)
Grower-cooperator: Nick Edsall (530) 867-6161
Jan 30, 2017: Fresno (Favagrossa Farms; 435 North Blythe Ave, Fresno)
Grower-cooperator: Gino Favagrossa (559) 346-8919

Agenda

9:00 Arrival, Sign-in and Refreshments

9:15 Almond Board Update
Jenny Nicolau, Almond Board of California

9:30 Sustainability Program Tools to Support Almond Growers
Cliff Ohmart, SureHarvest, and Almond Board Staff

- Overview about relevant CASP tools and activities
    - Brief about revised online system (new look and feel, self-assessment, irrigation and nitrogen calculators, etc.)
- Hands-on orchard assessment using new Bee Health and Pollination module

10:00 Almond Board's Honey Bee Best Management Practices for Almond Growers
Bob Curtis, Almond Board of California

- Ensure awareness of ABC's guide and video (handouts already distributed)
- Review and group discussion of key practices as follow-up to earlier self-assessment

10:30 Projects for Improving Honey Bee Forage and Habitat
Billy Synk, Director of Pollination Programs, Project Apis m.

- Seeds-for-bees and other voluntary/cost-share activities

11:00 Orchard Demonstration: Alternative Forage and Habitat for Pollinators
Host Grower

11:30 Lunch

Efficient Irrigation and Nitrogen Use:
Almond Board Tools, Grower Assistance Programs and Regulatory Update

Dates and Venues

Feb 22, 2017: Modesto Junior College Ag Pavilion, Brink Ave., Modesto
Mar 2, 2017: Fresno State CIT Conference Room, 5370 N. Chestnut Ave., Fresno

Agenda

8:00 Arrival, Sign-in and Refreshment

8:15 Almond Board Update
Jenny Nicolau, Almond Board of California

8:30 Online Tools Overview and Self-Assessment Exercise
Cliff Ohmart, SureHarvest

- Brief verbal CASP overview then *online tour* emphasizing assessment elements but note access to irrigation, nitrogen & mapping tools (more per tool later)
- Include assessment of Irrigation and/or Nutrient & Soil modules

9:30 Update on Almond Board's Irrigation Continuum Standards
Spencer Cooper, Almond Board of California

- Description of consolidated irrigation continuum, details about 1.0, 2.0 and 3.0 standards and how to achieve (including online resources)
- Content here to set stage for following demo of ABC irrigation tool

10:00 Demonstration: FREE Irrigation Budgeting Tool
Spencer Cooper, Almond Board of California

10:20 Break

10:30 Irrigated Lands Regulatory Program Update – Nitrogen Management Plans etc.
Parry Klassen, East San Joaquin Water Quality Coalition

- Update on ILRP requirements (expectations, forms, certification, submission, records)

11:00 Demonstration: FREE Nitrogen Budgeting and Farm Mapping Tools
Spencer Cooper, Almond Board of California &
Cliff Ohmart, SureHarvest

11:30 CDFA Financial Assistance Programs for Growers
Carolyn Cook & Geetika Joshi, California Department of Food and Agriculture

- Funding opportunities & eligibility requirements (SWEEP and Healthy Soils Initiative)

Noon Lunch

SCB14041: Attachment 3

Tailored CASP Workshops - A Product of Cumulative Data
California Almond Outlook Newsletter
May 13, 2015



UC IPM farm advisor David Haviland talks about IPM practices for leaffooted bugs, navel orange worm and spider mites at a CASP workshop in March.

When it comes to following sustainable agricultural practices, California Almond growers and processors have been progressive and are continuously challenging themselves to do more. The California Almond Sustainability Program* (CASP) was established in 2009 to better understand and advocate the sustainable practices followed by growers related to the many facets of almond operations, and to identify opportunities for improvement.

Practices advocated by CASP, a program of the Almond Board of California (ABC), are based on knowledge gained from research and experience. A self-assessment process is used to document almond growers' and handlers' thoughtfulness and achievements in adopting cost-effective, environmentally and socially responsible practices.

Almond growers of all sizes and backgrounds have voluntarily assessed their farming practices through CASP, either by completing self-assessment modules at ABC and allied industry hosted workshops, or by using the online system at SustainableAlmondGrowing.org.

To provide a representative snapshot of almond growing practices, cumulative assessment data collected through July 2013 was evaluated using a value analysis method. This procedure identified CASP practices that add the most value for the environment and for the grower's bottom line. By aligning value with statewide uses (percent of orchards), the strengths and potential opportunities for improvement for high-value practices were determined. The result was the "2014 Almond Sustainability Report," which outlines and describes industry strengths and potential opportunities according to environmental and economic value in four main areas — energy, air, water, and land.

By identifying and communicating industry opportunities, almond workshops can be tailored to provide information on improving operational efficiencies and decreasing environmental impacts. Accordingly, three series of regional educational workshops were designed and held from February to May covering water and nitrogen management, pest and honey bee management, and energy stewardship and air quality.

The three-part series included expert speakers ranging from UC farm advisors and Extension specialists, to USDA-NRCS biologists, custom harvesters, solar experts and gas and electric utility representatives. Presentations covered practical ways to implement high-value practices along with associated research updates

and incentives. Workshop attendees included almond growers, processors, pest control advisers, beekeepers, and other allied industry members.

In addition to educational workshops, almond communication and outreach through Almond Board vehicles and other influential almond channels have been customized using what has been learned by the CASP Report. UC Extension, county Farm Bureaus, and pest control advisers are commonly referring to the opportunities identified in the Report to drive their messages and demonstrations. Moreover, specific tools such as the Nitrogen Calculator have been created to not only assist growers to make timely, informed decisions, but also to help meet regional regulatory requirements.

The formal presentations provided at these workshops are available to view online.

* Sustainable almond farming utilizes production practices that are economically viable and are based upon scientific research, common sense and a respect for the environment, neighbors and employees. The result is a plentiful, nutritious and safe food product.

Tailored Sustainability Workshops - A Product of Cumulative Data
California Almond Outlook Newsletter
Jun 15, 2015

California Almond growers and processors have been progressive when it comes to following sustainable agricultural practices, and are continuously challenging themselves to do more. This is demonstrated through the California Almond Sustainability Program[1] (CASP), a program of the Almond Board of California (ABC).

Practices advocated by CASP are based on knowledge gained from research and experience. A self-assessment process is used to document almond growers' and handlers' thoughtfulness and achievements in adopting cost-effective, environmentally and socially responsible practices.

Almond growers of all acreages and backgrounds have voluntarily assessed their farming practices through CASP, either by completing self-assessment modules at ABC and allied industry-hosted-workshops, or by using the online system.

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The three-part series included expert speakers ranging from UC farm advisors and Extension specialists, to USDA Natural Resources Conservation Service biologists, custom harvesters, solar experts, and gas and electric utility representatives. Presentations covered practical ways to implement high-value practices along with associated research updates and incentives. Workshop attendees included almond growers, processors, pest control advisers, beekeepers and other allied industry members.

UC Extension, county farm bureaus and pest control advisers commonly refer to the opportunities identified in the Sustainability Report to drive their messages and demonstrations. Moreover, the data gathered through CASP has proved critical to counter often erroneous reporting on water use in almonds. Participation in CASP by a broad cross-section of California Almond growers and processors continues to be important in managing the image of California Almonds among buyers and consumers, now and in the future. The presentations provided at these workshops are available at online.

1. Sustainable almond farming utilizes production practices that are economically viable and are based upon scientific research, common sense and a respect for the environment, neighbors and employees. The result is a plentiful, nutritious and safe food product.

Grants Available to Experiment with New Irrigation Practices
California Almond Outlook Newsletter
October 12, 2015

Grants of up to $25,000 are available to fund experiments on your farm to see if new irrigation practices could fit in your operation. The grower-led projects are supported and guided by a technical advisor — either a University of California irrigation specialist or other technical expert. Individual growers may apply for up to $20,000, and a group of three or more growers may apply for up to $25,000. Both your operation and the environment can be improved through these experiments. Results are shared with other producers.

Applications are being accepted through Dec. 2, 2015, from growers applying for Farmer/Rancher Research and Education grants through the Western Sustainable Agriculture Research and Education (WSARE) program. Grants last one to three years, and funds will become available in the summer of 2016.

Given concerns about drought and water use, almond growers with a knack for research are encouraged to apply for projects to improve irrigation efficiency.

WSARE Farmer/Rancher grants are for on-farm research, education and outreach. Programs primarily for equipment cost-share include the State Water Efficiency and Enhancement Program (SWEEP) by the California Department of Food and Agriculture (CDFA), the Water Energy Technology program (WET) by the California Energy Commission and the Environmental Quality Incentives Program (EQIP) by USDA Natural Resources Conservation Service. Templates for these cost-share programs may be developed later.

Interested growers should see Almonds.com/Grants for 1) an overview of WSARE and Research and Education grants, and 2) a template with draft language for a project that compares basic to advanced irrigation approaches. A key element is the monitoring of water and associated energy use, yield and costs. Draft language can be adapted for your project based on consultation with your technical advisor.

Grower-applicants will benefit from working with their technical advisor in accessing the latest irrigation technology and cutting-edge methods. If funded, they will benefit from measuring differences in water use, energy use and cost between irrigation approaches. Statewide, growers will benefit by viewing and discussing the irrigation-efficient methods at field days. Almond Board of California can assist by helping coordinate logistics for field days and with outreach.

Almond Board Initiative Targets Sustainability
The Packer
December 9, 2015

A new Almond Board of California program, Accelerated Innovation Management, aims to speed up the industry's progress on sustainable water management and reduction of greenhouse gas emissions.

"We now produce a pound of almonds with about a third less water than we did 20 years ago," Almond Board CEO Richard Waycott said Dec. 8 at a news conference during the trade group's annual meeting in Sacramento. "With the acceleration of innovation coming up, we hope that we'll be able to, if not replicate that, continue to advance in that direction."

During California's fourth year of drought, almond production — the state's No. 2 crop in acres with more than 1 million planted — has been a target for media critics of agricultural water use. While almond growers have a history of sustainability efforts — the board budgeted more than $4 million for research this year — some of the industry's recent moves are also responses to such criticism, Waycott said.

One example is the board's new partnership with nonprofit Sustainable Conservation, which will study the potential for groundwater recharge in almond orchards. The collaboration was announced in October. "We realized we needed to bring the consumer into our journey down the innovation path that we've been on for many years, as a means of helping the public understand what the almond industry has been doing," Waycott said.

Groundwater recharge is also an element in Accelerated Innovation Management, or AIM. At first, the program will have four initiatives:

- Water management efficiency, focusing on consistency of irrigation techniques among the state's 6,800 almond growers and adoption of advanced water management technologies;
- Sustainable water resources, focusing on recharge of aquifers and on recycling of water, including municipal wastewater, for use in irrigation;
- Quality standards, managing greenhouse gas and energy impacts; and
- 22nd century agronomics, which could feature big data, drones or other high-tech tools.

The program aims to benefit growers of all crops, Waycott said, and aspires to carbon neutral or even carbon negative status.

Study of groundwater recharge is expected to start soon.

"With the El Niño water we're waiting for, we've recruited several farmers to participate in voluntarily flooding their fields this winter to see the impact on highly permeable soil," he said.

The board is also working with the University of California-Davis on three test sites to monitor anticipated flooding. That may tell researchers how much water can help recharge, and how much is overkill.

The board is also working with the Environmental Defense Fund to improve nitrogen management and better understand greenhouse gas emissions, especially nitrous oxide.

AIM Sets Path toward Improved Water Management and Efficiency
The Handle Newsletter
January 8, 2016

The Almond Board of California's (ABC's) newly adopted Accelerated Innovation Management (AIM) program focuses on the innovative almond farming practices that will be required to meet the future needs of the California Almond industry, as well as the consumer, the community and the planet (See "Almond Industry Leadership: Providing Next-Generation Solutions"). Water management and efficiency is a key component of the AIM program.

One of AIM's four key initiatives is accelerating almond grower transition to and adoption of research-based, commercially available and increasingly water-efficient irrigation management and scheduling tools. An Almond Irrigation Improvement Continuum has been developed in concert with UC experts to provide a pathway toward improved water stewardship and management.

The continuum was introduced at The Almond Conference in December, and the full Irrigation Improvement Continuum and comprehensive background materials will be posted on the Almond Board's website by March 1, 2016, providing "one stop shopping" for almond irrigation management at all levels. It will answer questions like these: What do I need to know? What are the key resources I need? How do I execute?

The continuum describes three proficiency levels and provides a comprehensive program of irrigation management and scheduling practices in five key areas, and also explains how these practices can be effectively integrated at each level. The five key areas include:

- Measuring irrigation system performance and efficiency;
- Estimating orchard water requirements based on evapotranspiration;
- Determining the amount of water applied;
- Evaluating soil moisture; and
- Evaluating plant water status.

Proficiency level 1.0 (minimum) outlines research-based irrigation management practices that are within reach of all California Almond growers. Proficiency level 2.0 (intermediate) and level 3.0 (advanced) advance practices to more sophisticated levels that attain even more "crop per drop."

ABC's objective through this AIM initiative is to assist all almond growers in meeting level 1.0 proficiency. Beyond this, ABC will work with growers to help them progress along the continuum to proficiency levels 2.0 and 3.0. This will be done in partnership with the many trusted and respected technical experts and resources available to California Almond growers, such as through University of California Cooperative Extension.

Attaining Irrigation Uniformity in Almond Orchards
California Ag Today
January 11, 2016

Terry Prichard, a water management specialist with UC Cooperative Extension at UC Davis for 35 years when he retired five years ago, is still at work. Prichard is currently collaborating with Almond Board of California to improve water management in almonds, especially irrigation uniformity. “I am still researching nitrogen management for all crops through a grant through the UC from CDFA, and I am helping the Almond Board with their irrigation initiative and their Irrigation Improvement Continuum,” Prichard said.

Prichard explained, “We try to apply water in order to get an average amount of water throughout the field and do that very uniformly. When it is done non-uniformly, farmers are using extra water to reach all parts of the field. So improving irrigation uniformity allows us to apply less total water, but still meet the crop’s water demands,” Prichard noted.

Improvements to irrigation uniformity can be done in any field, according to Prichard. He suggests your designer should strive for good irrigation uniformity when creating your irrigation design. “However,” he clarified, “if you design a less expensive minimal system which uses minimal size piping, you end up using extra energy to drive the pressure through the system to deliver water to the end. Driving that pressure causes friction loss in the pipe—pressure differentials from the top of the system near the pump to the end of the system on the last sprinkler or dripper. These pressure differentials deliver different volumes of water out of each sprinkler, micro-sprinkler or drip emitter, and that is what drives non-uniformity.”

Also important is irrigation maintenance—making sure the system is flushed out and emitters are changed when needed. “Improving uniformity with large orifice-type sprinklers or even larger micro-sprinklers,” stated Prichard, “tends to be a little easier because the holes are larger and don’t plug as easily. In smaller orifice-type systems such as drip irrigation, emitters easily become clogged with physical particulates or biological particulates like slime and algae. Most commonly, lime or manganese forms inside the emitter, clogs it up and reduces the flow, so maintenance of those systems is very important to maximize your designed-in uniformity,” he said.

“*Continuum irrigation* is an important concept because there is a whole array of current grower practices, some at the minimum level for what we consider for most growers, some are transitioning to more sophisticated methods, and others are already there. I think this continuum will reassure people who are at the minimum level and encourage them to adopt more technological solutions to irrigation scheduling.”

Prichard said the Almond Board’s Almond Irrigation Improvement Continuum doesn’t have a set timeframe. ”It has more accomplishment phases and so what we hope to do is provide each grower with information that they can use on their farm to improve their efficient use of water to produce almonds.”

“And the Almond Board is making these strategies and new technology systems web-based,” noted Prichard. “It is very easy with a web-based system to input new things. The current continuum on the website conceptualizes the basic visual measurements and practices, and you can click on a specific practice for more information on how to incorporate it to accomplish your goals. Then there is a link to a specific discussion such as how to accomplish these efficiencies using drip irrigation, for example,” said Prichard.

”Almond growers have made tremendous strides in improving their efficient use of water, primarily from changing older flood-type irrigation systems to the newer pressure systems. This progress has been tremendous for the industry and for growers in terms of producing more crop using less resources.”

“However, we are now at the next level of using these methods, such as weather-based irrigation scheduling estimates, followed by soil- and plant-based checks, to ensure that you are delivering just the right amount of water,” explained Prichard. “The continuum has generated a lot of grower interest. We have several ways to go and many more tools now than we did ten or twenty years ago.”

Introduced at The Almond Conference in December, the full Irrigation Improvement Continuum and comprehensive background materials will be posted on the Almond Board’s website by March 1, 2016, providing “one-stop shopping” for almond irrigation management at all levels.

According to Almond Board’s January 2016 *Outlook* newsletter, the continuum describes three proficiency levels and provides a comprehensive program of irrigation management and scheduling practices in five key areas, and also explains how these practices can be effectively integrated at each level. The five key areas include:

1. Measuring irrigation system performance and efficiency;
2. Estimating orchard water requirements based on evapotranspiration;
3. Determining the amount of water applied;
4. Evaluating soil moisture; and
5. Evaluating plant water status.

Proficiency level 1.0 (minimum) outlines research-based irrigation management practices that are within reach of all California Almond growers. Proficiency levels 2.0 (intermediate) and 3.0 (advanced) enhance practices to more sophisticated levels to attain even more “crop per drop.”

The goal is to assist all almond growers in meeting level 1.0 proficiency. Beyond this, Almond Board will work with growers to help them progress along the continuum to proficiency levels 2.0 and 3.0, in partnership with technical experts and resources available to California Almond growers, such as through University of California Cooperative Extension.

Accurate Nitrogen Budgeting Important for Almonds
Western Farm Press
February 4, 2016

Part of what makes almonds so desirable to consumers - aside from the great taste and crunch - is their high protein content. Ensuring good human nutrition means ensuring a strong tree nutrition plan is in place. With almond bloom under way, almond growers should remember to utilize the nitrogen budgeting tool available atwww.almonds.com/NitrogenBudgeting when making their plans.

While nitrogen (N) in the form of protein is desirable, many forms of nitrogen can be a serious problem in the environment. Ammonia and nitrate, the forms applied for plant uptake, can leach into surface water and groundwater, contribute to PM2.5 formation, and be converted to nitrous oxide (N_2O), a potent greenhouse gas. Moreover, there is a lot of fossil fuel energy hidden in nitrogen fertilizer production. Despite current cheap oil prices, the N fertilizer costs are substantial in almonds.

At the same time, plants are highly sensitive to too little nitrogen, leading quickly to decline in production. The uncertainty a grower is trying to manage is that some of the N applied is taken up by the microflora in the soil or converted by microbes to plant-unavailable forms of nitrogen (N_2, N_2O, etc.).

The grower's goal - without knowing exactly how much N might be lost or otherwise unavailable - is to apply enough nitrogen to ensure the trees are adequately supplied when needed.

Nitrogen management plans
With a better understanding of when exactly the tree takes up nitrogen, as well as what the nitrogen demand of the tree is, improved N efficiency can be achieved. This is the goal of the 4Rs of Nutrient Management philosophy: applying N at the right rate, at the right time, in the right place, and using the right source. A nitrogen management plan is a tool to help achieve the goals of the 4Rs.

Carefully planning N and other nutrient inputs, which does require putting a pen to paper or fingers to a keyboard, can help growers improve yields, reduce input costs, meet regulatory requirements, and maintain environmental stewardship. Planning is accomplished by utilizing data from past yields, leaf sampling and future yield potential.

Leaching risk
Nitrate leaching, which degrades groundwater (drinking water) quality, occurs when water moves nitrates below the root zone before the plant roots (or soil microbes) have a chance to take up the nitrogen. It is more likely to occur when larger amounts of nitrogen and/or excess water are applied. Strong El Niño rains can abet leaching, depending on their timing relative to N applications.

In order to prevent nitrate leaching, growers should spread out N applications, applying smaller amounts of N but at a greater frequency. This can reduce the risk of off-site movement plus allow for more efficient uptake of applications that are made when the trees are receptive (the right time).

With the hope that El Niño rains will continue into the spring, almond growers should delay applying nitrogen until the tree has leafed out. According to the results of a research study funded by the Almond Board of California and USDA, almond trees do not take up applied nutrients from the soil until leaves are present to support transpiration through the leaf system.

The research demonstrated that mature almond trees rely upon stored nitrogen to feed bloom and leaf-out activities rather than taking in N from the ground. Therefore, almond growers should wait until leaf-out occurs. Furthermore, premature N applications are more prone to leaching, especially with rainfall.

Nitrogen calculator

A tool to help determine the amount of nitrogen to apply (right amount) to almonds is the Almond Board's online nitrogen budgeting calculator, available through the California Almond Sustainability Program (CASP) at www.SustainableAlmondGrowing.org.

The nitrogen budgeting calculator is a free online tool that provides private assessment of N needs to enable more efficient use of nitrogen and avoid off-site movement.

The beauty of the tool is that it can store the information entered, allowing a grower to recalculate demand during the growing season as better assessments of yield and/or April leaf sampling data or other changes in the orchard become available.

Growers enter information on orchard configuration and yields (past and estimated current), along with nitrogen credits from nitrate in irrigation water, cover crops, compost and other sources, as well as data from leaf sampling. Utilizing this information, the system provides a total N fertilizer recommendation along with recommended amounts by crop growth stage.

In addition to refining the N demand based on tree needs, the nitrogen calculator can also help growers through the process of submitting a basic nitrogen management plan (NMP), which, under the revised Irrigated Lands Regulatory Program (ILRP), all growers on irrigated farmland in the Central Valley are required to complete and submit through their regional water quality coalition.

The almond nitrogen budgeting tool provides specific almond information that goes beyond the ILRP requirement.

Deadlines for initial management plans vary depending on the coalition, size of farm, and the vulnerability for N leaching of the operation.

This year also marks the start of reporting nitrogen applications from the previous year. Growers in the Sacramento Valley, San Joaquin County, East San Joaquin County, Westside San Joaquin River Watershed, and Westlands Watershed must report how much N they applied in 2015. The rest of the Central Valley growers will begin to report in 2017 or 2018, depending on the size and vulnerability of the farm.

Key deliverable deadlines and contact information for Central Valley coalitions can be found on the CURES Watershed Coalition pages at www.CuresWorks.org.

Regional CASP Workshops Coming to a Locale near You
California Almond Outlook Newsletter
February 8, 2016

A three-part series of sustainability[1] workshops, part of the California Almond Sustainability Program (CASP), will bring forth tools, techniques and strategies to assist industry members in meeting current needs and taking advantage of future opportunities.

Starting mid-March, the first series will focus on Almond Board of California tools to ease irrigation and nitrogen-budgeting compliance pressures. Industry experts will review the following topics:

- Using CASP online tools to meet your growing needs
    - Nitrogen calculator, mapping, irrigation
- Water use efficiency in the 22nd century
    - Irrigation scheduling and infrastructure
    - Presented by UC farm advisors, specialists and private-sector experts
- Available incentive programs
    - State Water Efficiency and Enhancement Program (SWEEP), Natural Resources Conservation Service (NRCS) EQIP and Conservation Stewardship Program (CSP), among others.
- Irrigated Lands Regulatory Program (ILRP) updates
    - Nitrogen management plans, farm evaluation surveys

These regional workshops will be held in Tulare on March 15, Modesto on March 16, and Chico on March 18.

Part two of the series of workshops will feature pest management, and part three will focus on dust management, renewable energy and incentives. Look for more details in future articles.

All workshops are free to attend and include a complimentary lunch. Attendees are encouraged to bring laptops, tablets or other electronic devices to demo tools on-site.

To RSVP, please contact Rebecca Bailey at rbailey@almondboard.com or call (209) 343-3245.

Budgeting Nitrogen is Season-Long Process
California Almond Outlook Newsletter
April 11, 2016

At least 80% of nutrients should be applied to almonds during the active tree growth period beginning in early spring and continuing through early hullsplit. To be sure your trees are getting the right amount of nitrogen at the right time, use the in-season nitrogen budgeting model at Almonds.com/NitrogenBudgeting.

Almond trees need nitrogen (N) to form protein-rich almonds, which is why it is an essential nutrient for almond trees. However, nitrate can pose a problem to the environment, because it can leach into groundwater, or drinking water.

Nitrate leaching occurs when larger, concentrated amounts of nitrogen and/or excess water are applied. This year, growers may experience problematic excess water due to heavy rainfalls from El Niño, depending on their timing relative to N applications. In order to prevent nitrate leaching, growers should spread out N applications, applying smaller amounts of N but at a greater frequency.

Growers can receive help budgeting for nitrogen with the nitrogen budgeting calculator, a free online tool that provides private assessment of N needs to more efficiently use nitrogen, made available through the California Almond Sustainability1 Program (CASP).

In addition to refining the N demand based on tree needs, the nitrogen calculator can also help growers through the process of submitting a basic nitrogen management plan, which, under a revised Irrigated Lands Regulatory Program (ILRP), all growers on irrigated farmland in the Central Valley are required to complete and submit through their regional water quality coalition.

Deadlines for initial management plans vary depending on the coalition, size of farm and vulnerability for nitrogen leaching of the operation.

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Final CASP Workshops will Address Harvest Dust, Renewable Energy
California Almond Outlook Newsletter
April 13, 2016

The final round of California Almond Sustainability Program (CASP) workshops for 2016 will be held in late June/early July. As with series 1 and 2, they will take place in three locations — one in each of the state's growing regions — to be announced later.

These workshops will demonstrate ways that growers can keep harvest dust at a minimum using techniques research has shown to be effective in helping to keep dust in the orchard. Tentative plans include demonstrations of equipment that incorporates new technology to reduce dust. Harvest dust is both a nuisance and an air quality issue. This is a great opportunity to learn how you can modify your equipment and your technique to reduce dust, or to utilize clean harvest technology.

The second topic will cover renewable energy, such as solar. Manufacturers have been invited to give presentations and display their renewable energy systems.

Incentive programs for clean harvest technology will be outlined by representatives from Natural Resources Conservation Service, and incentives for renewable energy by representatives from PG&E and Southern California Edison.

These workshops will also be your final opportunity of the season to fill out CASP modules with input and assistance from SureHarvest representatives, who manage the sustainability program on behalf of the Almond Board. They will also be demonstrating the three online tools available at SustainableAlmondGrowing.org: the nitrogen calculator, irrigation calculator and mapping tool.

Dates, times and locations will be announced soon. Please keep this opportunity in mind for a preharvest check-in and opportunity to do your part for the good of your operation, your neighbors and the California Almond industry.

CASP Instrumental in Changing Almond Drought Conversation
California Almond Outlook Newsletter
April 15, 2016

The number of media articles questioning almonds' water efficiency has greatly decreased since the spikes of April through August of last year. This change didn't happen by accident. Yes, the election year and El Niño took a share of media focus, but it's the Almond Board of California (ABC) proactive public relations work that has helped change the story about growing almonds.

In short, the story has changed from "The California Almond industry is making the drought worse" to "The California Almond community is progressive in its approach to minimizing its water use and overall environmental impact."

How did it happen? Through a steady drumbeat of positive media activities humanizing the almond community, rapidly correcting misinformation, and consistently sharing industry stats from the California Almond Sustainability1 Program (CASP).

Data on almond growers' irrigation practices compiled from the 2014 Almond Sustainability Report were key to shaping the almond industry's response to misinformation about almond water use.

"CASP data helped us — when we were rebutting misconceptions in the media about water use in almonds — to be able to say with statistical certainty, for instance, that 83% of growers review weather, soil moisture and/or tree demand to determine irrigation strategies rather than watering on a predetermined schedule," explained ABC's Gabriele Ludwig.

Collective data from CASP has helped the ABC respond with facts about how almond growers use water in their orchards. A number of production practices have helped almond growers over the last two decades improve their water use efficiency by more than one-third for every pound of almonds grown today.2

CASP has helped to improve and amplify the favorability and reputation of almonds, but there's a need for much more participation.

A three-part series of sustainability workshops are being held throughout the almond-growing region. In March, Series 1 covered irrigation and nutrient budgeting, and the May series covers weed identification and management. Stay tuned for dates and locations for the third and final series on managing dust at harvest and renewable energy. Assessments can also be completed online at SustainableAlmondGrowing.org.

Trio of Tools Streamlines Crop Input Decisions, Reporting Requirements
California Almond Outlook Newsletter
April 15, 2016

The Almond Board of California (ABC) constantly explores ways that it can help growers become more productive, efficient and sustainable1, while at the same time meeting regulatory requirements. The California Almond Sustainability Program (CASP) is a good example of how ABC brings all these elements together.

The eight individual sustainability modules are both instructive and add to the body of evidence that California's Almond growers use sustainable practices. But the program also includes online tools that streamline calculations and reporting requirements for growers.

Nitrogen Calculator
The first tool to become available was the nitrogen calculator. This tool uses models developed by UC Davis plant scientist Dr. Patrick Brown and colleagues to predict how much nitrogen to apply and when to apply it to meet yield-based demand. To use this tool, growers enter their yield estimates pre- and post-bloom, and then add early-season tissue-sampling results. "The model is reactive, and you can revise your yield estimate as many times as you see fit between post-bloom and final harvest," said Franklin Dlott, product manager for SureHarvest, which developed CASP for the ABC and maintains the website SustainableAlmondGrowing.org, where the modules and tools are housed.

As a bonus, using the nitrogen calculator can also satisfy all of the Nitrogen Management Plan reporting requirements of the Irrigated Lands Regulatory Program (ILRP). "The model that Patrick Brown came up with includes all of the elements that are required for reporting under the ILRP," continued Dlott. "It has estimated yield, fertilizer plan, actual yield and fertilizer applied in irrigation water, so by hitting one button, growers can produce the Nitrogen Management Plan report required by coalitions."

Mapping Tool
The mapping tool allows users to draw boundaries of their fields and enter APNs (assessor's parcel numbers), and then drop pins to plot the locations of active or abandoned wells or observation wells, as well as discharge points and any other feature the grower wishes to record. "When you have that map together with borders or APNs, you can create a map report that is required as Part D of the ILRP farm evaluation plan, and is also required to have on file for your Nitrogen Management Plan," Dlott explained, adding that the two tools are integrated so the information does not have to be entered twice.

For growers who have fields in multiple coalitions, which may have different reporting requirements, both the mapping tool and the nitrogen calculator allow you to enter the name of the coalition and create separate reports for each coalition, according to Dlott.

Irrigation Calculator
Still in beta testing but destined to be a popular tool for those who haven't invested in complex irrigation monitoring and reporting systems is the irrigation calculator. This calculator also uses the latest UC research, and recommends the amount and timing of water to be applied to almond orchards based on evapotranspiration (ET). "This system is integrated with active CIMIS [California Irrigation Management Information System] stations as well as spatial CIMIS, which is a CIMIS project that integrates stations in your area with an overhead satellite image to calculate ETo," Dlott said. "Enter your latitude and longitude to get your ETo, based on an integration of the stations around you plus some satellite data." Using active CIMIS stations, spatial CIMIS and historical climatic zones, the calculator can show both past and forecasted water demand for a whole season, he noted. The tool updates CIMIS data automatically.

An online irrigation calculator, coming soon, uses the latest UC research and recommends the amount and timing of water to be applied to almond orchards based on evapotranspiration (ET).

To utilize the calculator, growers will enter information about their orchard, such as row and tree spacing, soil texture, root depth, etc., as well as some basic information about the irrigation setup for each field or block. “Hit ‘Go,’ and the calculator will update the weather information and calculate the run time for that system, as defined, that it would take to replace the water lost as calculated by ETc for that week,” Dlott asserted.

The irrigation calculator is being further aligned with the Irrigation Continuum, which is one of Almond Board of California’s Accelerated Innovation Management (AIM) initiatives. Using the irrigation calculator and taking advantage of the educational content in the form of pop-ups and hover text with how-to links to the Irrigation Continuum will qualify growers at the 1.0 or higher level 2.0 or 3.0 in the Irrigation Continuum.

Confidential Information

All data entered in these tools by the grower is strictly confidential. Education and outreach may reference anonymous collective data, according to Dlott. By saving the data every time new information is entered, users can access the cloning tool. By cloning the data entered for a field or orchard for any of these tools, growers save themselves the trouble of re-entering data for a different field that may have only slight variations. It is also convenient for updating information as changes are made from report to report or year to year.

To use these tools, go online to SustainableAlmondGrowing.org and request a username and password (if you don’t already have one). Sustainability modules are also at this website; while you’re at the website, take the time to explore the almond sustainability program if you haven’t tried it before, or to fill out a new module or reassess one if it has been a while since you updated your information.

Sustainability Program: Good for the Grower, Good for the Industry

California Almond Outlook Newsletter
April 15, 2016

Growers who participate in the California Almond Sustainability1 Program (CASP) help the almond industry by providing the data to educate buyers, regulators and the public that almond growers and handlers follow sustainable practices and are considerate of neighbors and the consuming public. At the same time, it is an opportunity for growers to reflect on the management of their operations.

And that's exactly how grower Kent Stenderup responds when asked about his impression of the program after filling out all eight modules of the CASP assessments. He says it has given him greater insight — both into the efficiency and sustainability of his own operation and into the value of the program to the California Almond industry at large.

Ideas for Efficiency
"There's definitely an educational value to growers," Stenderup said. "Filling out the forms made me think about my practices in a way that I had not before. For example, there is a question about irrigating at night in the Irrigation Management module, and I learned that irrigating at night is more efficient and it saves on the electricity rate for pumping."

Stenderup farms 2,500 family-owned acres for Stenderup Ag Partners in the Kern County town of Arvin. He has been attending CASP workshops for the past four years, and said he gets as much out of the workshops as he does from the modules.

"I really appreciate the educational value of the CASP workshops," he stated. "You have an opportunity to pick up some ideas for changing your cultural practices, and all you have to do is show up for a few hours. This makes me a more progressive farmer by looking at some possible inefficiencies that I can correct."

Cloning Option Online
But Stenderup doesn't take the time to fill out modules at workshops; instead, he takes advantage of the online version of the program, noting that it is much easier than filling out forms on paper, and you have the ability to clone. Cloning allows growers to copy all of the data they have entered for one field or block into another field or block, and then just modify the data where there are differences between blocks. It also allows growers to go back to the forms in the future to reassess the same blocks, which will demonstrate improvement in sustainable practices.

"Filling out the forms online also gives you access to online tools — the nitrogen budgeting calculator, the mapping tool and the irrigation calculator, which we learned about at the March workshops and is now available," Stenderup pointed out. Growers can access these tools by going to SustainableAlmondGrowing.org. This provides a portal both to participate in CASP by filling out modules, and to access the online tools. (All you need is a username and password.)

Industry Reputation
The California Almond Sustainability Program has also been a "big performer" for the almond industry as a whole, Stenderup noted. "The collective data substantiates the industry's progress as stewards of our land," he added. "It has done wonders for the industry's reputation management in the past year-and-a-half."

Realizing this, Stenderup has become more transparent in everything he does. "We have more than a million acres of almonds in California," he continued. "When you get to that level, you have to be responsible. Every

grower who has an acre is part of that one million. Participation in CASP by every almond grower — large and small — is vital to the integrity of the industry. Being transparent about our cultural practices builds the trust of our buyers and the consuming public.”

New Irrigation Calculator Utilizes Latest Technology to help Growers improve Efficiency
The Handle Newsletter
June 8, 2016

To help almond growers determine optimum irrigation schedules using the best technology available, the Almond Board of California (ABC), in partnership with irrigation experts, has defined an Almond Irrigation Improvement Continuum. ABC is committed to helping growers improve irrigation management and scheduling, and continuously works to add tools to help support this goal.

In conjunction with the Continuum, ABC has developed an Irrigation Calculator, available on the California Almond Sustainability Program (CASP) website, SustainableAlmondGrowing.org. The online tool calculates the amount and timing of water to be applied to almond orchards based on evapotranspiration (ET) and information about the individual orchard and irrigation system. Because the calculation is automated, growers save time, and because the tool is integrated with active California Irrigation Management Information System (CIMIS) stations to determine ETo, irrigation schedules are based on local data, specific to local growing conditions.

Links to Weather Stations
The Irrigation Calculator has built-in links to CIMIS, which has weather stations throughout the state to measure not only weather conditions, but also how much moisture plants are transpiring. Growers select which weather station is closest to their operation to receive the most accurate information. The time needed for different irrigation systems to replace the water lost in a specific time period will be determined and provided through the online calculator.

To use the Irrigation Calculator, growers will need to enter information about their orchard, including row and tree spacing, soil texture and root depth, as well as some basic information about their irrigation setup. Once this information is entered, the Irrigation Calculator will provide information for weekly irrigation run times.

Through means such as the Irrigation Calculator, ABC strives to assist all almond growers in adoption and transition across the three proficiency levels outlined in the Almond Improvement Irrigation Continuum. For more information to share with your growers, please contact Jenny Nicolau at jnicolau@almondboard.com or (209) 343–3248.

SCB14041: Attachment 4 – Performance Progress for Prioritized and High-Profile BMPs

			2014 Report Interval			Post-Report Interval			
BMP#	**Educational Priorities based on Environmental and/or Economic Value (practice then short name in bold)**	**Relevant Mgt Area(s)**	**% Orchards**	**N**	**95% CL**	**% Orchards**	**N**	**95% CL**	**Significant Change**
N7a	If the test (irrigation well water) indicates the water has nitrogen, the amount of nitrogen applied via irrigation over the season is calculated and used in calculating the total nitrogen applied. **Calculated Nitrate in Well Water**	Nutrients, Water, Air, Energy	59.1%	247	6.1	92.3%	104	5.1	Increase
N18	In addition to the above practices, I have written a comprehensive nutrient management plan and budget for this orchard which guides my annual nutrient management. **Nutrient Management Plan**	Nutrients, Energy	40.2%	371	5.0	81.3%	123	6.9	Increase
P141	Ground cover (resident or planted) was intentionally grown between orchard rows. **Ground Cover**	Pest, Air, Water, Nutrients	47.4%	211	6.7	79.8%	129	6.9	Increase
N17b	To reduce the likelihood of leaching or runoff, I use organic matter, filter strips, or cover crops. **Retained Nutrients via Soil Enhancements**	Nutrients, Air, Water	44.0%	318	5.5	75.0%	108	8.2	Increase
P151	Monitoring records included growth stages (seedling or mature) and potential herbicide resistance issues. **Monitoring Weeds Effectively**	Pests	48.2%	197	7.0	74.3%	105	8.4	Increase
A7	Natural habitat has been maintained and/or perennial vegetation (hedgerows or trees) has been planted or retained in unfarmed areas within or surrounding the orchard. **Vegetation in Unfarmed Areas**	Air, Water, Nutrients, Pests	39.5%	324	5.3	69.4%	111	8.6	Increase
I61	I irrigate following real-time evapotranspiration (ETc) data at least weekly and calculating the water volume leaving the plant and soil. **Real-Time Crop Evaopotranspiration**	Water, Air, Energy, Nutrients	42.5%	334	5.3	66.7%	138	7.9	Increase
P145	To prevent transferring weeds among orchards, equipment was cleaned after working in weedy areas, especially if herbicide-resistant species were suspected or present. **Equipment Cleaning to Reduce Weed Transfer**	Pests	48.8%	170	7.5	66.0%	97	9.4	Increase
A34	Diesel engines have been replaced (or retrofitted) with technology relying on cleaner-burning fuel (e.g., propane, natural gas or biodiesel) or electricity. **Reduced Diesel Engine Emissions**	Air	39.7%	300	5.5	57.4%	115	9.0	Increase
P36c	Choose the option that best reflects the scouting method used:**C. Representative sampling of the orchard (e.g., by adopting university recommendations).** **Representative Orchard Monitoring for Pests**	Pests, Energy, Air, Water	41.4%	191	7.0	56.3%	119	8.9	Increase
A35	On-site renewable energy sources (e.g., solar or wind) supplied at least some electricity requirements. **On-Site Renewable Energy**	Air, Energy	13.5%	341	3.6	20.8%	120	7.3	
P105	How many times have dormant sprays been applied to this orchard in the past five years?**0** **No Dormant Sprays in Last 5 Years**	Pests, Water	39.9%	208	6.7	16.7%	108	7.0	Decrease
P57	Spray coverage was periodically checked using water-sensitive paper placed in the target zone. **Checked Spray Coverage for Accuracy**	Pests, Water	29.8%	191	6.5	14.4%	104	6.7	Decrease
N5d	In past year, the following source of nitrogen was utilized: nitrogen-fixing cover crops. **Nitrogen-Fixing Cover Crops**	Nutrients, Air, Water, Pests	9.1%	329	3.1	11.5%	122	5.7	
P61	Ultra-low-volume spray equipment or target-sensing sprayers (e.g., SmartSpray® or WeedSeeker® technology) were used to reduce spray volumes or amounts of pesticides. **Specialized Spray Equipment**	Pests, Water	27.8%	194	6.3	9.7%	113	5.5	Decrease
I71h	My soil surface seals, and I use tillage to enhance water penetration. **Enhanced Infilitration via Tillage**	Water, Nutrients, Energy, Air	20.1%	159	6.2	6.3%	48	6.9	Decrease
E27	The irrigation system was computer controlled (e.g., by a SCADA system) to allow users to monitor flow rates and/or other efficiency data about the system. **Computer-Controlled Irrigation**	Energy, Air, Water	17.9%	252	4.7	2.9%	103	3.2	Decrease

I

			2014 Report Interval			Post-Report Interval			
BMP#	**Other Educational Priorities based on High-Profile Issues**	**Relevant Mgt Area(s)**	**% Orchards**	**N**	**95% CL**	**% Orchards**	**N**	**95% CL**	**Significant Change**
A14	Year-round orchard floor management resulted in a smooth and level orchard floor to optimize harvest efficiency and minimize dust.	Air	87.7%	422	3.1	96.0%	126	3.4	Increase
A16	To reduce dust, the sweeper head was set a the manufacturer-recommended height (not lower).	Air	79.3%	368	4.1	93.7%	111	4.5	Increase
A18	Sweepers designed to minimize passes and reduce dust were used.	Air, Energy	64.6%	364	4.9	73.9%	111	8.2	
A17	The sweeper head used tines made of wire instead of rubber/plastic.	Air	55.7%	350	5.2	41.4%	111	9.2	Decrease

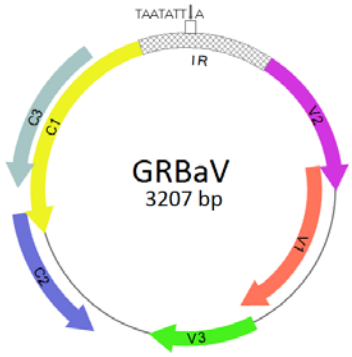


Figure 1. The single-stranded DNA genome of Grapevine red blotch virus (GRBaV) showing the predicated 6 genes (in colored arrows).

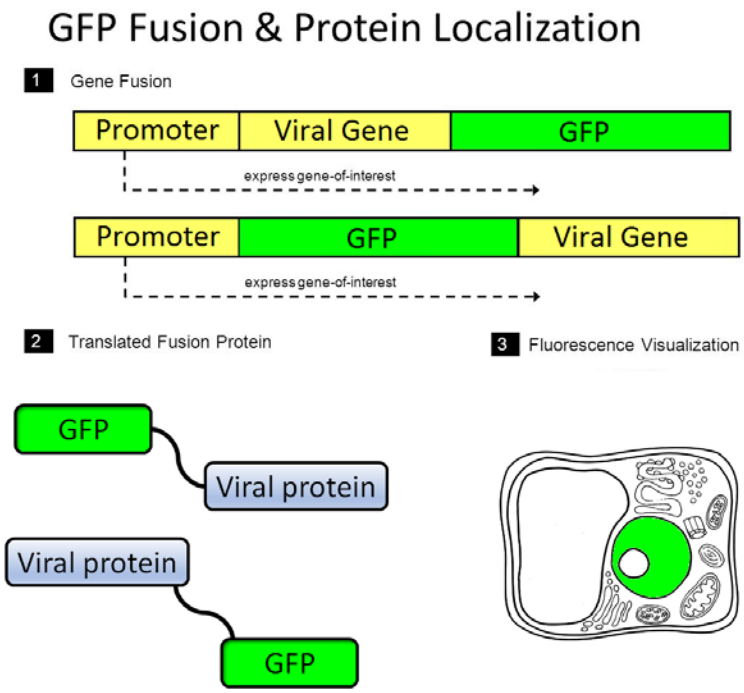


Figure 2. Strategy for making fusion proteins of Grapevine red blotch proteins with the green fluorescent protein (GFP). 1. Gene fusions with the viral gene at the 5' and 3' end. 2. A cartoon showing the predicted fusion protein. 3. A cartoon showing expression of GFP in the nucleus.

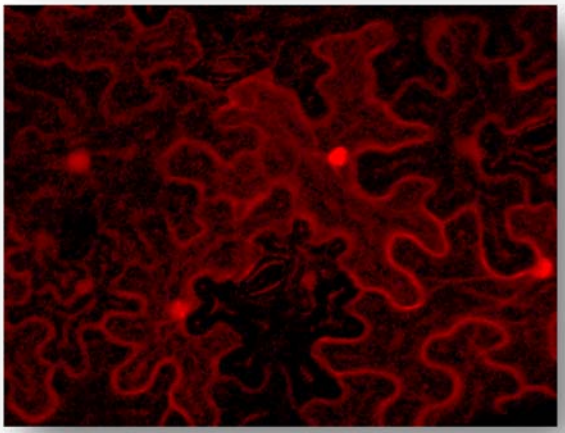


Figure 3. Expression of free GFP (red form) is *Nicotiana benthaniana* cells. Note the GFP is in the cytoplasm and the nucleus but not in the nucleolus.

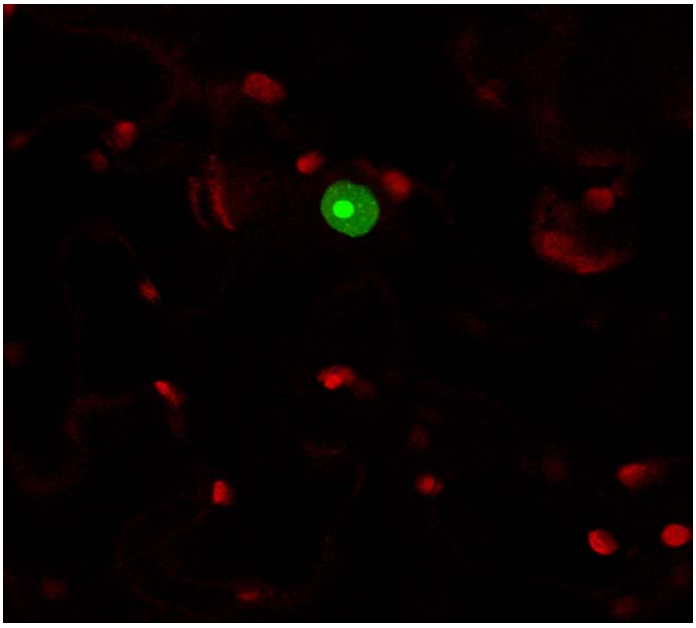


Figure 4. Subcellular localization of the GRBaV capsid protein to the nucleus and nucleolus. This is consistent with the protein being the capsid protein of the virus. Results of a protein search of the GRBaV CP showing that the identification of homology with known geminivirus capsid protein.

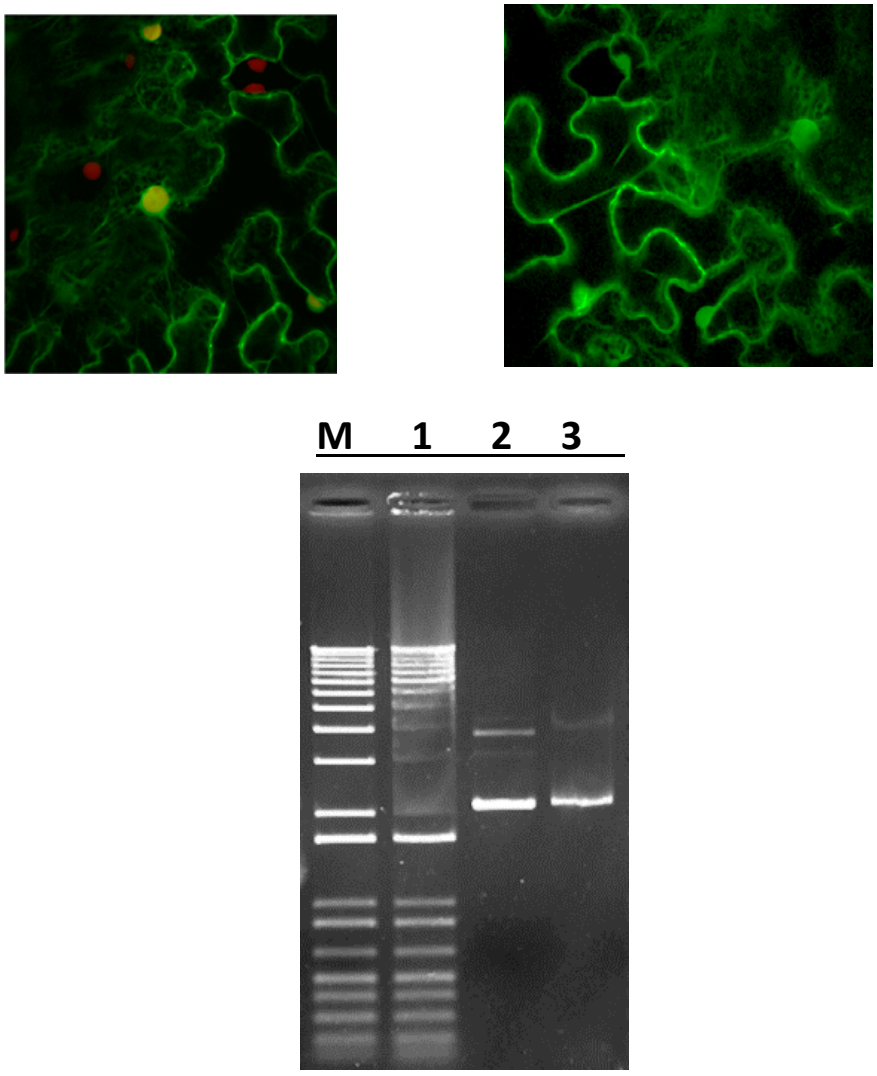
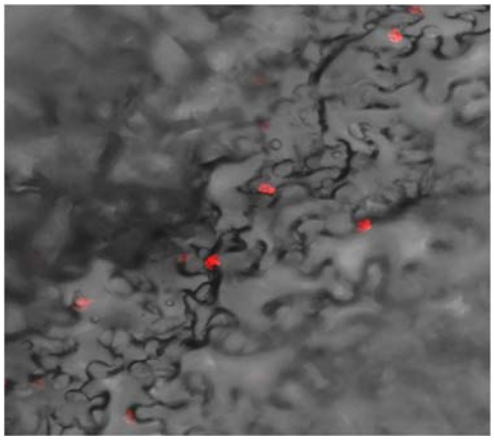


Figure 5. Upper Panels: Subcellular localization of the GRBaV V2 to the nucleus (upper left) and cell periphery (upper right). Lower Panel: The V2 protein binds DNA in a non-specific manner (lanes 1 and 3).

A.



B.

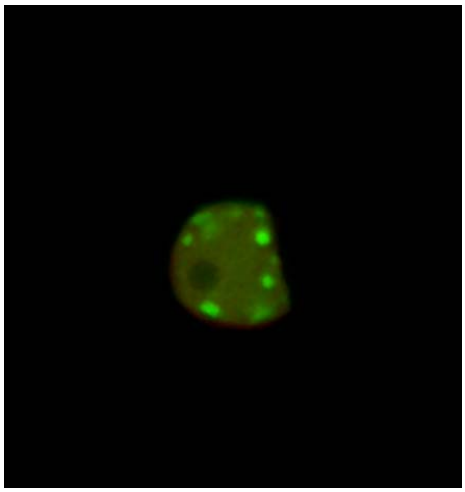


Figure 6. Subcellular localization of the GRBaV V3 to the nucleus (A) and cajal bodies (B).

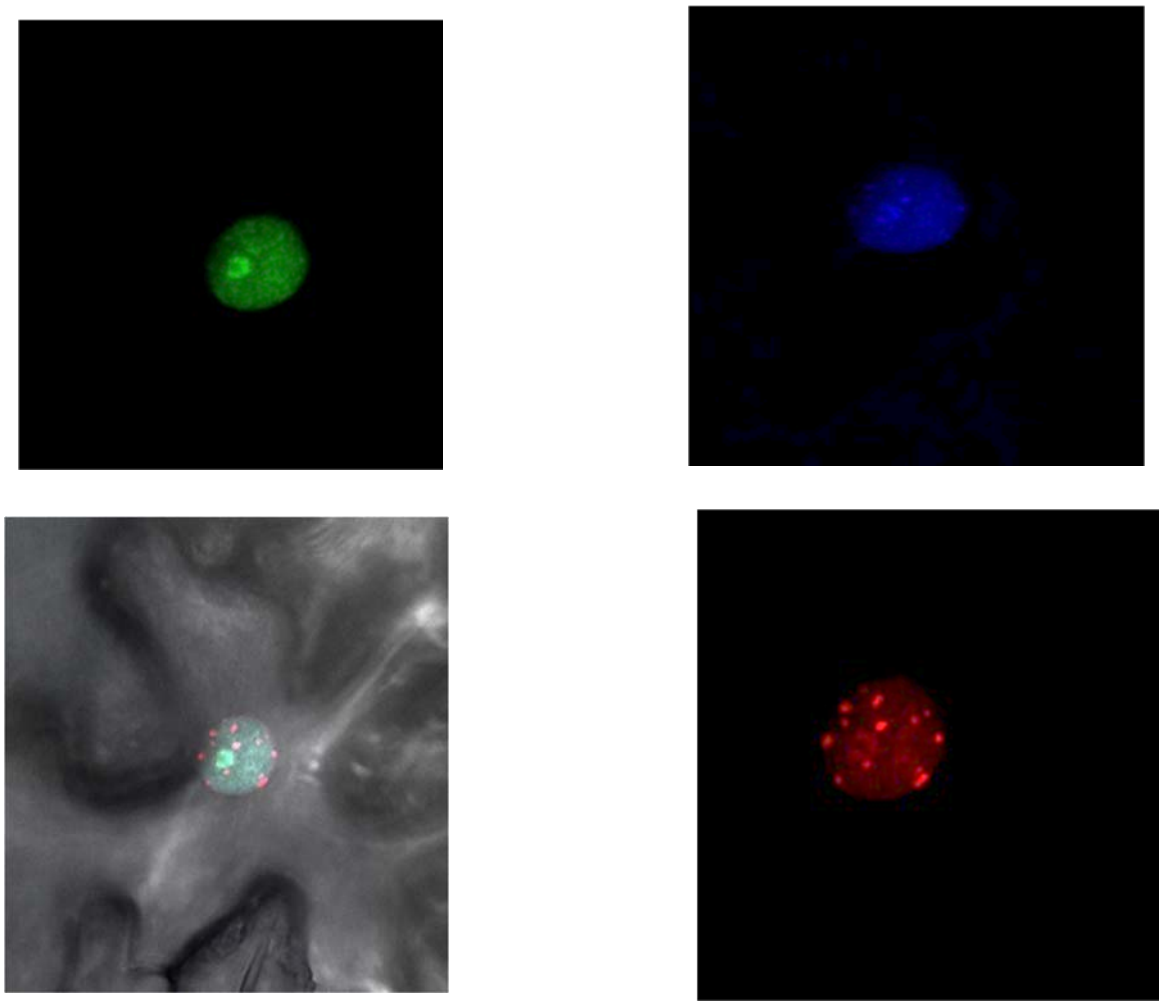


Figure. 7. Co-localization of V1, V2 and V3 proteins labelled three fluorescent signals showing that there is an interaction between V1 and V2 proteins. Upper Left – V1 alone, labeled with GFP (green); Upper Right - V2 alone labeled with BFP (blue); Lower Right - V3 alone labeled with RFP (red); Lower Left - All three proteins co-inoculated. Note the change in color resulting from simultaneous fluorescence of V1 and V2 in the same locations with concentrations of V3 fluorescence apparent.

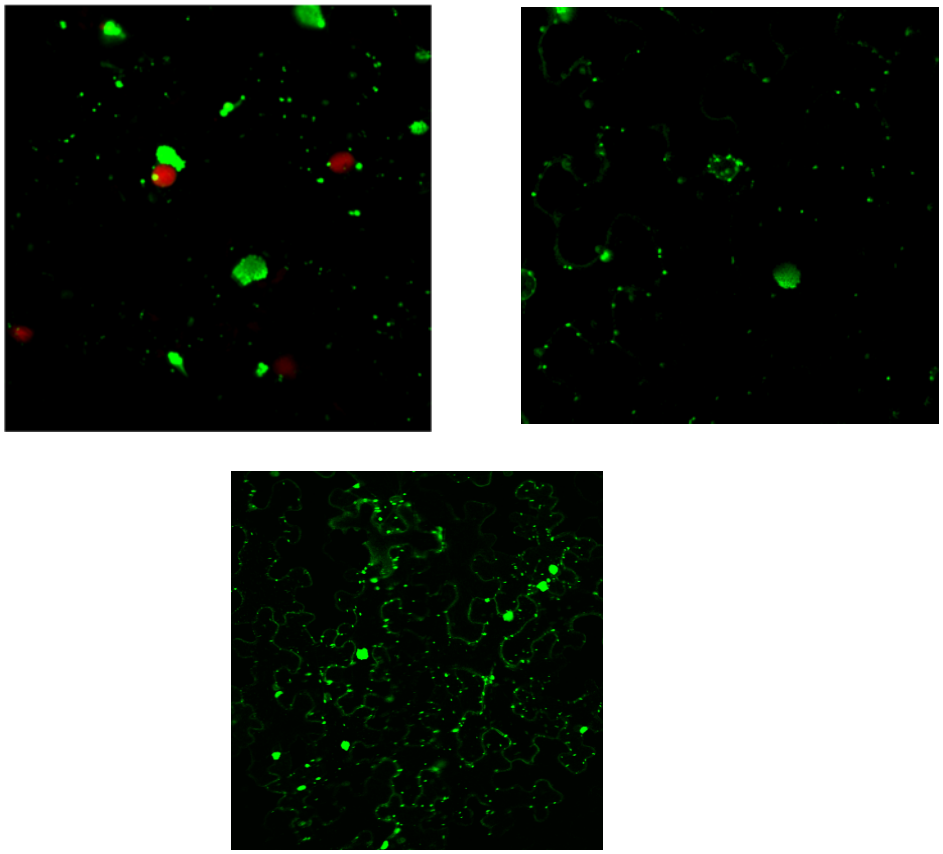
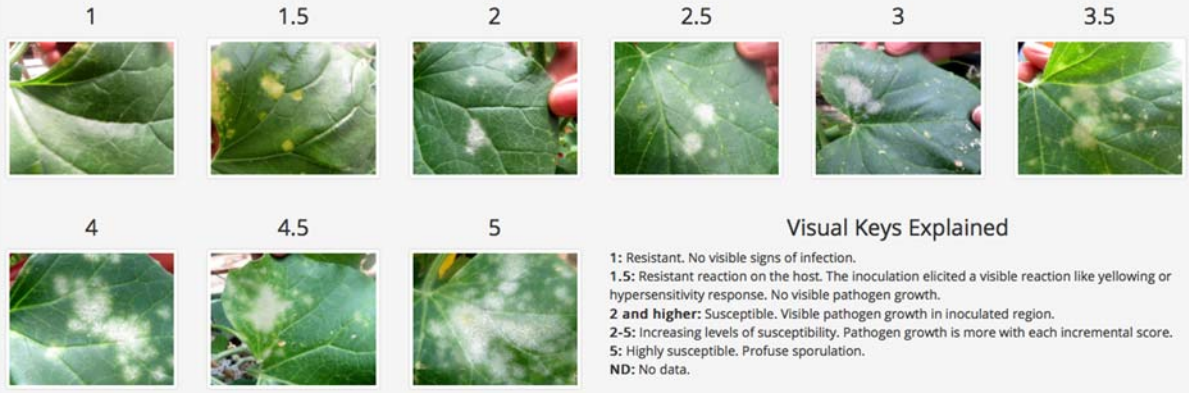


Figure 8. Sub-cellular localization patterns for GRBaV proteins in grape leaf cells. Upper Left - V1 and V3 localized in the nucleus. Upper Right - GFP-labeled V3 in the Cajal bodies. Lower Panel - V2 in the nucleus and cell periphery.



Visual Keys Explained

1: Resistant. No visible signs of infection.
1.5: Resistant reaction on the host. The inoculation elicited a visible reaction like yellowing or hypersensitivity response. No visible pathogen growth.
2 and higher: Susceptible. Visible pathogen growth in inoculated region.
2-5: Increasing levels of susceptibility. Pathogen growth is more with each incremental score.
5: Highly susceptible. Profuse sporulation.
ND: No data.

	Strain	Top Mark	PMR 45	PMR 5	PMR 6	WMR 29	Edisto 47	PI 414723	MR-1	PI 124111	PI 124112	PI 313970
1	JM001 FC	2.3	2.5	2.2	1.7	2.0	1.5	1.0	1.5	1.0	1.0	1.0
2	JM001 SS-1	4.9	2.5	2.2	1.7	2.0	1.5	1.0	1.5	1.0	1.0	1.0
3	JM002 FC	2.5	1.3	3.5	1.0	1.2	1.3	1.0	1.0	1.0	1.0	1.0
4	JM002 SS-1	3.1	1.9	2.1	1.1	3.1	2.0	1.0	1.1	1.0	1.4	1.0
5	JM005 FC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6	JM005 SS-1	3.3	1.0	1.0	1.2	1.6	2.0	1.0	1.0	1.0	1.0	1.0
7	JM007 FC	3.0	1.3	2.3	1.3	1.0	1.0	1.3	1.2	1.3	1.3	1.0
8	JM007 SS-2	2.1	1.0	1.4	1.0	2.3	1.8	1.0	1.2	1.0	1.3	1.0
9	JM008 SS-2	2.0	1.0	2.0	1.0	1.7	1.2	1.0	1.0	1.0	1.6	1.0
10	JM009 FC	2.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
11	JM009 SS-1	3.9	1.0	2.3	1.8	3.9	2.1	1.4	1.0	1.0	1.0	1.0
12	JM009 SS-2	3.4	1.0	2.1	1.4	1.0	1.0	1.0	2.5	1.0	1.1	1.2
13	JM009 SS-3	3.4	1.0	1.9	1.0	1.0	1.0	1.0	1.2	1.0	1.0	1.2
14	JM010 FC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
15	JM010 SS-1	5.0	1.2	2.1	1.6	3.8	2.4	1.0	1.0	1.3	1.0	1.0
16	JM011 FC	3.7	1.0	2.0	2.0	1.2	1.0	1.0	1.2	2.2	1.0	1.0
17	JM011 SS-1	2.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
18	JM011 SS-2	2.0	1.2	2.7	1.0	3.5	1.8	1.0	1.0	1.0	1.0	1.0
19	JM011 SS-3	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
20	JM012 FC	2.8	4.3	4.3	2.7	4.2	4.3	1.0	3.0	1.8	1.8	1.7
21	JM012 SS-1	5.0	1.0	1.8	2.0	3.9	2.7	1.4	1.1	1.0	1.0	1.0
22	JM013 FC	1.5	1.0	2.2	1.0	1.0	1.7	1.0	1.2	1.0	1.0	1.0
23	JM013 SS-1	2.8	2.1	2.1	1.0	1.6	2.4	1.1	1.2	1.1	1.0	1.0
24	JM014 FC	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
25	JM014 SS-1	2.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
26	JM014 SS-2	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.2
27	JM015 FC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
28	JM015 SS-1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
29	JM017 FC	3.9	1.0	2.1	1.0	2.4	1.0	1.0	1.0	1.0	1.0	1.4
30	JM017 SS-1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Strain	Top Mark	PMR 45	PMR 5	PMR 6	WMR 29	Edisto 47	PI 414723	MR-1	PI 124111	PI 124112	PI 313970

Invasive Shot-Hole Borers + Fusarium Dieback
Prioritizing Management Efforts

HOW TO USE THIS CHART

This chart is intended to help inform ISHB (Polyphagous and Kuroshio Shot-Hole Borers) management decisions. Consider potential safety hazards, tree value (economic and ecological), available resources, and other factors unique to each situation when using this tool.

REPRODUCTIVE HOSTS

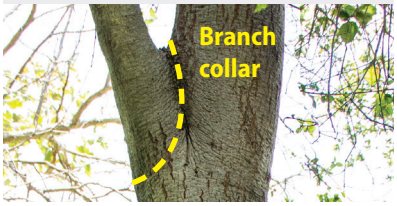
A reproductive host is a species that supports 1) ISHB reproduction and 2) growth and development of the beetle's symbiotic fungi. These species are currently the priority for control efforts as they can produce more beetles that may spread the infestation. Some of the more susceptible reproductive hosts appear to be box elder, castor bean, valley oak, Engelmann oak, coral, and several species of sycamore, willow, and cottonwood.

Visit pshb.org for the full host list.

LIMB FAILURE HAZARD

The point of attachment between a tree branch and the main stem is called the branch collar. ISHB infestation in this area poses a serious safety hazard: a weakened collar may not be able to support the weight of the branch, creating potential for limb failure.

Infested trees—including those that have been treated or pruned—must be regularly monitored so that hazards can be identified and removed. When monitoring, consider beetle attacks in the branch collar as part of the branch.



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Akif Eskalen[1], Ph.D; Monica Dimson[2]; John Kabashima[2], Ph.D; Shannon C. Lynch[1]; Michele Eatough-Jones[1], Ph.D; Tim Paine[1], Ph.D.

[1]UC Riverside [2]UC Cooperative Extension

IDENTIFYING + MANAGING ISHB: SUGGESTED STEPS

Identify the pest. Does the tree have multiple entry-holes with staining, gumming, frass, and/or sugar exudate?

- Yes → Scrape away the bark. Is the entry-hole about the size of the tip of a ball point pen? (~.85mm)
  - Yes → Is the tree a known reproductive host?
    - Yes → View the map at ucanr.edu/sites/pshb/map. Has ISHB been found in your city?
      - Yes → **Assess the damage.** Where is the infestation located?
        - **Branches Only** → Prune branches, treat cuts, and monitor*
        - **Trunk + Branches** → Does the tree have branch dieback?
          - No → Count active gallery holes. Look for clusters on the trunk and individual branches.
            - ≥50 (branch / trunk) → Treat and monitor tree*
            - <50 → Is the tree a reproductive host?
              - Yes → Treat and monitor tree*
              - No → Monitor tree regularly*
          - Yes → **Choose one:**
            - Remove entire tree
            - Treat and monitor tree if tree is of special value and **not** an isolated infestation
      - No → Send photos and a report to UC Riverside at eskalenlab@gmail.com. Is a ISHB-FD infestation confirmed?
        - Yes → **Assess the damage.** Where is the infestation located?
        - No → Symptoms may be caused by other factors. Consult a tree specialist.
    - No → Symptoms may be caused by other factors. Consult a tree specialist.
  - No → Symptoms may be caused by other factors. Consult a tree specialist.
- No → Symptoms may be caused by other factors. Consult a tree specialist.

Dispose of all infested material. Are plant parts small enough to chip?

- Yes → Chip wood parts to less than 1″ in diameter
- No → **Choose one:**
  - Solarize with clear tarp according to guidelines
  - Disinfect wood by kiln drying (60 min at 60°C)

Choose one:
- Solarize with clear tarp
- Compost at commercial facility
- Burn at biogeneration facility
- Send to landfill for use as Alternative Daily Coverage
- Chips that are not solarized, composted, or kiln-dried may only be used as mulch in ISHB heavily infested areas

** Tree removal is an option for trees of any infestation level.*

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Revised 04/2017

Invasive Shot-Hole Borers + Fusarium Dieback
How to Handle Infested Plant Material

CURRENT OPTIONS

Options for handling infested plant material include the following:

- Chip (less than 1") + compost
- Chip (less than 1") + solarize
- Cut logs + solarize
- Chip (less than 1") + deliver to landfill for use as Alternative Daily Coverage
- Cut logs + kiln-dry

Guidelines for effective solarization and composting are included below.

****If relocating infested material, cover in-transit to prevent beetles from escaping****

SOLARIZATION GUIDELINES

Solarization is a suitable method for handling either infested chips or logs. When done properly, solar energy will heat plant material until both the beetle and fungi are killed. It is most effective during the peak of summer, when temperatures are higher and days are longer, but may be used during the rest of the year as long as time and space can be committed.

Follow these tips for proper solarization:

- Use sturdy plastic sheeting/tarp (clear is recommended) that can withstand rain/wind
- Fully contain chips/logs by wrapping plastic both underneath and over the material
- During July - August: cover chips/logs with sturdy plastic for **at least 6 weeks**
  - Temperatures during these months should be regularly above 95°F
- During September - June: cover chips/logs with sturdy plastic for **at least 6 months**
- **Keep log/chip layers as thin as possible** (2 logs deep maximum) to ensure even heating throughout the pile

COMPOSTING GUIDELINES

When done correctly, composting can effectively control the plant pathogens that cause Fusarium Dieback. Composted, chipped plant material may then be repurposed as mulch or added back into soil to improve texture and water retention.

Requirements for adequate decomposition

If transporting chipped material is not an option, you can compost chips yourself. These general composting guidelines will help assure the destruction of pathogenic fungi.

- Woody material should be chipped to less than 1 inch.
- A mixture of equal volumes of green plant and dry plant material will normally achieve a proper carbon-to-nitrogen ratio of 30 to 1.
- Do not add soil, ashes from a stove or fireplace, dairy or meat products, or manure from meat-eating animals.
- A pile should be in bins at least 36 x 36 x 36 inches to assure adequate heating. Maintain a temperature of 160°F, turn the pile every 1-2 days, and add nothing to it once the composting process has begun. If temperatures do not get up to 160°F within 1-2 days, the pile is too wet or dry. If too dry, add water. If not enough nitrogen, add green material.
- Healthy compost has a pleasant odor, gives off heat as vapor when turned, has a white fungal growth on the decomposing material, gets smaller each day, and changes color to dark brown. Compost is ready when it no longer produces heat.

Source: UC IPM, ipm.ucanr.edu/PMG/GARDEN/FRUIT/ENVIRON/composting.html
Read more about composting at uccemg.com/files/78738.pdf and calrecycle.ca.gov/Organics/

PRUNING BMPS

Poor pruning practices can facilitate the spread of plant disease. For pruning and tool sterilization tips, see UC Riverside's "Best Management Practices for Disease in Oak Woodlands" (Lynch and Eskalen 2014).



TRUSTED COMPOST FACILITIES

It is **recommended** that chipped material be taken to a composting facility that has earned the US Composting Council's Seal of Testing Assurance (STA). Facilities in the STA program are tested for proper decomposition and pathogen control.

Find your local STA Compost Facility at:
compostingcouncil.org/participants

ISHB RESOURCES

Find ISHB research updates and news at:
www.pshb.org
www.eskalenlab.ucr.edu

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Revised 04/2017

SCB14049 Attachment 1

Arthropod-Plant Interactions
DOI 10.1007/s11829-017-9501-0

ORIGINAL PAPER

Susceptibility of germinating cruciferous seeds to *Bagrada hilaris* (Hemiptera: Pentatomidae) feeding injury

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Received: 22 March 2016 / Accepted: 31 January 2017
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Abstract *Bagrada hilaris* (Burmeister) (Hemiptera: Pentatomidae) is a serious pest that attacks both germinating and seedling stages of a variety of cruciferous crops grown in the Central Coast of California. *B. hilaris* feeding on germinating seeds can cause severe stunting and plant mortality, and little is known about the feeding preference of *B. hilaris* for germinating seeds of major cruciferous hosts and varieties of hosts. No-choice and choice experiments were conducted in which germinating seeds in soilless and soil settings were exposed to *B. hilaris* adults for 7 days. Susceptibility scores were developed using *B. hilaris* feeding injury sites, distorted leaves, and deformed and dead plants to determine the overall *B. hilaris* preference for germinating host seeds. Based on the scores, the order of preference was arugula (*Eruca sativa* L.) > turnip (*B. rapa* L. var. *rapa*) > mizuna (*B. rapa* L. *nipposinica*) > kale (*B. oleracea* L. *acephala*) > choi (*Brassica rapa* L. var. *chinensis*) > broccoli (*B.* oleracea var. italica Plenck) > cauliflower (*B. oleracea* L. var. *botrytis*) > lettuce (*Lactuca sativa* L.) > sweet alyssum (*Lobularia maritima* [L.] Desv.). The lowest feeding injury was recorded on germinating lettuce and sweet alyssum seeds. Furthermore, no-choice and choice experiments were conducted with four varieties each of arugula and mizuna, twelve varieties each of kale and choi, and nine varieties/types of leafy Asian greens. The arugula varieties 'Wild Rocket' and 'Spirit' were more damaged by *B. hilaris* than other varieties tested. Among mizuna varieties, 'Beira F1' was more attractive to *B. hilaris* than 'Scarlet' or 'Starbor F1.' The choi varieties 'Tokyo Bekana,' 'Feng Qing Choi F1,' 'Joi Choi F1,' and 'Win-Win Choi F1' were more attractive than 'Rosie F1.' The leafy Asian greens variety 'Carlton F1' was more attractive to *B. hilaris* than 'Yukina Savon,' 'Tatsoi OG,' 'Komatsuna Summerfest F1,' 'Red Rain F1,' and 'Shungiku.' Therefore, the results suggest that not all varieties were equally susceptible to *B. hilaris* feeding and possibly be utilized for further field evaluation as a trap crop or developing more resistant varieties to *B. hilaris*.

Keywords California's Central Coast · Brassicaceae · Asian leafy vegetables · Stink bug

Introduction

Bagrada hilaris (Burmeister) (Hemiptera: Pentatomidae) is an invasive stink bug species native to southern Africa, Middle East, and Asia (Reed et al. 2013). It was first detected in North America in Los Angeles Co., California in 2008 (Palumbo and Natwick 2010). Since then, it has been found in most of the counties in California and has become well established in the northern Central Coast of California since 2012 (Joseph 2014). In addition, *B. hilaris* has been detected or has established in Arizona, New Mexico, Nevada, Texas, Oklahoma, and Hawaii (Bundy et al. 2012; Vitanza 2012; Reed et al. 2013; Matsunaga 2014) as well as in Mexico (Sanchez-Pena 2014).

Bagrada hilaris preferentially feeds on cruciferous crops (Family: Brassicaceae), including broccoli (Brassica oleracea var. italica Plenck), cauliflower (*B. oleracea* L. var.

Handling Editor: Heikki Hokkanen.

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Published online: 22 February 2017

botrytis), kale (*B. oleracea* L. *acephala*), choi (*B. rapa* L. var. *chinensis*), arugula (*Eruca sativa* Mill.), mizuna (*B. rapa* L. *nipposinica*), and turnip (*B. rapa* L. var. *rapa*) (Reed et al. 2013; Huang et al. 2014a). In California alone, cruciferous crops were valued at an estimated 1 billion USD in 2013 (U.S. Department Agriculture, NASS 2014). Cruciferous crops were grown on >4390 ha in 2013 and valued at 679 million USD, with leafy Asian salad crops in Monterey Co. valued at 64 million USD (Monterey County Crop Report 2014).

Many stink bug species cause economic damage by feeding on fruits or seeds on mature plants, with damage of germinating seeds and seedlings occurring infrequently (McPherson and McPherson 2000; Chocorosqui and Panizzi 2004). In contrast, *B. hilaris* is most problematic when feeding in freshly seeded or transplanted fields (Reed et al. 2013). *B. hilaris* kill seedlings, reduce plant stands, and severely stunt surviving plants when they feed in fields immediately following planting and during the early stages of plant growth (Reed et al. 2013; Huang et al. 2014b). The harlequin bug [*Murgantia histrionica* (Hahn)] is a specialist of plants in the family Brassicaceae and can also be a pest of cruciferous crops, but it tends to attack crops later in the growing cycle than *B. hilaris* (White and Brannon 1933). *Bagrada hilaris* feeds via a lacerate-and-flush method in which it repeatedly inserts its stylets between layers of epidermal cells (Reed et al. 2013). This feeding pattern physically injures the epidermal cellular tissue and the injury manifests as "starbursts" on leaf surfaces. With time, starburst damage changes into necrotic tissue. This feeding injury on leaves, even when primarily cosmetic, can render leafy cruciferous crops such as choi, arugula, mizuna, and kale unmarketable. In broccoli and cauliflower, economic injury also occurs when feeding by *B. hilaris* kills the apical meristem of young seedlings, causing plants to not produce a head (a "blind head"; Palumbo and Natwick 2010). On some plants, *B. hilaris* feeding also stimulates the growth of multiple secondary shoots, which produces unmarketable and undersized broccoli and cauliflower heads.

Germinating seeds provide a potential window of vulnerability for direct-seeded crops and are therefore a critical stage for evaluating damage by *B. hilaris*. The yield loss attributable to mortality or damage to germinating seeds has not been quantified for cruciferous crops. However, large numbers of adults and nymphs have been found in the soil cracks and crevices on production beds during germination or emergence of the seeds, and these high populations can inflict substantial damage (SVJ unpublished data). For instance, extensive feeding injury by *B. hilaris* was evident on newly germinated broccoli, arugula, and mizuna (SVJ unpublished data). These crops, as well as other leafy greens, are entirely direct seeded in the Salinas Valley in conventional production, while cauliflower is entirely transplanted. For instance, broccoli is typically planted "to stand" with ~15.2 cm spacing between seeds. Seedling mortality reduces the number of plants in the stand, and damage caused from feeding can cause plants to produce small and unmarketable heads. Plant mortality or stunting can cause nearby plants to produce larger, unmarketable heads, causing further yield loss. Typically, leafy greens like arugula and mizuna are densely planted and their tender foliage are harvested several times within six weeks after planting. *Bagrada hilaris* feeding injury symptoms on these tender foliage of these leafy crops reduce the leaf quality and can result in complete rejection of the harvested produce. Damage to germinating seeds and cotyledons just emerging from the soil is a significant threat for direct-seeded crops, and both heading and leafy cruciferous crops can suffer significant economic losses from *B. hilaris* feeding.

To prevent damage by *B. hilaris*, growers typically rely on pyrethroid, neonicotinoid, or carbamate insecticides that are applied during the vulnerable seedling and young plant stages (Palumbo 2011a, b, c; Palumbo et al. 2015). Effective alternative methods to manage *B. hilaris* are still limited. Some growers have even transitioned from direct-seeding to transplanting for broccoli, which is more expensive, to reduce yield loss (Reed et al. 2013) or have avoided planting some crops during periods of greatest *B. hilaris* pressure (SVJ unpublished data). For many cruciferous crops, including baby leafy greens, direct-seeding remains a standard practice, and *B. hilaris* can therefore damage germinating seeds.

Because *B. hilaris* quickly find and colonize newly planted cruciferous crop fields and damage seeds as they germinate, there is an urgent need to reduce *B. hilaris* feeding on germinating seeds. A better understanding of plant damage by *B. hilaris* and the preference for different crops will facilitate more effective management of this pest and better predictions of when economic damage will occur. Previous work has determined how attractive and susceptible seedlings of different cruciferous crops are to *B. hilaris* using cotyledon-stage plants (Huang et al. 2014a). Adult *B. hilaris* were most attracted to radish (*Raphanus sativus* L.) seedlings, followed by those of red cabbage (*Brassica oleracea* L. var. *capitata*) and were less attracted to seedlings of arugula, Napa cabbage (*Brassica rapa* var. *pekinensis* [Lour.], and green mustard (*Brassica juncea* var. *rugosa* [Roxb.]) (Huang et al. 2014a). For red and green cabbage, the combined characteristics of high attractiveness, but lower susceptibility to damage compared to radish, suggested these crops may be good candidates as a trap crop (Huang et al. 2014a).

In contrast, susceptibility of germinating seeds to *B. hilaris* feeding is not well understood, nor is the preference of *B. hilaris* for these seeds. In addition, varieties of individual may vary in their susceptibility and attractiveness.

This information is necessary to predict damage to recently seeded crops. Additionally, differences in preference among germinating seeds could be used for developing sustainable management tactics. Trap cropping is a tactic used to attract or divert invading pests using a preferred plant host or cultivar (Hokkanen 1991; Shelton and Badenes-Perez 2006; Wallingford et al. 2013). This tactic could be used to divert or concentrate colonizing *B. hilaris* protecting the germinating main crop by planting seeds of more attractive host plants. Laboratory screening experiments can serve as a first step to selecting trap crop candidates by determining the attractiveness of various potential hosts to the targeted pest, and can be complemented by subsequent field tests (Shelton et al. 1991; Shelton and Nault 2004; Cook et al. 2006). It will be necessary to evaluate various stages of a potential trap crop (germinating, cotyledon, seedling). Developing non-chemical tactics to reduce *B. hilaris* feeding (e.g., trap cropping) is necessary for organically managed farms and could increase the sustainability of conventional farms.

Thus, the major objectives of this study were to (1) assess the relative feeding preference of *B. hilaris* for different germinating cruciferous crop types and susceptibility of the crop types to feeding injury and to (2) evaluate the preference of *B. hilaris* for different germinating leafy cruciferous crop varieties and susceptibility of the varieties to *B. hilaris* injury.

Materials and methods

General methods and insects

We conducted no-choice and choice assays for both types of crops and crop varieties for certain crops (Table 1). In the crop type experiments, we tested eight crops in no-choice and choice tests: broccoli ('Heritage'), cauliflower ('Herman'), turnip ('Tokyo'), choi ('Mei Qing Choi'), kale ('Red winter'), arugula ('Astro'), mizuna ('unknown'), and lettuce (*Lactuca sativa* L., 'Rouge d'hiver'), as well as the insectary plant sweet alyssum (*Lobularia maritima* [L.] Desv., Snow Seeds Co., Salinas, California). Lettuce, which typically does not incur damage by *B. hilaris*, was included as a non-host. No-choice and choice assays were conducted both with and without soil substrate for the seeds. Lettuce and kale were not included in the choice test with soil, while sweet alyssum was only included in this test. Because *B. hilaris* encounter soil when they interact with planted seeds, experiments were conducted with and without a soil substrate. The soil type used was "Clear lake clay" and was collected from a field in Salinas, California. For both assay types, only adult bugs, rather than nymphs, were used because adults are more mobile and are the life stage that typically colonizes newly planted beds.

Crop variety experiments were conducted with multiple varieties of five crop types: arugula, mizuna, kale, choi, and leafy Asian greens. We used four varieties each of arugula and mizuna, twelve varieties each of kale and choi, and nine varieties/types of leafy Asian greens. The varieties used were arugula: 'Sprint,' 'Astro,' 'Wild Rocket,' and 'Roquette Cultive'; mizuna: 'Mustard,' 'Mizuna OG,' 'Kyoto,' and 'Dark Purple'; kale: 'Scarlet,' 'Beira F1,' 'Starbor F1,' 'Olympic Red OG,' 'Premier OG,' 'Toscano,' 'Red Russian OG,' 'Siberian,' 'Black Magic,' 'Lacinato,' 'Redbor F1,' and 'Rogue'; choi: 'Tokyo Bekana,' 'Rosie F1,' 'Gunsho F1,' 'Red Choi F1,' 'Black Summer F1,' 'Feng Qing Choi F1,' 'Joi Choi F1,' 'Win-Win Choi F1,' 'Red PAC F1,' 'White Flash F1,' 'Shiro F1,' and 'Mei Qing Choi'; assorted leafy Asian greens: 'Yukina Savon' (*B. rapa*), 'Hon Tsai Tai' (*B. rapa*), 'Koji F1' (*B. rapa*), 'Tatsoi OG' (*B. rapa* var. *narinosa*), 'Vitamin Green' (*B. rapa* var. *narinosa*), 'Komatsuna Summerfest F1' (*B. rapa* var. *perviridis*), 'Carlton F1' (*B. rapa* var. *perviridis*), 'Red Rain F1' (*B. juncea*), and 'Shungiku' (*Glebionis coronaria* (L.) Cass. ex Spach) (Johnny's Seeds, Winslow, Maine [USA], Snow Seeds Co., Salinas, California, USA).

All assays were conducted in plastic tool organizer boxes, each of which contained a number of individual open-top plastic compartments (Table 1). For each assay, an individual compartment served as a replicate, and *B. hilaris* adults were given access to seeds within the compartment. *Bagrada hilaris* adults were restricted to the individual compartments by securing the tops with no-see-um mesh (Bioquip, Rancho Dominguez, California, USA) held in place with a rubber band or Velcro, or a plastic lid with twelve 2-mm-diameter holes to ensure airflow. Treatments were randomly assigned to compartments of different crop types and varieties were randomly arranged within compartments. Compartments varied in size for different assays, as did the number of compartments per organizer box (Table 1). Compartments were larger for the choice tests compared to the no-choice tests to accommodate multiple types of seeds and more *B. hilaris* individuals (one in no-choice vs. five in choice). For the crop type assays, both no-choice and choice tests were performed with and without soil, whereas the crop variety assays were only conducted using a potting mix substrate (Sun Gro, Sunshine Aggregate Plus Mix 4, Agawam, Massachusetts, USA) for the seeds to rest on. Groups of replicates were completed in successive trials and number of trials and replicates are listed in Table 1. All assays were evaluated after seven days of exposure time to *B. hilaris* to allow sufficient time for seeds to germinate and for feeding damage to become visible. After three days of exposure time, any dead *B. hilaris* were replaced with healthy adults. This mortality was likely due primarily to old age because adults used in the experiment were of varying ages. All experiments were conducted in a controlled

Table 1 Treatments and experimental design for choice and no-choice tests with *B. hilaris* in no-choice and choice tests

Crop type or variety test	Choice or no-choice	Treatments	Substrate	Box mfr.	No. compartments	Compartment size (cm)	Trials	Replicates per treatment[d]	No. *B. hilaris* per compartment
Crop type	No -choice	Arugula, broccoli, choi, cauliflower, kale, lettuce, mizuna, and turnip	Paper towel	NA[a]	16	5.5×4×4.2	4	16	1
		Arugula, broccoli, choi, cauliflower, kale, lettuce, mizuna, and turnip	Soil	Stanley[b]	48	5.0×3.5×3.8	3	12	1
	Choice	Arugula, broccoli, choi, cauliflower, mizuna, turnip, alyssum	Paper towel	Tactix[c]	18	7.0×10.0×6.0	2	36	5
		Arugula, broccoli, choi, cauliflower, kale, lettuce, mizuna, and turnip	Soil	Tactix[c]	9	12.2×8.3×9.7	4	36	5
Variety	No-choice	Varieties of arugula and mizuna	Potting mix	NA[a]	16	5.5×4×4.2	2	8	1
		Varieties of kale and choi and types of leafy Asian greens	Potting mix	Stanley[b]	48	5.0×3.5×3.8	2	12	1
	Choice	Varieties of arugula and mizuna	Potting mix	Tactix[c]	18	7.0×10.0×6.0	2	28	5
		Varieties of kale and choi and types leafy Asian greens	Potting mix	Tactix[c]	9	12.2×8.3×9.7	2	18	5

[a]Manufacturer unknown, but purchased from Walmart, Salinas, CA

[b]Stanley Tools, New Britain, CT

[c]Meridian International Co., Shanghai, China

[d]All the replicates were combined by trial type for analysis purpose

environmental chamber (21 ± 1 °C, 45% relative humidity, and L:D 16:8 photoperiod). Seeds used in the experiments were not treated with any pesticides.

The experiments were conducted in University of California Cooperative Extension-Monterey County Laboratory, Salinas, California. *Bagrada hilaris* adults were collected from broccoli fields in Salinas and Chualar, California and maintained in an environment chamber at 21 ± 1 °C; 45% relative humidity; and L:D 16: 8 photoperiod in cages. Two- to five-week-old potted-broccoli plants were provided as food source for the *B. hilaris* and the plants were changed every week.

Crop type studies

No-choice assays

In the no-choice assay, single *B. hilaris* were given access to only one type of seed. For the assay without soil, three seeds of a host plant were placed inside the compartment in a seed holder. The seed holder was constructed from a plastic vial lid (1.5 cm diam.) that had been inverted and glued to the center of a 5.3×3.8 cm piece of cardboard and lined with 2×2 cm of moistened paper towel and followed

by introduction of one *B. hilaris* adult into each compartment to start the assay. The paper towel within the inverted vial tops was moistened three times during the 7 days period with 0.5 mL of distilled water starting from the set-up.

For the no-choice assays with soil, the seed holder consisted of a modified single well of a plastic seed sprouting tray (1.5 × 1.5 × 1.5 cm; Hummert Greenhouse Supplies, Topeka, Kansas, USA), which was glued directly in the center of the compartment. The well was modified by removing the top of the well to produce a total height of 1.5 cm. Each well was filled with oven-dried soil to 3 mm from the top, and three seeds of each crop type were placed on the soil surface. One *B. hilaris* adult was introduced into each compartment to start the assay and water was added.

Choice assays

Bagrada hilaris were given a choice among different crop types in the choice assays. In the choice assay without soil, the seed holder in the compartment comprised eight inverted plastic vial lids (1.5 cm diameter) glued to a piece of cardboard in two rows with 1.5 cm between rows and 1 cm between lids within rows. Each vial lid was lined with folded 2 × 2 cm of paper towel moistened with distilled water. Three seeds of each crop type were placed in each inverted vial top. Five *B. hilaris* adults were introduced into the compartment at the start of the assay. The paper towel within the inverted vial tops was moistened three times during the 7 days period with 0.5 mL of distilled water.

The experiment with soil used a group of 24 wells of a plastic seed sprouting tray (12 × 8.5 × 3.7 cm, 2 × 2 cm per well) as the seed holders. The group of wells completely filled the bottom of the compartment. Six of the 24 wells were used for the assay and the rest of the wells were closed using paper tape. Open wells were spaced 2 cm apart. Each well was filled with oven-dried soil up to 3 mm from the top, and three seeds of each crop type were placed on the soil surface. Five *B. hilaris* adults were introduced to each compartment at the start of the assay.

Crop variety test

No-choice assays

In the no-choice assays, *B. hilaris* were given access to only one crop variety at a time. For the assay with arugula and mizuna, the seed holder consisted of a single well of a seed tray (1.5 × 1.5 × 1.5 cm) glued directly to the center of a piece of cardboard (5.3 × 3.8 cm). The well was filled with potting mix to 3 mm from the top, and three seeds of each variety were added to the surface of the potting mix. One *B. hilaris* adult was introduced into each compartment at the start of the trial.

The no-choice assays for kale, choi, and leafy Asian greens also used a well of a seed tray (1.5 × 1.5 × 1.5 cm) as the seed holder, although it was glued directly in the center of the compartment. Each well was filled with 0.37 g of potting mix. Three seeds of each species/variety were placed on the surface of the potting mix. One *B. hilaris* adult was introduced into the compartment to start the trial.

Choice assays

Choice assays for arugula and mizuna used seed tray wells (1.5 × 1.5 × 1.5 cm) glued to a piece of cardboard (7 × 10 cm). There were four wells per replication arranged 2 × 2 and each well was filled with potting mix. Three seeds of each host species were placed in each well on the potting mix. At the start of the assay, five *B. hilaris* adults were introduced into the compartment.

For choice assays with kale, choi, and leafy Asian greens, the seed holder consisted of multiple wells from a seed sprouting tray cut and glued to the piece of cardboard (12.2 × 8.3 cm). The number of wells per compartment depended on the number of crop varieties for a given crop type, which varied (Table 1). The wells were arranged in two rows in each compartment. Three seeds of each variety were placed on the surface of the potting mix in the different wells. Five *B. hilaris* adults were introduced into a cell to start the assay.

Evaluation

Seeds or newly germinated seedlings (maximum of two leaves) or were evaluated after 7 days of exposure to *B. hilaris*. We determined the number of germinated seeds, seedlings with *B. hilaris* feeding injury on leaves, discrete feeding injury sites on leaves, distorted leaves with discrete feeding sites coalesced, and completely deformed or dead plants. Seeds and seedlings were evaluated with a dissecting microscope at 10 × magnification. Seeds were determined to be germinated if the radicle had emerged from the seed coat. Intact seeds and seeds with a cracked seed coat but no visible radicle were grouped as un-germinated seeds. Because there were several variations of "starburst" injury on leaves, all discrete discolored spots caused by *B. hilaris* feeding on intact leaves were quantified as injury sites (Fig. 1a, b). Distorted or misshapen leaves with completely discolored dead tissue were quantified as distorted leaves (Fig. 1c, d). Severe *B. hilaris* feeding can deform the seedling to the point where no leaves are present. Those completely destroyed seedlings were classified as deformed or dead (Fig. 1e, f). Individual feeding injury sites were indistinguishable for both distorted leaves and deformed seedlings.

Bagrada hilaris feeding on various crops and varieties was evaluated using three measures of feeding damage: number of feeding sites on leaves, distorted leaves, and dead or deformed seedlings. There could be subtle differences in expression of *B. hilaris* feeding on these hosts as measured by these different types of feeding damage. To accommodate these differences and provide a measure of overall susceptibility levels to *B. hilaris* feeding, susceptibility scores were generated where the number of feeding injury sites per germinated seeds was converted to a scale (0–9) denoted as 0 (0); 1 (0.1–1.0); 2 (1.1–2.0); 3 (2.1–3.0); 4 (3.1–4.0); 5 (4.1–5.0); 6 (5.1–6.0); 7 (6.1–7.0); 8 (7.1–8.0); and 9 (≥8.1). The number of distorted leaves and dead or deformed seedlings per germinated seeds were converted to a scale (0–9) denoted as 0, (0); 1 (0.01–0.25); 2 (0.26–0.50); 3 (0.51–0.75); 4 (0.76–1.00); 5 (1.01–1.25); 6 (1.26–1.50); 7 (1.51–1.75); 8 (1.76–2.00); and 9 (≥2.01).

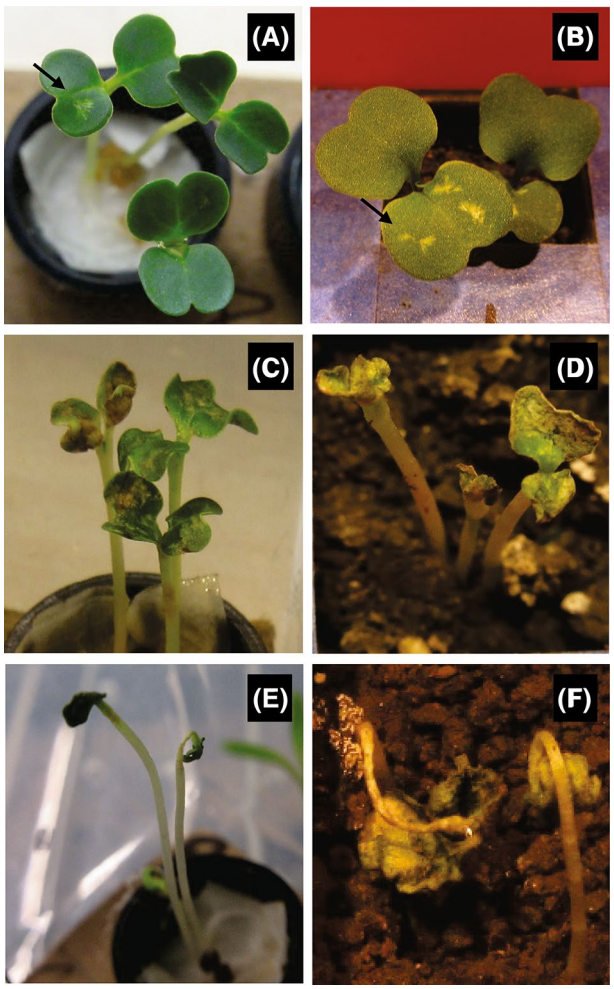

Fig. 1 *Bagrada hilaris* feeding injury types: **a, b** starburst or discolored spots as pointed out using black arrows, **c, d** distorted leaves, and **e, f** completely destroyed leaves or dead seedlings

$$SC = \frac{FS(Scale) + DL(Scale) + DS(Scale)}{Sum\,of\,maximum\,scale\,value} \times 100. \quad (1)$$

The abbreviations are as follows: SC, susceptibility score; FS, number of feeding sites; DL, number of distorted leaves; DS, number of deformed plus dead seedlings. To generate susceptibility scores, the sum of individual scores for the two or three parameters was divided by the sum of the maximum values for each scale (27 for no-choice assays and 18 for choice assays) and percentage was calculated for each replication (1). Susceptibility scores were calculated for assays with or without soil in both the no-choice and choice tests.

Statistical analyses

SAS was used for all statistical analyses (SAS Institute 2012). Analyses were conducted for each assay type (choice/no-choice) for each trial type (crop type/crop varieties), as well as for each substrate type (soil/soilless) for crop type experiments and crop type (e.g., arugula) for crop variety experiments (see Table 1). Number of seeds germinated per well among crop types and crop varieties were analyzed with analysis of variance (ANOVA) using a general linear model (PROC GLM), and means were separated using Tukey's HSD test. All statistical comparisons were considered significant at $\alpha = 0.05$. The number of *B. hilaris* feeding injury sites, distorted leaves, and dead/deformed seedlings were standardized for the number of seeds that germinated by dividing them by the number of germinated seeds per well. For some damage measures, data were not available for certain replicates because high levels of some damage measures (e.g., no seeds germinated) precluded data collection for other damage measures (e.g., distorted leaves), and these data were excluded from the analyses. Each damage measure was analyzed with ANOVA using the PROC GLM procedure. Susceptibility scores were analyzed with ANOVA after arcsine square root transformation using the PROC GLM procedure. Means were separated using Tukey's HSD method. Averages of scores by crop type or variety were ranked to determine the overall susceptibility of each host to *B. hilaris* feeding. Because kale and sweet alyssum were not included in the choice soil assay, the assay was excluded from these averages.

Results

Crop type studies

No-choice assays

In soilless assays, cauliflower seeds germinated at the lowest rate (<50%) after exposure to *B. hilaris* compared to

all other crop types, with the exception of choi, which was intermediate to cauliflower and the other crops (Table 2). The number of *B. hilaris* feeding sites was significantly greater for arugula than for kale, cauliflower, and lettuce, although number of feeding sites was similar between arugula, broccoli, mizuna, and choi ($F=6.8$; df = 7, 130; $P<0.001$; Fig. 2a). The number of leaves deformed by *B. hilaris* feeding in arugula was significantly greater than in broccoli, cauliflower, kale, lettuce and turnip; however, the number of distorted leaves was not significantly different between arugula, mizuna and choi (Fig. 2b) ($F=2.5$; df = 7, 130; $P=0.017$). The number of dead or deformed seedlings was highest for arugula and turnip compared to all other hosts except mizuna, for which the difference was not significant (Fig. 2c) ($F=3.2$; df = 7, 130; $P=0.003$). There was no significant difference in number of deformed or dead seedlings between cauliflower and lettuce.

In the assays with soil, the number of seeds that germinated for cauliflower and mizuna were significantly lower than for lettuce (Table 2). The number of *B. hilaris* feeding sites for seeds that did germinate was significantly greater in kale than in broccoli and lettuce (Fig. 2d) ($F=3.3$; df = 7, 73; $P=0.004$). There were no differences in number of feeding sites between arugula, cauliflower, kale, mizuna, choi, and turnip. A similar number of leaves were deformed by *B. hilaris* feeding across hosts, although no leaves of lettuce were fed upon (Fig. 2e) ($F=1.8$; df = 7, 73; $P=0.089$). The number of dead or deformed seedlings was significantly greater in mizuna than in broccoli, cauliflower, lettuce, and choi (Fig. 2f) ($F=2.4$; df = 7, 73; $P=0.029$), and similar numbers of seedlings did not successfully germinate for arugula, kale, mizuna, and turnip.

Choice assays

In soilless assays, the number of seeds that had germinated after 7 days was greater in arugula than choi and cauliflower (Table 2). Among germinated seeds of arugula, broccoli, kale, mizuna, turnip, and lettuce, there were no significant differences. After 7 days, number of feeding injury sites was significantly greater in turnip and arugula than in broccoli, cauliflower, kale, mizuna, and lettuce ($F=26.7$; df = 7, 236; $P<0.001$), but was not significantly different from choi (Fig. 3a). Number of leaves distorted by *B. hilaris* feeding was significantly greater in mizuna than in kale and lettuce ($F=5.2$; df = 7, 236; $P<0.001$) and it was not significantly differently among arugula, broccoli, choi, cauliflower, and turnip (Fig. 3b).

In the assays with soil, the number of germinated choi seeds after 7 days was significantly lower than germinated broccoli and sweet alyssum seeds (Table 2). Significantly more feeding sites were found in turnip than in choi, cauliflower, and sweet alyssum but number of feeding sites in turnip was not different from arugula, broccoli, and mizuna ($F=11.2$; df = 6, 140; $P<0.001$) (Fig. 3c). The number of distorted leaves was significantly less in sweet alyssum than in all other hosts ($F=3.2$; df = 6, 140; $P=0.005$) (Fig. 3d).

Susceptibility scores

In the no-choice assay without soil, the susceptibility scores were significantly lower in kale, lettuce, and cauliflower than in other hosts (Table 3). However, in the no-choice assays with soil, the susceptibility score was only lower in lettuce than other hosts. In choice assays without soil, susceptibility scores were significantly greater in turnip than in kale, cauliflower, and lettuce, whereas there was no difference in susceptibility scores in choice assays with soil.

Table 2 Mean (±SE) number of seeds germinated out of three after 7 days in the test arena

Host plant	No-choice		Choice	
	Soilless	Soil	Soilless	Soil
Arugula	2.35 ± 0.18a	2.16 ± 0.27abc	2.88 ± 0.05a	2.32 ± 0.12ab
Broccoli	2.70 ± 0.13a	2.83 ± 0.11ab	2.83 ± 0.06ab	2.74 ± 0.11a
Choi	2.20 ± 0.22ab	2.50 ± 0.19ab	2.47 ± 0.11bc	2.00 ± 0.19b
Cauliflower	1.45 ± 0.22b	1.25 ± 0.25c	2.33 ± 0.13c	2.44 ± 0.15ab
Kale	2.45 ± 0.17a	2.50 ± 0.15ab	2.74 ± 0.09ab	–
Mizuna	2.35 ± 0.18a	1.91 ± 0.28bc	2.56 ± 0.12abc	2.57 ± 0.14ab
Turnip	2.70 ± 0.13a	2.25 ± 0.30ab	2.60 ± 0.12abc	2.60 ± 0.12ab
Lettuce	2.65 ± 0.18a	2.91 ± 0.08a	2.77 ± 0.07 ab	–
S. alyssum	–	–	–	2.86 ± 0.26a
F (df1, df2)	5.7 (7, 137)	6.3 (7, 77)	4.2 (7, 236)	3.2 (6, 140)
P	<0.001	<0.001	<0.001	0.004

Means followed by the same letters within a column are not significantly different (Tukey's HSD Test, $\alpha=0.05$)

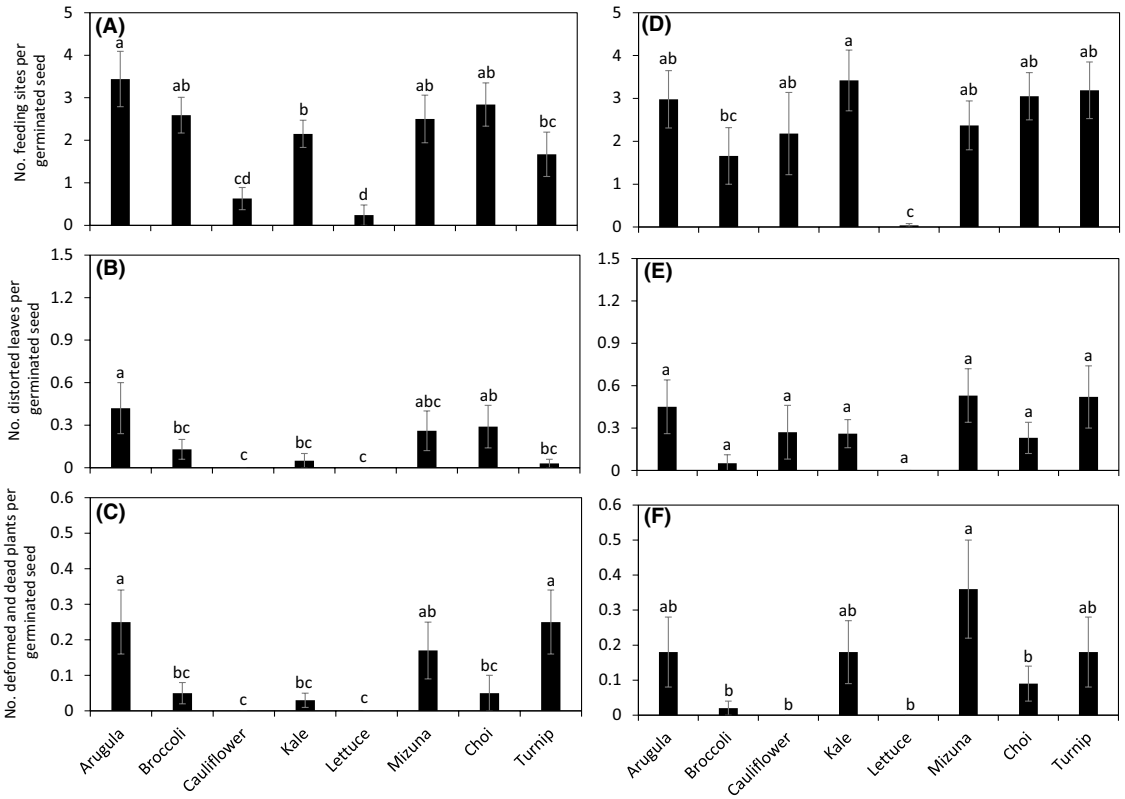

Fig. 2 *Bagrada hilaris* feeding injury (mean ± SE) on germinating seeds in the no-choice assays using of different crop types without soil (**a**–**c**), and with soil (**d**–**f**). Assays were evaluated after 7 days of *B. hilaris* exposure. Bars with the same letter within a figure are not significantly different ($P > 0.05$)

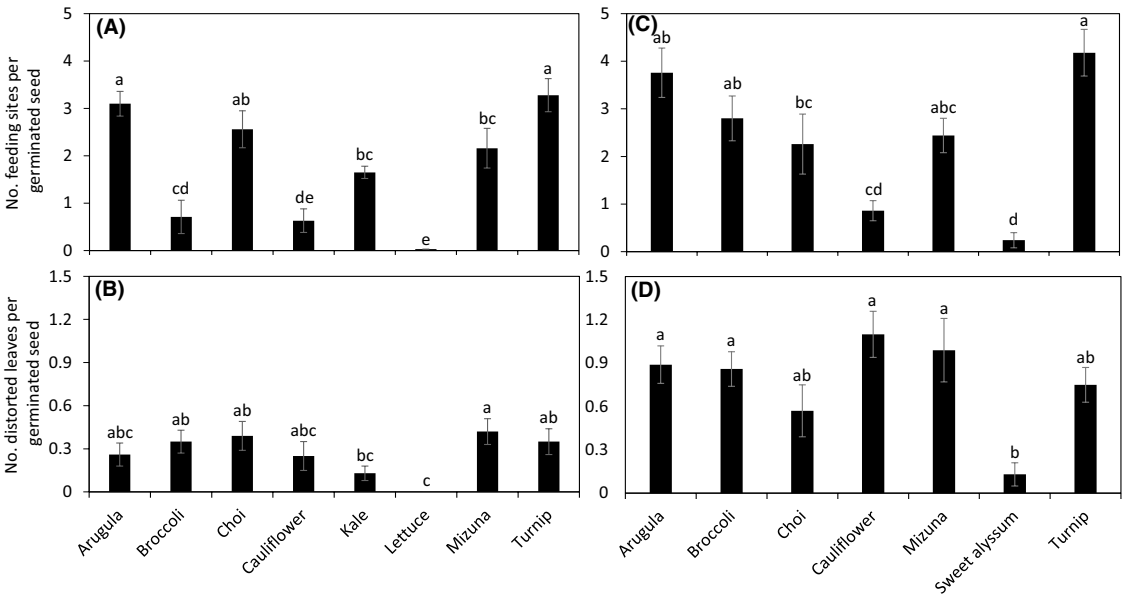

Fig. 3 *Bagrada hilaris* feeding injury (mean ± SE) on various germinating host seeds in the choice assay in the absence (**a, b**) and presence of soil (**c, d**) when evaluated after 7 days of exposure. No plants were severely deformed or dead and therefore these data are not included in the figure. Within a figure, *bars marked* with the *same letter* are not significantly different ($P > 0.05$)

The average of mean susceptibility scores by host indicated that the order of preference/susceptibility to *B. hilaris* feeding from highest to lowest was as follows: arugula > turnip > mizuna > kale > choi > broccoli > cauliflower > lettuce (Table 3).

Assays with crop varieties

On arugula, the number of feeding sites, distorted leaves, and dead or deformed seedlings was significantly lower in 'Wild Rocket' than other varieties in the no-choice assay (Table 4). In the choice assay, a significantly lower number of seeds germinated in 'Roquette Cultive' variety than 'Wild Rocket' and 'Sprint.' The number of feeding sites was significantly greater on 'Spirit' than on 'Wild Rocket' and 'Roquette Cultive,' although there was no difference between 'Spirit' and 'Astro' and or 'Sprint.' The number of distorted leaves was significantly greater on 'Wild Rocket' than on 'Spirit' and 'Roquette Cultive.' The dead and deformed seedlings were significantly greater on 'Wild Rocket' than on 'Astro' and 'Roquette Cultive.'

On mizuna, there were no significant differences among varieties in both no-choice and choice assays (Table 4). On kale in the no-choice assay, the varieties did not differ for number of germinated seeds, feeding injury sites, distorted leaves, and dead or deformed seedlings. In the choice assay, number of seeds germinated among varieties was not significantly different. The number of feeding injury was significantly greater on 'Beira F1' than 'Scarlet' and 'Starbor F1.' Similarly, number of distorted leaves was significantly greater on 'Beira F1' than on 'Starbor F1.' There was no difference among varieties for dead and deformed seedlings.

In no-choice assays with choi, numbers of germinated seeds, feeding injury sites, and distorted leaves were similar among varieties, although dead and deformed seedlings were significantly greater on 'Rosie F1' than 'Mei Qing Choi' (Table 4). In the choice assay, number of seeds germinated was not different among varieties. The number of feeding injury sites was significant greater on 'Tokyo Bekana,' 'Feng Qing Choi F1,' 'Joi Choi F1,' 'Win-Win Choi F1' than on 'Rosie F1,' while the number of distorted leaves was significantly more on 'Win-Win Choi F1' than on 'Rosie F1.' The choi variety 'Joi Choi F1' had significantly greater number of dead and deformed seedlings compared to 'Rosie F1.'

For the no-choice assay with leafy Asian greens, number of germinated seeds, feeding injury sites, distorted leaves, and dead or deformed seedlings did not differ significantly among varieties (Table 4). In choice assay, number of germinated seeds and dead or deformed seedlings was not significantly differently among varieties but number of feeding injury sites and distorted leaves varied with varieties. The feeding injury sites were significantly greater on 'Carlton F1' than on 'Yukina Savon,' 'Tatsoi OG,' 'Komatsuna Summerfest F1,' 'Red Rain F1,' and 'Shungiku.' The leaves distorted after *B. hilaris* feeding were significantly greater on 'Hon Tsai Tai' and 'Carlton F1' than on 'Shungiku.'

Discussion

We assessed the relative susceptibility of germinating seeds of cruciferous species and varieties to *B. hilaris* feeding injury under controlled environmental conditions. First, the ability of *B. hilaris* to feed on germinating cruciferous host

Table 3 Relative susceptibility of germinating host plant seeds to *B. hilaris* feeding injury based on susceptibility scores (%)

Plant host	No-choice		Choice		Ave. susceptibility score[a]	Rank[b]
	Soilless	Soil	Soilless	Soil		
Arugula	23.8 ± 3.8a	21.9 ± 5.5a	25.4 ± 3.1ab	43.9 ± 4.8a	23.70	1
Turnip	11.2 ± 1.8ab	23.9 ± 6.9a	28.1 ± 2.5a	43.9 ± 4.8a	21.06	2
Mizuna	15.9 ± 2.9ab	23.6 ± 6.1a	23.6 ± 2.6abc	36.2 ± 3.9a	21.03	3
Kale	9.9 ± 1.6bc	20.9 ± 3.9a	14.6 ± 1.7 cd	–	15.13	4
Choi	16.7 ± 2.8ab	17.9 ± 3.7a	10.6 ± 2.6ab	27.4 ± 5.9a	15.06	5
Broccoli	13.8 ± 2.9ab	8.3 ± 3.1ab	16.5 ± 2.2bc	36.9 ± 4.6a	12.87	6
Cauliflower	2.8 ± 1.0 cd	12.1 ± 6.2ab	10.6 ± 2.6d	32.9 ± 3.9a	8.50	7
Lettuce	1.0 ± 1.0d	0.3 ± 0.3b	0.3 ± 0.2e	–	0.53	8
Sweet alyssum	–	–		5.2 ± 2.9b	–	–
F (df1, df2)	8.2 (7, 130)	4.9 (7, 73)	21.9 (7, 236)	7.5 (6, 140)		
P	<0.001	<0.001	<0.001	<0.001		

[a]Generated by averaging the percentage susceptibility scores in each tests excluding soil test in choice assay

[b]Generated based on the average susceptibility score. Highest susceptibility score corresponds to higher levels of damage. Values followed by the same letter within the column are not significantly different (Tukey's HSD Test, $\alpha = 0.05$)

Table 4 *B. hilaris* feeding injury on germinating seeds of leafy cruciferous crop varieties

Host varieties	No-choice				Choice			
	Germinated seeds	Feeding sites	Distorted leaves	Dead seedlings	Seeds germinated	Feeding sites	Distorted leaves	Dead seedlings
Arugula[a]								
'Sprint'	3.0 ± 0.0a	5.7 ± 1.4a	1.2 ± 0.3a	0.6 ± 0.2a	2.8 ± 0.1a	7.4 ± 0.7a	0.8 ± 0.1b	1.6 ± 0.9ab
'Astro'	2.6 ± 0.2a	5.7 ± 1.4a	1.3 ± 0.3a	0.6 ± 0.2a	2.6 ± 0.2ab	5.8 ± 0.6ab	0.6 ± 0.1bc	0.3 ± 0.1b
'Wild Rocket'	2.5 ± 0.3a	0.1 ± 0.1b	0.1 ± 0.1b	0.0 ± 0.0b	2.9 ± 0.1a	4.4 ± 0.5b	1.6 ± 0.2a	4.7 ± 1.5a
'Roquette Cultive'	2.6 ± 0.2a	5.4 ± 1.1a	1.7 ± 0.1a	0.9 ± 0.1a	2.1 ± 0.2b	0.3 ± 0.1c	0.1 ± 0.1c	0.2 ± 0.2b
$F_{df1,df2}$; P	$F_{3, 21} = 1.5$; $P = 0.252$	$F_{3, 18} = 7.9$; $P = 0.001$	$F_{3, 21} = 10.8$; $P < 0.183$	$F_{3, 21} = 10.8$; $P < 0.001$	$F_{3, 71} = 4.6$; $P = 0.006$	$F_{3, 67} = 21.6$; $P < 0.001$	$F_{3, 67} = 13.4$; $P < 0.001$	$F_{3, 69} = 4.8$; $P = 0.005$
Mizuna[b]								
'Mustard'	1.9 ± 0.3	3.8 ± 1.4a	0.3 ± 0.2a	0.5 ± 0.2a	2.3 ± 0.1a	6.5 ± 1.0a	0.8 ± 0.1a	0.6 ± 0.1a
'Mizuna OG'	1.3 ± 0.3	6.0 ± 1.3a	1.0 ± 0.4a	0.7 ± 0.2a	2.0 ± 0.2a	7.2 ± 0.8a	0.8 ± 0.1a	0.6 ± 0.1a
'Kyoto'	2.0 ± 0.3	4.1 ± 1.1a	0.5 ± 0.2a	0.6 ± 0.1a	2.3 ± 0.2a	6.4 ± 0.8a	0.9 ± 0.2a	0.6 ± 0.1a
'Dark Purple'	2.3 ± 0.2	3.6 ± 0.6a	0.5 ± 0.1a	0.3 ± 0.1a	2.4 ± 0.1a	7.6 ± 0.9a	0.9 ± 0.1a	0.5 ± 0.1a
$F_{df1,df2}$; P	$F_{3, 33} = 2.1$; $P = 0.113$	$F_{3, 13} = 1.2$; $P = 0.325$	$F_{3, 12} = 1.9$; $P = 0.183$	$F_{3, 26} = 1.1$; $P = 0.387$	$F_{3, 80} = 1.6$; $P = 0.203$	$F_{3, 42} = 0.8$; $P = 0.515$	$F_{3, 47} = 0.1$; $P = 0.938$	$F_{3, 77} = 0.3$; $P = 0.809$
Kale[c]								
'Scarlet'	2.1 ± 0.3a	6.3 ± 1.1a	0.8 ± 0.3a	0.5 ± 0.2a	2.1 ± 0.3a	1.2 ± 0.4c	0.2 ± 0.1bc	0.2 ± 0.1a
'Beira F1'	2.3 ± 0.4a	6.2 ± 0.7a	0.8 ± 0.3a	0.5 ± 0.1a	2.8 ± 0.1a	6.8 ± 1.1a	0.8 ± 0.1a	0.4 ± 0.1a
'Starbor F1'	2.8 ± 0.2a	3.2 ± 1.2a	0.2 ± 0.1a	0.2 ± 0.1a	2.5 ± 0.2a	1.6 ± 0.4c	0.1 ± 0.1c	0.1 ± 0.0a
'Olympic Red OG'	2.6 ± 0.4a	2.5 ± 0.9a	0.2 ± 0.1a	0.2 ± 0.1a	2.3 ± 0.2a	3.4 ± 0.6bc	0.5 ± 0.2abc	0.2 ± 0.1a
'Premier OG'	1.8 ± 0.3a	3.8 ± 1.2a	0.2 ± 0.1a	0.3 ± 0.2a	2.4 ± 0.2a	3.1 ± 0.5bc	0.4 ± 0.1abc	0.2 ± 0.1a
'Toscano'	1.8 ± 0.5a	3.8 ± 1.5a	0.8 ± 0.3a	0.6 ± 0.2a	2.6 ± 0.2a	3.2 ± 0.5bc	0.4 ± 0.1abc	0.2 ± 0.0a
'Red Russian OG'	1.9 ± 0.5a	2.8 ± 0.9a	0.8 ± 0.4a	0.4 ± 0.2a	2.3 ± 0.2a	3.3 ± 0.4bc	0.6 ± 0.1abc	0.3 ± 0.1a
'Siberian'	2.1 ± 0.3a	6.1 ± 0.7a	0.8 ± 0.2a	0.5 ± 0.2a	2.6 ± 0.1a	4.8 ± 0.9ab	0.5 ± 0.1abc	0.3 ± 0.1a
'Black Magic'	2.4 ± 0.4a	4.8 ± 1.4a	0.6 ± 0.3a	0.3 ± 0.1a	2.4 ± 0.2a	2.9 ± 0.6bc	0.3 ± 0.1abc	0.3 ± 0.1a
'Lacinato'	2.3 ± 0.4a	2.6 ± 1.5a	0.5 ± 0.2a	0.5 ± 0.2a	2.6 ± 0.1a	3.5 ± 0.5bc	0.7 ± 0.1abc	0.3 ± 0.1a
'Redbor F1'	1.8 ± 0.4a	3.8 ± 1.9a	0.6 ± 0.2a	0.4 ± 0.2a	2.4 ± 0.2a	3.3 ± 0.7bc	0.3 ± 0.1abc	0.2 ± 0.1a
'Rogue'	2.4 ± 0.3a	6.1 ± 1.5a	0.6 ± 0.2a	0.3 ± 0.1a	2.5 ± 0.1a	3.6 ± 0.6bc	0.4 ± 0.1abc	0.2 ± 0.1a
$F_{df1,df2}$; P	$F_{11, 77} = 0.9$; $P = 0.474$	$F_{11, 53} = 1.6$; $P = 0.132$	$F_{11, 57} = 1.1$; $P = 0.356$	$F_{11, 68} = 0.7$; $P = 0.710$	$F_{11, 187} = 0.9$; $P = 0.555$	$F_{11, 172} = 5.1$; $P < 0.001$	$F_{11, 176} = 2.9$; $P = 0.002$	$F_{11, 182} = 1.7$; $P = 0.076$
Choi[d]								
'Tokyo Bekana'	2.8 ± 0.2a	2.3 ± 1.1a	0.5 ± 0.3a	0.3 ± 0.1ab	2.3 ± 0.2a	7.3 ± 0.8a	1.0 ± 0.3ab	0.2 ± 0.1ab
'Rosie F1'	2.0 ± 0.4a	2.0 ± 1.0a	1.6 ± 0.3a	0.8 ± 0.1a	2.7 ± 0.1a	2.5 ± 0.7b	0.3 ± 0.1b	0.1 ± 0.1b
'Gunsho F1'	1.8 ± 0.4a	3.0 ± 1.3a	0.5 ± 0.3a	0.2 ± 0.2ab	2.4 ± 0.2a	5.3 ± 0.8ab	0.8 ± 0.2ab	0.3 ± 0.1ab
'Red Choi F1'	2.2 ± 0.4a	4.8 ± 1.6a	0.9 ± 0.2a	0.5 ± 0.1ab	2.4 ± 0.2a	5.1 ± 1.1ab	0.5 ± 0.1ab	0.2 ± 0.1b
'Black Summer F1'	2.8 ± 0.2a	3.6 ± 1.2a	0.9 ± 0.3a	0.5 ± 0.2ab	2.3 ± 0.2a	5.3 ± 1.2ab	0.4 ± 0.1ab	0.2 ± 0.1b
'Feng Qing Choi F1'	2.6 ± 0.3a	3.7 ± 0.9a	0.6 ± 0.3a	0.4 ± 0.2ab	2.7 ± 0.1a	6.9 ± 1.2a	0.6 ± 0.1ab	0.3 ± 0.1ab
'Joi Choi F1'	2.6 ± 0.3a	5.6 ± 1.7a	0.9 ± 0.3a	0.9 ± 0.3ab	2.8 ± 0.1a	7.3 ± 1.2a	0.8 ± 0.2ab	0.5 ± 0.1a

Table 4 (continued)

Host varieties	No-choice				Choice			
	Germinated seeds	Feeding sites	Distorted leaves	Dead seedlings	Seeds germinated	Feeding sites	Distorted leaves	Dead seedlings
'Win–Win Choi F1'	2.8 ± 0.2a	3.5 ± 1.4a	0.4 ± 0.2a	0.4 ± 0.2ab	2.5 ± 0.2a	8.5 ± 1.0a	1.2 ± 0.3a	0.4 ± 0.1ab
'Red PAC F1'	2.3 ± 0.3a	3.1 ± 0.9a	0.5 ± 0.3a	0.5 ± 0.3ab	2.3 ± 0.2a	4.3 ± 0.8ab	0.4 ± 0.2ab	0.2 ± 0.1ab
'White Flash F1'	2.4 ± 0.2a	3.2 ± 0.9a	0.4 ± 0.2a	0.3 ± 0.1ab	2.4 ± 0.2a	4.9 ± 1.0ab	0.6 ± 0.2ab	0.3 ± 0.1ab
'Shiro F1'	2.8 ± 0.2a	5.8 ± 1.6a	1.2 ± 0.3a	0.6 ± 0.1ab	2.4 ± 0.2a	6.3 ± 1.3ab	0.5 ± 0.2ab	0.3 ± 0.1ab
'Mei Qing Choi'	2.6 ± 0.2a	2.8 ± 1.3a	0.1 ± 0.1a	0.0 ± 0.0b	2.7 ± 0.2a	6.9 ± 1.2ab	0.7 ± 0.1ab	0.3 ± 0.1ab
$F_{df1,df2}$; P	$F_{11, 77} = 1.7$; $P = 0.094$	$F_{11, 56} = 0.7$; $P = 0.771$	$F_{11, 64} = 1.6$; $P = 0.109$	$F_{11, 74} = 2.1$; $P = 0.034$	$F_{11, 187} = 0.9$; $P = 0.539$	$F_{11, 168} = 3.1$; $P = 0.001$	$F_{11, 168} = 2.1$; $P = 0.022$	$F_{11, 180} = 2.7$; $P = 0.003$
Leafy Asian greens[e]								
'Yukina Savon'[f]	2.3 ± 0.4a	2.4 ± 0.7a	0.1 ± 0.1a	0.1 ± 0.1a	2.2 ± 0.2a	2.1 ± 0.7bc	0.5 ± 0.1ab	0.2 ± 0.1a
'Hon Tsai Tai'[f]	2.3 ± 0.3a	1.9 ± 0.9a	0.3 ± 0.3a	0.1 ± 0.1a	2.6 ± 0.2a	3.5 ± 1.1ab	0.9 ± 0.2a	0.4 ± 0.1a
'Koji F1'[f]	1.9 ± 0.4a	5.2 ± 2.6a	0.6 ± 0.4a	0.2 ± 0.2a	2.6 ± 0.2a	3.6 ± 0.6ab	0.6 ± 0.2ab	0.2 ± 0.1a
'Tatsoi OG'[g]	1.2 ± 0.4a	1.5 ± 1.5a	0.4 ± 0.4a	0.2 ± 0.2a	1.8 ± 0.2a	1.8 ± 0.6bc	0.6 ± 0.2ab	0.3 ± 0.1a
'Vitamin Green'[g]	2.0 ± 0.4a	3.8 ± 1.8a	0.9 ± 0.4a	0.4 ± 0.2a	2.6 ± 0.2a	1.7 ± 0.5bc	0.3 ± 0.1ab	0.1 ± 0.1a
'Komatsuna Summerfest F1'[h]	1.5 ± 0.4a	1.8 ± 1.1a	0.6 ± 0.3a	0.4 ± 0.2a	2.6 ± 0.2a	1.7 ± 0.6bc	0.6 ± 0.2ab	0.2 ± 0.1a
'Carlton F1'[h]	1.1 ± 0.3a	4.2 ± 1.8a	1.0 ± 0.4a	0.7 ± 0.2a	2.4 ± 0.2a	5.7 ± 1.2a	0.9 ± 0.2a	0.5 ± 0.1a
'Red Rain F1'[i]	1.9 ± 0.2a	5.3 ± 1.3a	1.0 ± 0.4a	0.4 ± 0.2a	2.3 ± 0.2a	1.6 ± 0.6bc	0.4 ± 0.2ab	0.4 ± 0.2a
'Shungiku'[j]	1.4 ± 0.5a	0.0 ± 0.0a	0.0 ± 0.0a	0.0 ± 0.0a	2.2 ± 0.2a	0.0 ± 0.0c	0.0 ± 0.0b	0.0 ± 0.0a
$F_{df1,df2}$; P	$F_{8, 56} = 1.4$; $P = 0.208$	$F_{8, 37} = 1.3$; $P = 0.259$	$F_{8, 42} = 1.0$; $P = 0.439$	$F_{8, 43} = 1.6$; $P = 0.154$	$F_{8, 133} = 1.7$; $P = 0.117$	$F_{8, 103} = 6.5$; $P < 0.001$	$F_{8, 124} = 2.7$; $P = 0.008$	$F_{8, 124} = 1.6$; $P = 0.138$

Values followed by the same letter within a host type are not significantly different (Tukey's HSD Test, $\alpha = 0.05$)

[a] *Eruca sativa*

[b] *B. juncea* var. *nipposinica*

[c] *B. oleracea*

[d] *B. rapa* var. *chinensis*

[e] Various species of *Brassica* spp.

[f] *B. rapa*

[g] *B. rapa* var. *narinosa*

[h] *B. rapa* var. *perviridis*

[i] *B. juncea*

[j] *Glebionis coronaria*

seeds, as well as a non-host (lettuce), was evaluated in a no-choice setting. Next, feeding preference was assessed in a choice setting. For the crop type experiments, patterns of damage varied widely among the tested hosts, including among only cruciferous crops. In the crop variety experiments, difference in damage was evident among varieties, although in some cases, there were no varietal differences. In the no-choice assays, *B. hilaris* fed on all cruciferous hosts, although germinating seeds of arugula, turnip, and mizuna were most affected by feeding damage such as leaf distortion and seedling deformity or mortality. This suggests that *B. hilaris* is capable of feeding on germinating stages of all cruciferous hosts that we tested if they can physically access the seeds. Interestingly, the choice assay

results also show that arugula, turnip, and mizuna had more feeding injury than other hosts, suggesting that germinating seeds of these hosts were most preferred by *B. hilaris*, although patterns could also be driven by susceptibility to injury. Previous research on host preference used seedlings (Makwali et al. 2002; Huang et al. 2014a) that were already past the germination stage. With seedlings, *B. hilaris* adults preferred seedlings (cotyledon-stage) of radish and red and green cabbage over sweet alyssum, arugula, and broccoli plants (Huang et al. 2014a). Radish was not used in our study because this crop is not grown extensively in the Central Coast of California. By describing the susceptibilities of germinating seeds of various crop types and varieties, our results expand the information available on crop susceptibility to include the time period when seeds first begin germinating.

It is unclear why certain crop types or varieties suffered more damage than others (e.g., arugula, turnip, and mizuna in the crop type experiment). First, these species/varieties may germinate more quickly than others. The seeds in this study were evaluated after 7 days to provide sufficient time for all seeds to germinate. It is possible that early geminating seeds are more vulnerable to *B. hilaris* feeding than slowly germinating seeds. Second, it is also possible that *B. hilaris* is more attracted to germinating seeds of certain hosts. This could be related to preference of varying levels and blends of volatiles released. Germinating cauliflower seeds release volatile chemicals such as cyanides and isothiocyanates after hydrolysis of glucosinolates (Valette et al. 2006). The strength of the volatiles released varies across cruciferous species and varieties (Valette et al. 2006; Hong and Kim 2013). Variation in defensive chemical content can be important for feeding by herbivores on cruciferous host. For two specialist herbivores, the flea beetle, *Phyllotreta cruciferae* (Goeze) and diamondback moth, *Plutella xylostella* (L.), feeding was greatest when glucosinolate levels in *B. rapa* (syn. *campestris*) (L.) were intermediate (Siemens and Mitchell-olds 1996). It is likely that *B. hilaris* are similarly responding to chemical compounds released by germinating seeds of all of the tested cruciferous hosts and that this affects preference. Moisture content in the seeds may further affect the type and amount of volatiles released from the seeds, which could influence *B. hilaris* behavior and feeding damage (Jorgensen 2001; Hudaib et al. 2010).

Our results show that germinating seeds of lettuce were not attractive to *B. hilaris*. Lettuce was included in this study because it is the major, high-value crop (US$1.4 billion) in the Salinas Valley of California (Monterey County Crop Report 2014). Our results dismiss the anecdotal reports that *B. hilaris* can damage germinating seeds of lettuce. Sweet alyssum was included because it is a commonly used insectary plant in the Central Coast of California which is direct seeded in beds interspersed with the main crop to enhance predation of aphids by syrphid flies (Bugg et al. 2008). Mature sweet alyssum is attractive to *B. hilaris* (Joseph 2014), but our results show that germinating stages of sweet alyssum was not very attractive. This suggests that at least when seeds are still germinating, sweet alyssum would likely not be useful as a trap crop.

Trap crops could provide an additional tool for reducing damage by *B. hilaris* to germinating crops, and our results can inform their development. Although leafy Asian crops, arugula, turnip, and mizuna appear to have relatively similar levels of attractiveness compared to each other, these crops could still be used as a trap crop when the leafy Asian crops are grown as main crops. Crops with the same level of attractiveness can be developed as a trap crop by manipulating the spatial and temporal planting of trap and main crops, thereby diverting or concentrating the incidence and colonization of the pest (Shelton and Badenes-Perez 2006). Early planting of arugula, turnip, and mizuna, possibly before the main crop, may trap invading *B. hilaris*, allow them to be managed, and reduce the impact on the main crop as it germinates. When heading crops such as broccoli or cauliflower are the main crop, leafy Asian crops could be developed as a trap crop because the germinating stages of broccoli and cauliflower were less attractive to *B. hilaris* relative to leafy Asian crops. These tactics would function better if the *B. hilaris* adults attracted to the trap crop are killed or removed via chemical controls (conventional or organic) or with mechanical controls, such as incorporation of the trap crop into the soil or vacuuming. Lettuce, or another non-preferred crop, could serve as a barrier crop in between the trap crop and the main crop, limiting movement of *B. hilaris* into the main crop. It is possible that planting a trap crop before the main crop could attract *B. hilaris* adults earlier to the field and increase damage to the main crop. Thus, this tactic needs to be carefully evaluated in the field to determine its utility for effective *B. hilaris* management.

Although all varieties of leafy Asian crops developed *B. hilaris* feeding injury symptoms after a week of *B. hilaris* exposure, certain varieties of arugula, kale, choi, and Asian greens were fed upon more and developed more symptoms of damage. Perhaps, these differences in feeding preferences could be utilized for management of *B. hilaris* feeding at the germination stages. Those highly preferred varieties could be potentially considered as a trap crop, whereas the less preferred varieties which suffer less feeding injury could be planted as the main crop. These differences in susceptibility or attractiveness to *B. hilaris* could be also be used to develop more resistant varieties for *B. hilaris* management. The arugula varieties 'Wild Rocket' and 'Spirit' were more attractive to *B. hilaris* than other varieties tested. On mizuna, the variety

'Beira F1' was more attractive to *B. hilaris* than 'Scarlet' and 'Starbor F1.' The choi varieties 'Tokyo Bekana,' 'Feng Qing Choi F1,' 'Joi Choi F1,' and 'Win-Win Choi F1' were most attractive. The leafy Asian greens varieties 'Carlton F1' was more attractive to *B. hilaris* than 'Yukina Savon,' 'Tatsoi OG,' 'Komatsuna Summerfest F1,' 'Red Rain F1,' and 'Shungiku.'

In conclusion, our results suggest that germinating stages of arugula, mizuna, choi, and turnip seeds are more attractive to *B. hilaris* than cauliflower or broccoli and may be utilized as a trap crop when seeds are first planted. Although the results did not provide a clear indication of *B. hilaris* feeding preference among arugula, mizuna, choi, and turnip in the choice tests, when planted early along the field edges, one or more of these hosts may diffuse *B. hilaris* pressure and may produce lower feeding injury on the main crop than if the main crop was planted alone. Sweet alyssum plants have been found to be attractive to *B. hilaris* in the field (Joseph 2014), but *B.* hilaris adults did not show any preference for germinating seeds of sweet alyssum in this study, suggesting that it would likely not be useful as a trap crop but also that new plantings should not be highly attractive. Similarly, lettuce was not preferred by *B. hilaris* adults when provided in no-choice and choice studies. Varieties of several cruciferous salad crops demonstrated a spectrum of preference. Our results demonstrate that when seeds first germinate, the susceptibility and attractiveness of different crop types and crop varieties can be useful for determining the threat of *B. hilaris* injury to newly planted fields and for developing effective management tactics.

Acknowledgements The authors appreciate the technical assistance provided by C. Ramirez and J. Martinez with experiments, and agro-chemical companies, and University of California Integrated Pest Management (UC IPM) state-wide program for providing funding for this project. This publication was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

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Crop Protection 87 (2016) 68–77

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Insecticides applied to soil of transplant plugs for *Bagrada hilaris* (Burmeister) (Hemiptera: Pentatomidae) management in broccoli

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ARTICLE INFO

Article history:
Received 3 February 2016
Received in revised form
29 April 2016
Accepted 29 April 2016

Keywords:
Brassicaceae
Integrated pest management
Seedling tray drench
Salinas Valley
Neonicotinoid

ABSTRACT

Chemical control with insecticides, typically applied as foliar sprays or chemigation, is the primary tactic used to manage *Bagrada hilaris* (Burmeister) (Hemiptera: Pentatomidae). We evaluated the efficacy of 14 insecticides, including both systemic and non-systemic insecticides, against *B. hilaris* applied as a seedling tray drench. Experiments were conducted in both greenhouse and field settings. In all experiments, we used the maximum label rate of insecticides and calculated dose per seedling based on this rate and standard plant density per hectare. Each seedling in the tray received 2-mL insecticide solution, and the seedlings were then exposed to *B. hilaris* adults after transplanting in cages for greenhouse experiments or natural *B. hilaris* populations in the field experiments. A scale system (0–4) was used to evaluate the severity of *B. hilaris* feeding injury on leaves where 0 = no injury and 4 = >75% of the leaf margins with *B. hilaris* feeding injury. We evaluated damage using the rating system, percentage of damaged leaves, number of feeding injury sites, as well as plant height, leaf width, and fresh and dry weight. In the greenhouse experiment, percentage of injured leaves, number of injury sites, and damage rating were significantly lower for transplants treated with acetamiprid, clothianidin, dinotefuran, imidacloprid, and thiamethoxam, and cyclaniliprole compared with the untreated. There was a relationship between feeding injury sites and plant height, leaf width, fresh and dry weight ($R^2 > 0.5$) in both 2015 field experiments. Similarly, the transplants treated with acetamiprid, clothianidin, dinotefuran, imidacloprid, thiamethoxam, thiamethoxam + chlorantraniliprole, imidacloprid + β-cyfluthrin and cyclaniliprole had significantly lower damage ratings than those treated with chlorpyrifos, bifenthrin, tolfenpyrad, flonicamid, cyantraniliprole, spinetoram and the untreated control. For transplanted broccoli, treatment of transplant plugs with neonicotinoid insecticides prior to planting can be an effective method for controlling *B. hilaris*.

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1. Introduction

Bagrada hilaris (Burmeister) (Hemiptera: Pentatomidae), commonly referred to as the bagrada bug or painted bug, is a stink bug species invasive in North America and native to old world countries of southern Africa, Middle East and Asia (Reed et al., 2013). *B. hilaris* is a serious pest of a wide array of *Brassica* crops in the Central Coast of California (area northwest of Los Angeles and South of San Jose, CA; Joseph, 2014). It was first detected in North America in 2008 in Los Angeles Co., California (Palumbo and Natwick, 2010) and is now found in Arizona, New Mexico, Texas, Utah, and Nevada (CISR, 2014). This pest threatens a valuable industry, with the value of cruciferous crops in California estimated at ~US$1 billion in 2013 (U.S. Department Agriculture, NASS, 2014). In Monterey Co. alone, cruciferous crops are grown year-round on > 34,390 ha and are valued at > $679 million USD (Monterey County Crop Report, 2014). Yearly losses to *B. hilaris* are estimated in the several millions of US dollars in the region in recent years (SVJ, pers. comm.).

Bagrada hilaris can damage cruciferous crops and reduce yields in several ways. The pest develops high populations on mustard weed species commonly found in ditches, roadsides, and edges of agricultural fields, as well as in unmanaged cruciferous crops, and then invades newly planted fields (Reed et al., 2013; I. Grettenberger, unpublished data). *B. hilaris* damages crops most when attacking germinating or cotyledon stage plants (Palumbo and

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http://dx.doi.org/10.1016/j.cropro.2016.04.023
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Natwick, 2010). In broccoli and cauliflower, serious economic injury occurs when feeding by *B. hilaris* kills the apical meristematic tissue of the young seedlings, creating a "blind head" (plant without a head; Palumbo and Natwick, 2010). *B. hilaris* feeding also triggers production of multiple adventitious shoots, causing plants to produce unmarketable, undersized broccoli and cauliflower heads. Severe feeding during early stages of plant growth depletes the nutrient reserves of the plant and causes stunting (Huang et al., 2014). *B. hilaris* feeding injury on leaves appears as "starbursts" on leaf surfaces which then develop into necrotic tissue. In California's Central Coast, direct-seeded broccoli plants are vulnerable until approximately the six-leaf stage to *B. hilaris* feeding injury such as stunting, blinds, and many adventitious shoots (I. Grettenberger, unpublished data).

In the pursuit of methods to manage *B. hilaris*, pyrethroid and carbamate insecticides were quickly found to be effective (Palumbo, 2011a, b, c; Palumbo et al., 2015). However, multiple sprays of these insecticides have been needed to manage *B. hilaris*, especially during the vulnerable seedling stages of the plant. This has increased overall insecticide use in cruciferous crops in the Central Coast of California (California Department of Pesticide Regulation, 2016). Although potential biological control agents have been identified in the native range in Asia of *B. hilaris* (Mahamood et al., 2015), their climate matching, importation, non-target host screening, and subsequent field release in the Central Coast will take several years, and success is not guaranteed. Until sustainable tactics are developed and readily available, chemical control will remain the primary tool for *B. hilaris* management in conventionally managed vegetable production. Unfortunately, the Central Coast, pesticide transport into surface waters in suspended sediments was already a problem prior to the surge in sprays targeting *B. hilaris* (Ng and Weston, 2009). Commonly detected pesticides included the pyrethroids bifenthrin and zeta-cypermethrin (Anderson et al., 2003a, b; Anderson et al., 2006; Starner et al., 2006; Ng and Weston, 2009; Schmidt et al., 2010). Detections of even higher pesticide residues would most likely trigger stringent regulations on the use of pyrethroid insecticides. Under these circumstances, there is an urgent need to develop alternative but effective Integrated Pest Management (IPM) approaches that will reduce the use and off-site movement of pyrethroid insecticides. Drenching seedling trays with insecticide is a precise application tactic in which the insecticide dose is placed directly onto the transplant plugs before transplanting. Previously, this technique has proven effective in managing lepidopteran and coleopteran pests of *Brassica* crops (Cameron et al., 2015), but little is known about how well it will control *B. hilaris*. Thus, the major objective of this study was to evaluate the efficacy of insecticides against *B. hilaris* when delivered as a seedling tray drench before planting. We conducted both greenhouse and field experiments to a range of insecticides with both systemic and non-systemic activity. Our results demonstrate the utility of a seedling tray drench for preventing damage by *B. hilaris*, protecting *Brassica* crops, and increasing the sustainability of pest management practices.

2. Materials and methods

2.1. Greenhouse experiment

We conducted a greenhouse experiment to test the efficacy of an insecticide seedling tray drench for management of *B. hilaris*. The experiment was conducted at the Monterey County University of California Cooperative Extension (UCCE) facilities in Salinas, CA. Broccoli seeds ('Marathon') were planted in 256-cell seed trays (one seed per cell) filled with potting media (Sun Gro, Sunshine Mix #4 Aggregate Plus, Agawam, MA). The potting media contained Sphagnum peat moss, coarse perlite with gypsum and dolomitic limestone, starter fertilizer, and gypsum. Based on manufacturer-provided information, the pH of the media is initially between 4.6 and 5.2, and 14 d after saturation, pH is between 5.5 and 6.5. Seedlings were grown in a commercial greenhouse (Growers Transplant Inc., Salinas, CA) for 5 wks and then transferred to the UCCE greenhouse, where they remained for the duration of the experiment. *B. hilaris* adults used in the experiment were collected from perennial pepperweed (*Lepidium latifolium* L.) and shortpod mustard [*Hirschfeldia incana* (L.) Lagr.-Fossat] in San Ardo, CA. *B. hilaris* were maintained on potted broccoli plants and heads in a controlled environmental chamber at ~20 °C, ~45% relative humidity, and 16:8 L:D for two days before they were used in the experiment.

The experiment was conducted in three separate trials, each with slightly different treatments. Both contact and systemic insecticides currently in use or that have potential for registration were included in the experiment (Table 1), even though the non-systemic insecticides were unlikely to perform well against *B. hilaris* via application as a seedling tray drench. In the first trial, we tested five insecticide treatments: clothianidin, chlorpyrifos, bifenthrin, cyantraniliprole, and spinetoram, plus an untreated control. In the second trial, we tested five insecticide treatments: acetamiprid, dinotefuran, imidacloprid, thiamethoxam, and thiamethoxam + chlorantraniliprole, plus an untreated control. In the third and final trial, the treatments used in the second trial were repeated with the addition of imidacloprid + β-cyfluthrin, tolfenpyrad, flonicamid, and cyclaniliprole.

To expose plants to *B. hilaris*, one pot of each treatment was randomly chosen and placed on a plastic tray (45 cm × 34 cm) in a collapsible mesh cage (catalog # 1466AV, Bioquip, Rancho Dominguez, CA). Each cage therefore contained one replicate of each treatment tested in the respective trial. Plants were randomly arranged within cages. The first trial was repeated twice (two "subtrials"), and each time, treatments were replicated 10 times (10 cages, six pots per cage) for a total of 20 replicates per treatment. In the second trial, treatments were replicated 10 times (six pots per cage). For the third trial, all treatments were replicated 10 times (10 pots per cage). Because all treatments from the second trial were repeated in the third trial, treatments from the second trial were replicated 20 times across trials, but those that were new in the third trial were only replicated 10 times.

To determine the insecticide dose per transplant plug, we first calculated the number of plants per ha based on standard planting practices in the Central Coast and then used the highest recommended field application rate per ha to determine dose per plant (Table 1). Growers typically plant broccoli transplants on 101.6 cm wide beds, with two rows per bed and 15.2–17.8 cm spacing between plants within rows. We used 17.8-cm spacing for our calculations, which would yield 110,668 plants per ha in the field. We injected 2 mL of the insecticide solution into the potting media of each transplant plug using a 6-mL syringe without a needle. The water volume per plug was determined after conducting preliminary tests to establish how much water the transplant plug could absorb and retain. After we applied the insecticide solution, the transplants remained in transplant trays for 7 d. At this point, the seedlings (6–7-wk old) were transplanted into 8.9-cm diameter plastic pots filled with potting media.

Seven days after transplanting (14 d after insecticide treatment), plants were exposed to *B. hilaris* for 14 d. In the first and second trials, five adults were initially introduced into each cage, and 7 d later, five more adults were added. Fourteen days after the addition of *B. hilaris*, the experiment ended and plants were evaluated. In the third trial, the *B. hilaris* exposure period was again 14 d, but eight adults were introduced into the cage at the start of the exposure

Table 1
Insecticides evaluated for *B. hilaris* management in both greenhouse and field experiments.

Class	Insecticide	Formulation	Tested rate (g A.I. per ha)
Neonicotinoid	Acetamiprid[a,c,d]	Assail 30 SG	84.02
	Clothianidin[a,b,c,d]	Belay EC	224.05
	Dinotefuran[a,c,d]	Venom	294.64
	Imidacloprid[a,d]	Admire Pro	404.39
	Thiamethoxam[a,c,d]	Platinum SC	55.5
Neonicotinoid + Diamide	Thiamethoxam + Chlorantraniliprole[a,c,d]	Durivo EC	189.60 + 94.05
Neonicotinoid + Pyrethroid	Imidacloprid + Beta-cyfluthrin[a,c,d]	Leverage EC	52.56 + 25.85
Organophosphate	Chlorpyrifos[a,b,c,d]	Lorsban Advanced	1367.12
Pyrethroid	Bifenthrin[a,b,c,d]	Capture LFR	89.61
Pyridazinone	Tolfenpyrad[a,c,d]	Torac EC	237.11
Pyridinecarboxamide	Flonicamid[a,c,d]	Beleaf 50 SG	99.71
Ryanodine receptor activator	Cyantraniliprole[a,b,c,d]	Verimark SC	197.18
	Cyclaniliprole[a,c,d]	IKI 3106 50 SL	59.89
Spinosyn	Spinetoram[a,b,c,d]	Radiant SC	87.52

[a] Insecticides used in greenhouse experiment in 2015.
[b] Insecticides used in field experiment in 2014.
[c] Insecticides used in field experiment 1 in 2015.
[d] Insecticides used in field experiment 2 in 2015.

period, followed by eight more 7 d later. After 14 d (for all three trials), we evaluated plants for damage by counting the number of feeding injury sites on leaves and the number of leaves with injury. In addition, a scale system (damage rating from 0 to 4) was developed to rate the severity of leaf feeding injury. *B. hilaris* individuals tend to feed on the leaf margins, so we focused on the leaf margins for the evaluation. All leaves on a plant were assessed for damage and the scale values were averaged for each plant (treatment replicate). The scale system is as follows: 0 = 0%; 1 = 1–25%; 2 = 26–50%; 3 = 51–75%; and 4 = >75% of the leaf margin with *B. hilaris* feeding injury.

2.2. Field experiments

2.2.1. 2014 experiment

This experiment was conducted in a commercial broccoli field near Gonzales, CA. Similar to the greenhouse experiment, broccoli seeds ('Heritage') were planted in a transplant tray and then grown in a commercial greenhouse. We prepared and applied insecticide solutions as described in the greenhouse protocol. In the field experiments, transplant plugs were transplanted within 1 h after insecticides were applied. The insecticides tested and rates used are listed in Table 1. The transplants were hand-planted into plots on 19 August. Each plot consisted of 7.6 m of a 101.6 cm wide bed, and plants were planted in two rows with 17.8 cm spacing between plants. The treatments were arranged in a randomized complete block design with four replications. On 6 October, 10 plants were removed per plot to determine the severity of *B. hilaris* feeding injury on leaves. From the 10 plants, one of the third or fourth leaves from the top (i.e., older leaf) was assessed using the injury scale (0–4) described in section 2.1. The scale values were averaged per plot (treatment replicate). Older leaves, but not the absolute oldest, were chosen for assessment of injury symptoms. These leaves were chosen over younger leaves because older leaves were more damaged; damage to these leaves occurred when plants were young and most susceptible to yield reduction, and plant stunting resulted from damage to these leaves. The oldest leaves were not used because individual injury sites were not distinguishable when damage was assessed. In addition, 20 plants were destructively sampled per plot on 6 October and plant height and fresh weight were measured in the laboratory within a day.

2.2.2. 2015 experiments

Two field experiments were conducted near Gonzales, CA in 2015. The insecticide treatments and rates used for both experiments are listed in Table 1. Transplants were planted with 17.8 cm spacing in two rows on a 101.6 cm wide bed. Each block contained one plant of each treatment. Blocks were spaced 1.5-m apart in a randomized complete block design with 20 replications.

For the first experiment, broccoli seeds ('Patron') were planted on 10 June. Broccoli seeds ('Marathon') were planted for the second experiment on 25 July. Seeds were planted in 256-cell trays filled with potting media. Transplants for the first experiment were grown in the UCCE greenhouse, while transplants for the second experiment were grown in a commercial greenhouse facility (Growers Transplant Inc., Salinas, CA). The transplants were not fertilized in either experiment. The plugs were drenched with insecticides on 2 August for the first experiment and on 28 August for the second experiment. The first experiment was transplanted on 26 August, and the second experiment was transplanted on 4 September. Plants were evaluated for damage by counting the number of *B. hilaris* feeding injury sites and the number of injured leaves. The number of injured leaves was not evaluated in 2014 field experiment because nearly all leaves had *B. hilaris* feeding injury. The leaves were also evaluated using the 0–4 scale system for damage. All the leaves on a plant were assessed for damage and the scale values were averaged for each plant. We measured plant height and width of three leaves. We determined plant fresh weight by cutting plants at the soil surface and weighing them. Plants were then dried in a drying oven at ~105 °C for three days and weighed to determine dry plant weight. In addition, total number of leaves per plant (both injured and uninjured) was quantified to evaluate plant growth.

2.3. Statistical analyses

All analyses were conducted in SAS (SAS Institute, 2012). Where applicable, data were tested for normality using the PROC Univariate procedure of SAS and data were transformed to establish homogeneity of variance. For the greenhouse experiment, the number of feeding injury sites average damage scale value (per plant) was analyzed with analysis of variance (ANOVA) using the general linear model procedure after log-transformation ($\ln[x+1]$). The proportion of leaves with feeding damage was analyzed with ANOVA after arcsine square root transformation. In the 2014 field experiment, average damage rating value (per plot), plant height, and fresh weight were analyzed with ANOVA without data transformation. For 2015 field experiments number of leaves and

feeding injury sites on leaves, average damage scale value (per plant), plant height, leaf width, fresh and dry plant weights were log-transformation (ln[x + 1]) and analyzed with ANOVA. Means were separated using Tukey's HSD method ($\alpha = 0.05$). The relationship between the mean number of *B. hilaris* feeding injury sites and plant height, average leaf width, fresh weight, and dry weight was analyzed with linear regression (JMP 12.01, SAS Institute, 2015). A small number of replicates were not included in the analyses either because data were missing for a specific variable or because the entire plant was destroyed by rodents.

3. Results

3.1. Greenhouse experiment

Percentage injured leaves, number of feeding injury sites, and damage rating were all substantially lower than the untreated when the transplants were treated with the neonicotinoids acetamiprid, clothianidin, dinotefuran, imidacloprid, and thiamethoxam (percentage injured leaves: overall $F = 21.4$, df = 14, 224, $P < 0.001$, Fig. 1A; feeding injury sites: $F = 23.8$, df = 14, 225, $P < 0.001$, Fig. 1B; damage rating: $F = 28.1$, df = 14, 224, $P < 0.001$, Fig. 1C). Damage, assessed with each of the three variables, was also significantly lower than untreated plants for plants treated with imidacloprid + β-cyfluthrin, thiamethoxam + chlorantraniliprole, and cyclaniliprole. For percentage injured leaves, number of feeding injury sites, and damage rating, none of the previous treatments (significantly different than the untreated) were different from each other (Fig. 1B). The one exception was dinotefuran for feeding injury sites, which had lower damage than thiamethoxam + chlorantraniliprole. However, dinotefuran was not significantly different from the other effective treatments. There were no significant differences in percentage injured leaves, injury sites, or damage rating among untreated, chlorpyrifos, bifenthrin, tolfenpyrad, flonicamid, cyantraniliprole, and spinetoram treatments.

3.2. Field experiments

3.2.1. 2014 experiment

Feeding injury rating ranged from 0.76 to 1.63 and did not differ significantly between treatments ($P = 0.427$). Similarly, there was no significant effect of insecticide treatment on plant height ($P = 0.059$), although height was numerically higher for clothianidin-drenched (43.3 cm) than untreated plants (33.3 cm). Fresh weight of plants was significantly greater for plants treated with clothianidin (~2.2×) and bifenthrin (~1.8×) than the untreated, which suggest that these insecticides reduced stunting from *B. hilaris* damage ($F = 2.9$; df = 5, 15; $P = 0.049$; Fig 2).

3.2.2. 2015 experiments

3.2.2.1. Experiment 1. The number of feeding injury sites was significantly lower than the untreated control for plants treated with acetamiprid, clothianidin, dinotefuran, thiamethoxam, thiamethoxam + chlorantraniliprole, imidacloprid + β-cyfluthrin, and bifenthrin ($F = 21.5$; df = 13, 245; $P < 0.001$; Fig. 3A). Plants

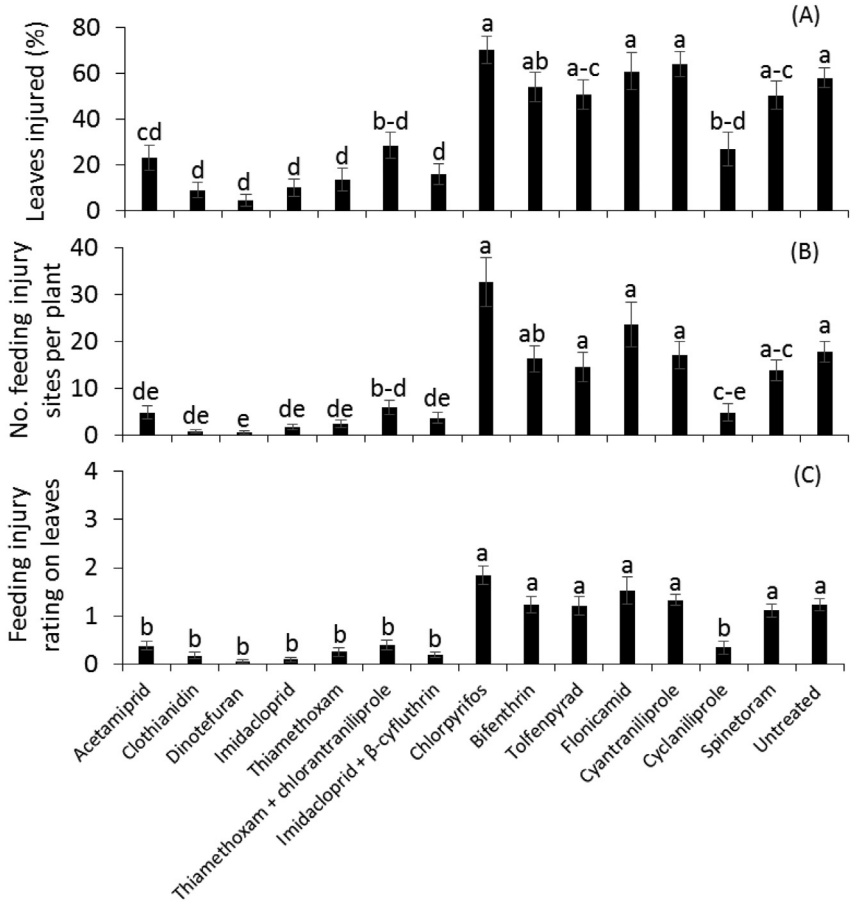

Fig. 1. Effect (mean ± SE) of tray drench application of insecticides on (A) leaves injured by *B. hilaris* feeding, (B) number of feeding injury sites, and (C) feeding injury rating on the leaves in greenhouse experiments. Bars with the same letters for each evaluation parameter are not significantly different ($P > 0.05$).

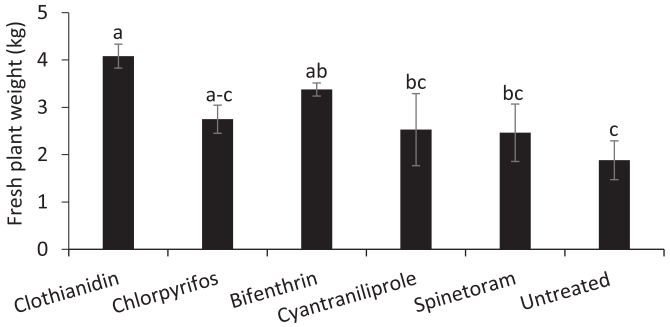

Fig. 2. Effect (mean ± SE) of tray drench application of insecticides on fresh plant weight when applied as tray drench against *B. hilaris* in the 2014 field experiment. Bars with the same letters are not significantly different ($P > 0.05$).

treated with clothianidin had the fewest injury sites, and the number was lower than all treatments other than dinotefuran. Similarly, bifenthrin and cyclaniliprole, as well all treatments containing a neonicotinoid, had significantly lower damage ratings than the untreated control ($F = 30.3$; df = 13, 245; $P < 0.001$; Fig. 3B). Other than plants treated with dinotefuran, plants treated with clothianidin had significantly fewer injury sites than all other treatments. Plant were taller when treated with clothianidin and dinotefuran than flonicamid, spinetoram, tolfenpyrad, but only clothianidin-treated plants were taller than untreated plants ($F = 4.5$; df = 13, 246; $P < 0.001$; Fig. 3C). Plants treated with clothianidin, dinotefuran, thiamethoxam + chlorantraniliprole, and imidacloprid + β-cyfluthrin had wider leaves than plants from a number of other treatments, including the untreated control ($F = 7.5$; df = 13, 246; $P < 0.001$; Fig. 3D). Fresh ($F = 5.8$; df = 13, 247; $P < 0.001$; Fig. 3E) and dry ($F = 8.4$; df = 13, 247; $P < 0.001$; Fig. 3F) plant weight were significantly greater for clothianidin, dinotefuran and imidacloprid + β-cyfluthrin treated plants than untreated plants. Number of leaves was not significantly different than the untreated control for any treatment ($P > 0.05$).

There was a significant negative relationship between number of feeding sites and plant height (y = 22.2−0.14x; Fig. 4A), leaf width (y = 8.1−0.08x; Fig. 4B), fresh weight (y = 86.8−1.3x; Fig. 4C), and dry weight (y = 11.6−0.16x; Fig. 4D).

3.2.2.2. Experiment 2. The number of feeding injury sites was significantly lower for plants treated with acetamiprid, clothianidin, dinotefuran, imidacloprid, thiamethoxam, thiamethoxam + chlorantraniliprole, imidacloprid + β-cyfluthrin, chlorpyrifos, and cyantraniliprole than for the untreated control ($F = 26.8$; df = 14, 261; $P < 0.001$; Fig. 5A). Plants treated with dinotefuran had the fewest injury sites, although there were no statistical differences between those treated with dinotefuran, imidacloprid, or thiamethoxam. When the transplants were treated with acetamiprid, clothianidin, dinotefuran, imidacloprid, thiamethoxam, thiamethoxam + chlorantraniliprole, imidacloprid + β-cyfluthrin, chlorpyrifos, and cyantraniliprole, injury ratings were lower than the untreated control ($F = 41.1$; df = 14, 261; $P < 0.001$; Fig. 5B). Similar to number of injury sites, plants treated with dinotefuran had the lowest damage ratings numerically, but they were not significantly different from plants treated with imidacloprid or thiamethoxam. Plant height was significantly higher than the untreated control only for the dinotefuran treatment ($F = 3.8$; df = 14, 251; $P < 0.001$; Fig. 5C); however, dinotefuran-treated plants were not significantly taller than many of the treatments, including all other neonicotinoid insecticides and insecticides from several other classes. A similar pattern was evident for leaf width, with only the dinotefuran treatment significantly different than the untreated control and a number of other treatments not significantly different than the dinotefuran treatment ($F = 4.2$; df = 14, 253; $P < 0.001$; Fig. 5D). Fresh plant weight was significantly greater for plants treated with clothianidin, dinotefuran, imidacloprid, thiamethoxam, and thiamethoxam + chlorantraniliprole than for the untreated control ($F = 5.4$; df = 14, 248; $P < 0.001$; Fig. 5E). The treatments that had greater fresh plant weight than the untreated control were not statistically different from one another. The pattern across treatments for dry plant weight was nearly the same as for fresh plant weight ($F = 9.1$; df = 14, 247; $P < 0.001$; Fig. 5F). The number of leaves was not significantly different among all insecticide-treated plants ($P > 0.05$).

There was a significant negative relationship between mean feeding injury sites and mean plant height (y = 26.8−0.08x; Fig. 6A), leaf width (y = 10.9−0.05x; Fig. 6B), fresh weight (y = 90.2−0.6x; Fig. 6C), and dry weight (y = 13.3−0.1x; Fig. 6D).

4. Discussion

These results demonstrate that drenching transplant plugs with neonicotinoid insecticides, and in particular acetamiprid, clothianidin, dinotefuran, imidacloprid, and thiamethoxam, reduce *B. hilaris* feeding damage and promote normal plant growth. Dinotefuran has previously performed better against *B. hilaris* than imidacloprid and thiamethoxam in field trials with foliar sprays (Palumbo et al., 2015), and this result was consistent with our study. When applied to the foliage in the field, performance of clothianidin has been unsatisfactory in preventing *B. hilaris* damage (Palumbo et al., 2013). Changing the application method may improve management of *B. hilaris* with these products. Tray drenches of neonicotinoids have been effective against other pests. For instance, drenches of imidacloprid, thiamethoxam or clothianidin reduced tobacco flea beetle [*Epitrix hirtipennis* (Melsheimer)] feeding damage and number of green peach aphids [*Myzus persicae* (Sulzer)] on tobacco (*Nicotiana tabacum* L.) (Semtner, 2005; Semtner and Srigiriraju, 2005; Semtner and Wright, 2005; Semtner et al., 2008), while chlorantraniliprole was effective against cabbage looper [*Trichoplusia ni* (Hübner)] on cabbage (Cameron et al., 2015). In our study with broccoli, we also tested non-neonicotinoid systemic insecticides as tray drenches including cyantraniliprole and cyclaniliprole, as well as contact insecticides, such as flonicamid, spinetoram, tolfenpyrad, and bifenthrin, but most did not consistently affect *B. hilaris* damage. The contact insecticides were tested in addition to systemic insecticides because these insecticides are commonly used as foliar sprays for various insect pests, including *B. hilaris* on *Brassica* crops, although positive results were not expected.

The efficacy of tray drench application for broccoli suggests that this application method could be useful for *B. hilaris* management in other *Brassica* crops, and in particular, cauliflower. The insecticide dose received by each transplant plug was based upon the number of plants per ha, which is related to plant spacing, number of rows per bed, and width of a bed. As the number of plants transplanted in a hectare decreases, the amount of insecticide received per plug will increase. In the Central Coast, cauliflower is planted at a greater spacing than broccoli, and only one row of cauliflower is typically planted per bed rather than the two rows used for broccoli in the same-sized bed. This suggests that if the same overall rate of insecticide is used at the field level, each cauliflower transplant will receive a larger insecticide dose than broccoli transplants because of the lower number of plants per ha. Our results show that *B. hilaris* was adequately controlled by the neonicotinoid insecticides when applied to broccoli transplants. Thus, cauliflower transplants, which would receive a higher dose

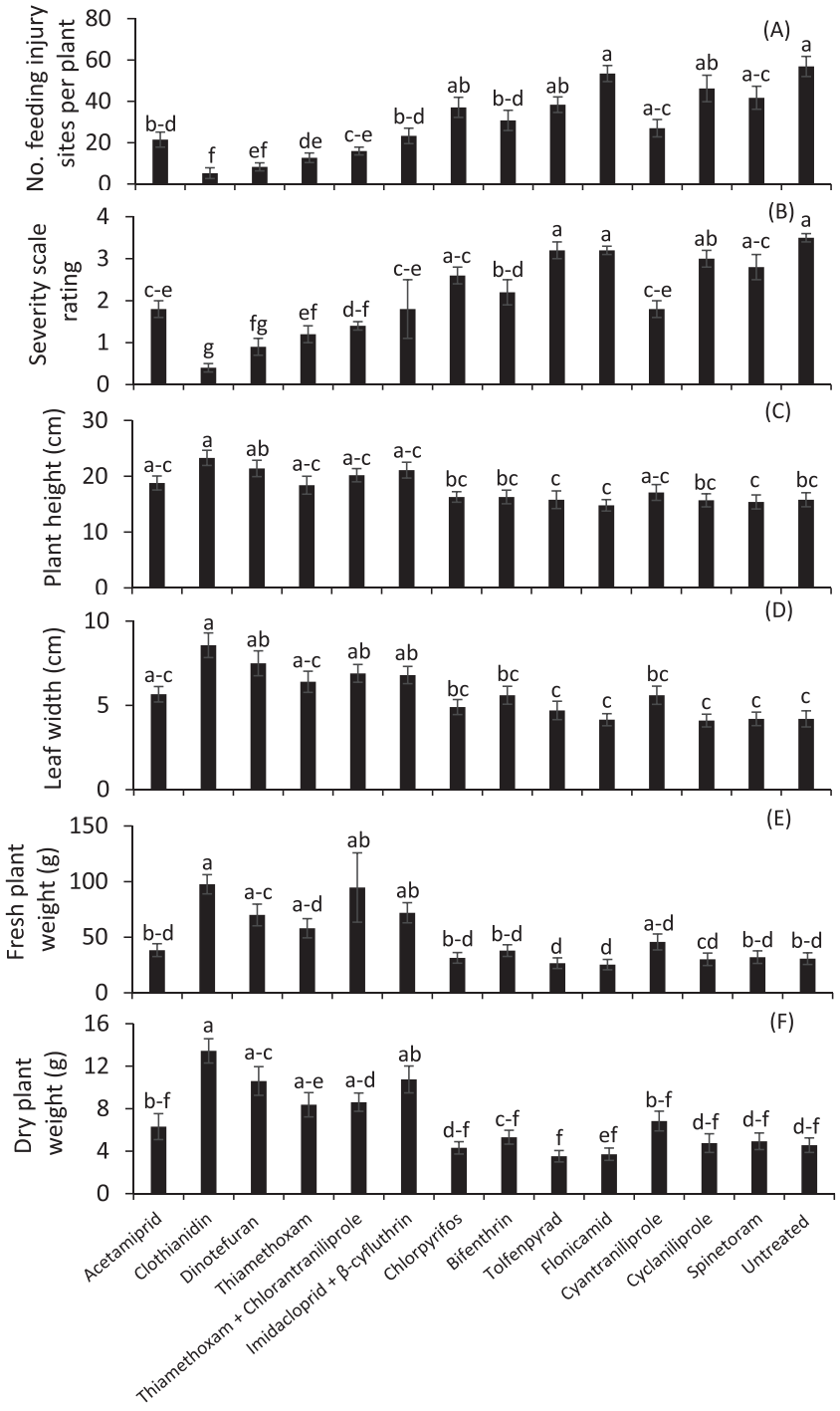

Fig. 3. Effect (mean ± SE) of tray drench application of insecticides on (A) *B. hilaris* feeding injury, (B) injury rating, (C) plant height, (D) leaf width, (E) fresh, and (F) dry weight per plant in the first 2015 field experiment. Bars with the same letters for each evaluation parameter are not significantly different ($P > 0.05$).

than broccoli at the same per ha rate, should perform even better. Future research will investigate the efficacy of lower rates of neonicotinoid insecticides, and in particular dinotefuran and clothianidin, against *B. hilaris* in cauliflower. We may be able to still achieve sufficient control of *B. hilaris* in cauliflower by reducing the amount of insecticide applied on a per-ha basis compared to broccoli, but keeping the rate the same at the individual transplant level.

Drenching transplant plugs could provide several benefits for *B. hilaris* control. First, this tactic applies the insecticide to a small volume of soil in the transplant plug. The plants can quickly uptake and translocate the active ingredient to the foliage of the young plant, targeting the pest in both space and time. This precise delivery of insecticide to plants when they are young and most vulnerable to injury will maximize the utility of the applied volume of insecticide, in contrast to foliar sprays. Second, establishment of *B. hilaris* in the Central Coast has increased insecticide use, especially of pyrethroids. Prior to the arrival of *B. hilaris*, surveys had

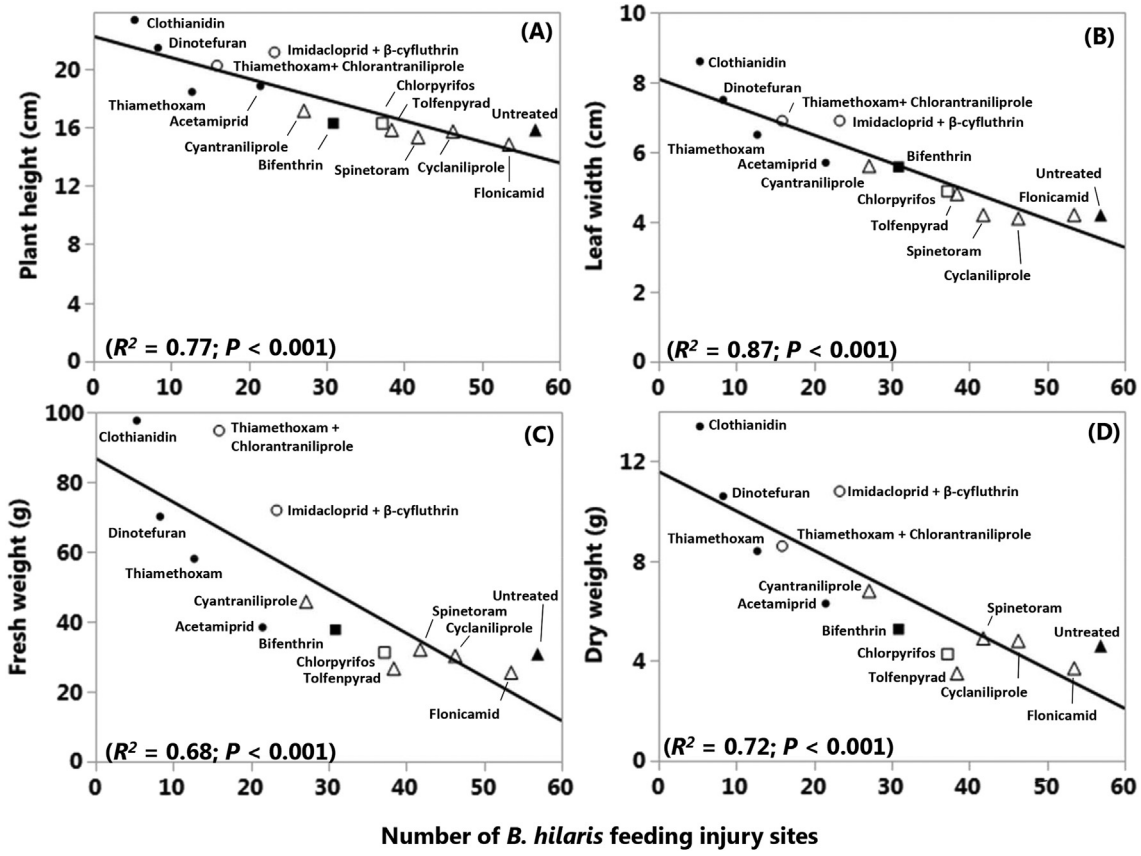

Fig. 4. The relationship between mean number of *B. hilaris* feeding sites and mean (a) plant height, (b) leaf width, (c) fresh, and (d) dry weight. The symbols: ● = neonicotinoid; ○ = combination product with neonicotinoid; ■ = pyrethroid; □ = organophosphate; Δ = reduced-risk insecticides; and ▲ = untreated in the first experiment in 2015.

found pyrethroids in suspended sediments in the lower reaches of major rivers of California's Central Coast (Anderson et al., 2003a, b; Anderson et al., 2006; Starner et al., 2006; Ng and Weston, 2009; Schmidt et al., 2010). Because *B. hilaris* poses a serious but unpredictable threat to newly planted *Brassica* crops, growers have responded with multiple foliar sprays or sprinkler chemigation of pyrethroid insecticides. Drenching transplants could reduce the number of applications to a single application before planting without compromising management of *B. hilaris*. This tactic could prevent economically significant damage during the window of vulnerability for *Brassica* crops when plants are young. Moreover, dinotefuran likely elicits antifeedant properties (Palumbo et al., 2015), which might be reducing the time spent feeding after initial probing by *B. hilaris*. Tray drench application with a follow-up foliar spray with a pyrethroid insecticide could therefore be a good, longer-term IPM strategy. Third, tray drench applications will likely reduce the off-site movement of applied insecticide. Currently, most insecticides are applied as foliar sprays or as sprinkler chemigations in the field, providing opportunities for loss of insecticides via run-off. Certain insecticides such as pyrethroids tend to bind to the soil organic matter (Harris et al., 1981), which can then be transported into waterways. Thus, insecticides drenched on the transplant plug are likely to be absorbed by the roots and not move off-site to the same degree. Finally, seedling tray drench of systemic insecticides is a cost-effective and efficient delivery method of insecticides. The insecticides are precisely placed with minimal loss. Some growers in the Central Coast are chemigating via sprinkler irrigation systems for *B. hilaris* management. Much of the insecticide is applied to the soil rather than the plants and may therefore not provide much activity for bagrada bug management. Seedling tray drench would provide a more efficient method of insecticide and would be compatible with current production methods.

Although application of systemic insecticides as a seedling tray drench would provide benefits for managing *B. hilaris*, there are a few challenges and issues that will need to be addressed if this tactic is to be employed. First, worker safety issues may arise when dealing with restricted insecticides. Depending on the type of restricted insecticide and re-entry period, the transplant date may need to account for the application date to avoid worker safety issues when handling the treated transplants and using the transplanting equipment. Also, the insecticide-contaminated trays will need to be washed properly (triple rinsed) if re-used for new transplants. The only product registered for seedling tray drench to date on *Brassica* crops is cyantraniliprole (Verimark). This product has a short re-entry period of 4 h and after this period, there is no requirement for personal protective equipment such as gloves while handling the treated trays or transplants, although these practices are encouraged (DuPont Crop Protection, 2014). Second, application as a tray drench is not yet a registered use for neonicotinoid insecticides. More research will be required to determine the breakdown pathways of systemic insecticides and if residues in the harvested heads are below established tolerances. Third, if neonicotinoids are consistently used as a tray drench, it could apply a strong selective pressure on *B. hilaris*, and would therefore create a high likelihood for development of resistance. *Bagrada hilaris* can complete a generation in 41 and < 21 d at 24 and 35 °C, respectively (Reed et al., 2013), and there is a strong possibility of overlapping generations as well. Before pursuing seedling tray drench application, pest managers should monitor the size of the local *B. hilaris*

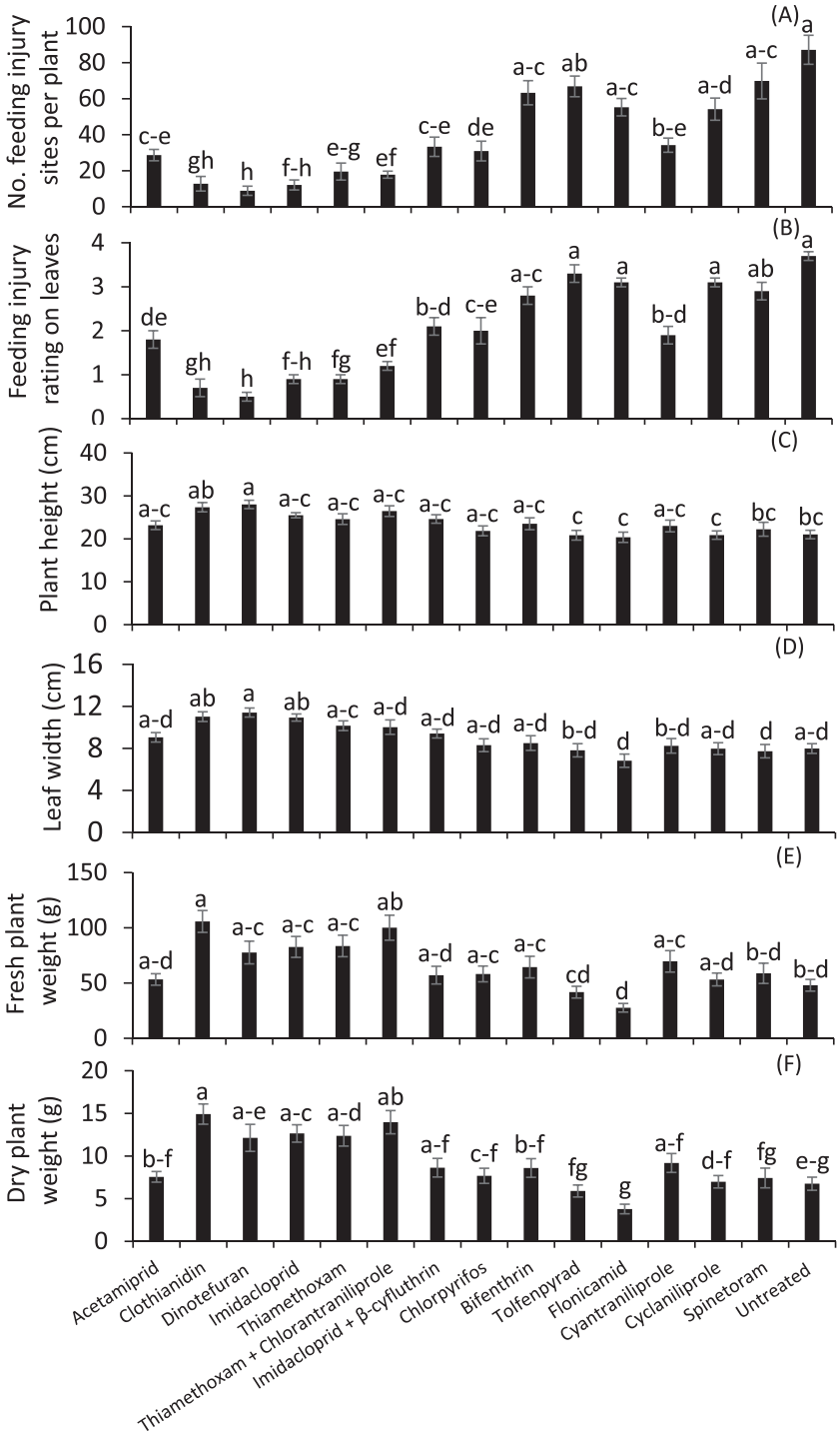

Fig. 5. Effect (mean ± SE) of tray drench application of insecticides on (A) *B. hilaris* feeding injury, (B) injury rating, (C) plant height, (D) leaf width, (E) fresh, and (F) dry weight per plant in the first 2015 field experiment. Bars with the same letters for each evaluation parameter are not significantly different ($P > 0.05$). Bars with the same letter are not significantly different ($P > 0.05$).

population in other fields and in patches of weed hosts outside of fields to identify the expected pest pressure and determine if the management tactic is warranted. This will help reduce the likelihood *B. hilaris* develop insecticide resistance and maintain the viability of these management tools.

Factors such as water volume, time of application, and insecticide properties for tray drenching may influence the efficacy of insecticides. The water volume used to apply the insecticides may be critical for placement of insecticides in the root zone of the plug. The quantity of solution should be low enough that it will not leach from the plug, which would waste insecticide and increase waste management problems. In this study, the ideal water volume was determined after a series of preliminary experiments to identify the maximum volume of insecticide solution that could be applied without leaching loss. The insecticide solution in this study was also injected using a syringe rather than sprayed with overhead

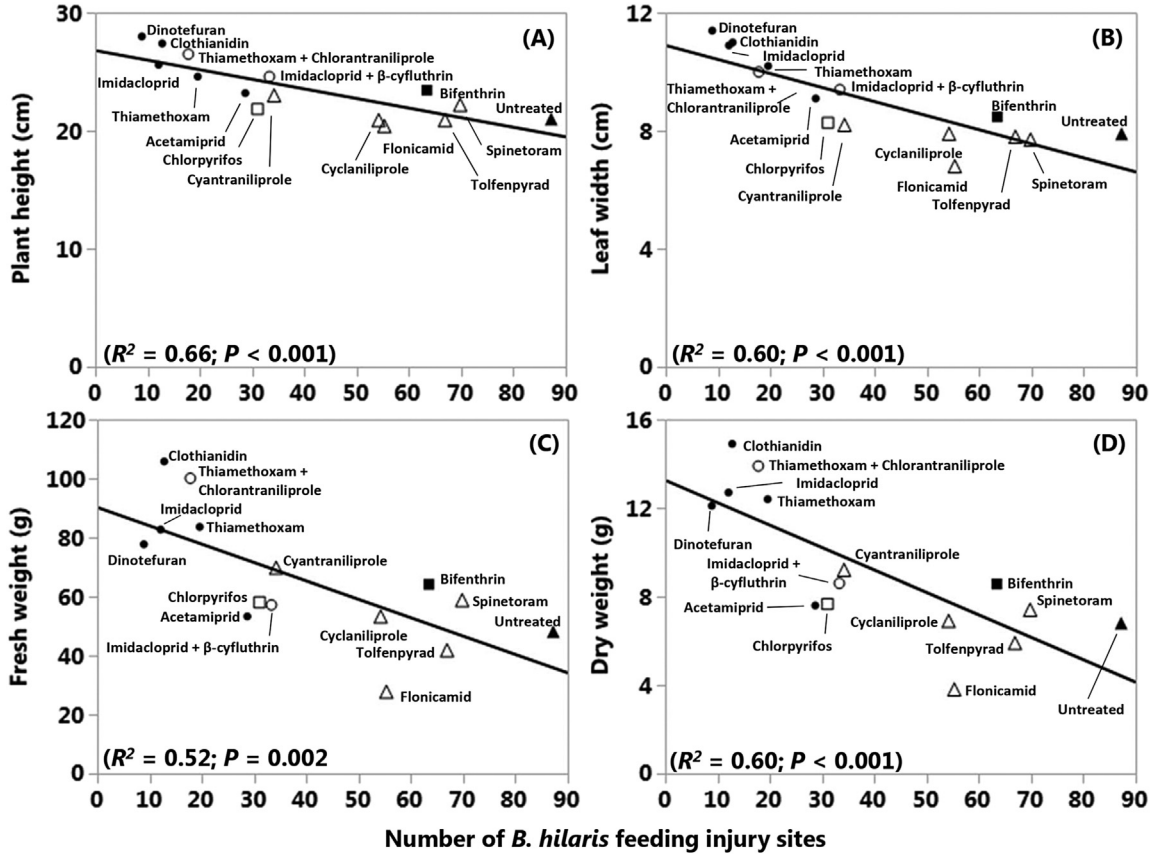

Fig. 6. The relationship between mean number of *B. hilaris* feeding sites and mean (a) plant height, (b) leaf width, (c) fresh, and (d) dry weight. The symbols: ● = neonicotinoid; ○ = combination product with neonicotinoid; ■ = pyrethroid; □ = organophosphate; Δ = reduced-risk insecticides; and ▲ = untreated in the second experiment in 2015.

sprinklers. In a commercial setting, the seedlings in the trays will likely be chemigated, and both the foliage and roots will be exposed to insecticides. The amount of insecticide solution received per seedling will depend on the set-up of the system, frequency, and pressure of the irrigation events. In this study, the interval between tray drench and transplanting was not uniform, although effective insecticides had activity within a time period of 0–3 wks between insecticide application and transplant in the field.

Typically, insecticide properties such as water solubility, and strength of binding with soil particles affect the speed of insecticide movement and their efficacy. Although dinotefuran is highly water soluble (39.8 g/L) and less likely to bind with the soil particles (Koc 30.0) than imidacloprid (514 mg/L; Koc 262.0) and clothianidin (259 mg/L; Koc 160.0) (Sur and Stork, 2003; Tomizawa and Casida, 2005; Ali and Caldwell, 2010), our results show that both dinotefuran and clothianidin can perform well against *B. hilaris* when applied as a seedling tray drench. This suggests that neonicotinoid insecticides move quickly from roots to leaves and affect feeding by *B. hilaris*. However, further research is needed to determine the optimal interval between insecticide application as a drench and transplanting to reduce *B. hilaris* feeding.

In conclusion, this study clearly shows that neonicotinoid insecticides were very effective against *B. hilaris* as a systemic application through a tray drench. Drenching transplant plugs with neonicotinoid insecticides protected plants from *B. hilaris* feeding beyond five weeks, which is the most vulnerable phase of crop development to *B. hilaris* feeding and injury. This suggests that if neonicotinoid insecticides are registered for this application method, it could reduce the need for multiple applications of foliar insecticides beginning at plant emergence. Cauliflower is 100% transplanted in the Central Coast of California while broccoli is ~95% transplanted in the southern half of the California, so tray drenches with neonicotinoids could provide a vital tool to help protect these crops from *B. hilaris*.

Acknowledgments

We appreciate the technical assistance provided by J. Martinez, C. Ramirez, C. Bettiga, E. Bejarano, J. Zarate, R. Ahedo, G. Reyes and G. Fletcher data collection. We thank two anonymous reviewers and the editor for the review of the earlier version of the manu-script. This research was supported by several agro-chemical companies, and the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGPCA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

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Photos:



Figure 1. Bagrada bugs feeding on shortpod mustard (*Hirschfeldia incana*), an important non-crop host of bagrada bug in the Salinas Valley.



Figure 2. Bagrada bugs feeding on perennial pepperweed (*Lepidium latifolium*), an important non-crop host of bagrada bug in the Salinas Valley.



Figure 3. One of the field sites dominated by perennial pepperweed surveyed for bagrada bugs (Objective 1).



Figure 4. Bagrada bugs found on perennial pepperweed during the survey of non-crop hosts (Objective 1).



Figure 5. Field site for study examining influence of plant characteristics on bagrada bug (Objective 1). Plants were individually tagged and followed, and these tags are visible in the photo.



Figure 6. Individually tagged shortpod mustard plants.



Figure 7. Choice arena used to compare preference of bagrada among broccoli and non-crop hosts (Objective 1).



Figure 8. Choice arenas used to examine the oviposition behavior of bagrada bug (Objective 1).



Figure 9. Plants in the study investigating damage to broccoli by bagrada bug using row cover (Objective 2). Plants in images on the far left and top right were exposed to a high density of bugs from the cotyledon stage for two weeks (12 bugs per cage). Plants in the plot in the middle image and image in the bottom right were not exposed to bagrada bugs.



Figure 10. Experiment using row cover cages to examine damage potential of bagrada bug to broccoli (Objective 2).



Figure 11. Trap crop field experiment, 2015 (Objective 3). Border trap crop plots are visible on the left.



Figure 12. Trap crop field experiment, 2016 (Objective 3). Border trap crop plots (turnip) are visible on the left.

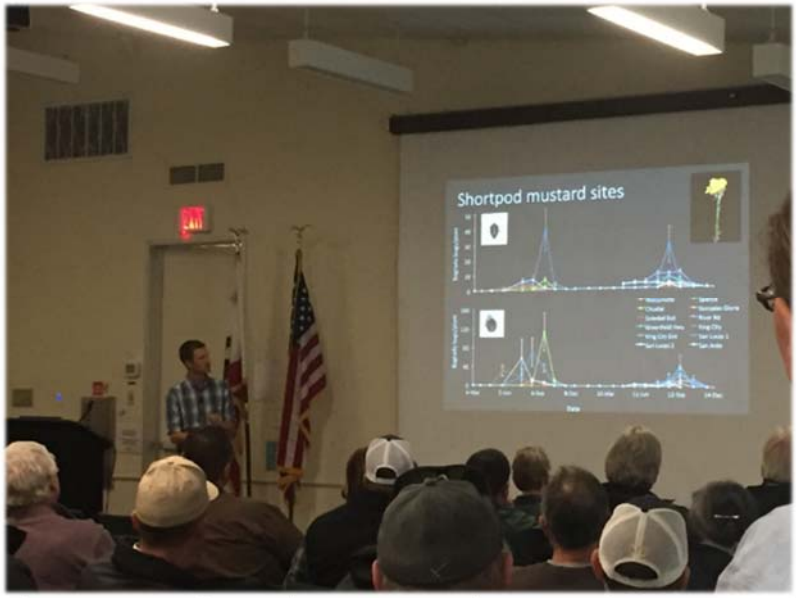

Figure 13. Dr. Grettenberger presenting research on non-crop hosts of bagrada bug at 2016 Monterey County Entomology Seminar (Objective 4).



Bagrada Bug News

Issue 1 • March 1, 2016

Welcome to the Bagrada Bug News!

By Jane Sooby, CCOF

The *Bagrada Bug News* is a service of the Bagrada Bug Working Group, a multi stakeholder collaboration that CCOF and CDFA initiated in 2015 to explore options for organic producers experiencing crop loss due to this invasive pest.

Bagrada bug is an invasive stink bug that has a taste for plants in the mustard family; however, it does not restrict its feeding to these crops. Much information about this pest is lacking, including the scope and degree of the damage it has caused. Based on anecdotal reports, crop losses in California could range in the hundreds of thousands to millions of dollars. In some parts of southern California, mustard crops can no longer be grown at certain times of the year.

While the Working Group focuses on organic management and biocontrol of bagrada bug, it is open to all participants.

Since the Working Group started, scientists from many agencies have joined. Developing strategies for non-chemical control of bagrada bug seems to be a passion for many of them.

What started as a California-specific effort quickly expanded into an international group, thanks largely to the participation of Dr. Walker Jones from the USDA-ARS, Biological Control of Pests Research lab in Stoneville, Mississippi. This year marks the third year that Dr. Jones has worked toward biocontrol of bagrada bug. He is connected with an international team that has traveled to Pakistan and South Africa seeking natural enemies of the pest.

Based on anecdotal reports, crop losses in California could range in the hundreds of thousands to millions of dollars.

The purpose of *Bagrada Bug News* is two-fold: to publish useful guidance for organic and other producers in managing bagrada bug infestations, and to serve as a resource for scientists worldwide working to manage this pest.

Feel free to contact us with any comments, suggestions, or articles.

Jane Sooby, editor, jsooby@ccof.org

Bagrada Bug, Painted Bug, *Bagrada hilaris*: A Wide-Ranging Pest of Brassicas

By Thomas M. Perring and Darcy Reed

Department of Entomology, University of California, Riverside

The painted bug was first detected in the United States in June 2008, at the port of Los Angeles. With a geographic

(continued)

Slides from Bagrada Bug Meeting Available Online

The Bagrada Bug Working Group held a meeting Dec. 11, 2015, in Salinas, CA. Co-organizer David Pegos with CDFA's Plant Health and Pest Prevention Services spearheaded the web broadcast, supported by Colleen Murphy. View presentations by clicking on this link: https://www.cdfa.ca.gov/plant/presentations/bagrada/

In this Issue

Bagrada Bug, Painted Bug, *Bagrada hilaris*: A Wide-Ranging Pest of Brassicas

Prospects for Biological Control of *Bagrada hilaris*

Bagrada Bug Moves into Central and Northern California

ARS-Albany Bagrada Bug Team In Place

Bagrada Bug Proposal Moves Forward

Bagrada Bug Exploration Continues Abroad

In the Literature

Bagrada Bug Found in Hawai'i

origin in Africa and the Middle East, it has quickly spread throughout California and into Arizona, New Mexico, Nevada, west Texas, and northern Mexico.

Climate matching models and host plant distributions predict its spread in North America from southern Mexico through the Pacific Northwest, and eastward through Texas and southern Oklahoma and most of Florida.

The painted bug is unique among stink bugs in that it lays its eggs singly in the soil or on plants, which makes it more difficult for egg parasitoids to find the eggs. There are 5 nymphal instars that mature from egg to adult in as little as 16 days at the optimal temperature of 95°F. At this temperature, the average generation time is 17 days. A warm weather insect, they are most active during the warm parts of the day, when the temperature is above 80°F. They have a single population peak in urban southern California that peaks in September, and a bimodal distribution in the desert agricultural regions of California and Arizona with peaks in April and October timed with the presence of cole crops (broccoli, cauliflower, cabbage, Brussels sprouts, and leafy brassicas).

In addition to brassicas, painted bug will utilize a wide range of plants including cheeseweed, groundsel, India mustard, sunflower, Bermuda grass, corn, cotton, cowpea, Sudan grass, and watermelon. The feeding is easily recognized by the star-shaped feeding patterns on the plant leaves. These insects have a tremendous ability to find brassicas, and the most damage is done when they feed on plants that just emerge from the ground. This feeding kills the seedling. Plants that survive continue to grow and many produced forked heads, or no head at all ("blind" plants).

Research has focused on developing a lure to attract painted bugs for monitoring, and this has been difficult. There do not appear to be any insect pheromones that work, and the best attractant so far has been sweet alyssum leaves or mustard seed meal. However, these attractants do not produce consistent results throughout the year.

Prospects for Biological Control of *Bagrada hilaris*

By Walker Jones[1] and Thomas M. Perring[2]

[1]ARS-USDA National Biological Control Laboratory, Stoneville, MS; [2]Dept. Entomology, University of California, Riverside, CA

There are a number of natural enemies that will feed on the painted bug (=bagrada bug). Generalist predators include assassin bugs, solitary wasps, ants, preying mantids, spider, and vertebrates (lizards and birds). These generalists don't have much of an impact on the population. More effective are parasitoids that attack the painted bug eggs.

Research has shown that one of our native parasitoids will parasitize *B. hilaris* but not in the soil where eggs are laid. Two species from Europe, *Trissolcus* sp. and *Ooencyrtus telenomicida,* were also able to parasitize eggs in the lab but not in the soil. Three additional parasitoids, *Trissolcus* sp., *Ooencyrtus* sp. and *Gryon* sp., were collected in Pakistan from *B. hilaris* eggs and these were brought into quarantine in Mississippi. While waiting on permits to bring the insects to the quarantine facility at UC Riverside, colonies of two of these species died. Consequently, we currently have only the *Ooencyrtus* species in Riverside, and we are beginning to conduct host range studies with this species.

At the same time, we suspect there are a number of other parasitoid species across the native range of the bagrada bug in the Old World. We are collaborating with the USDA-ARS European Biological Control Laboratory in France, CABI South Asia Station in Pakistan, and the Agricultural Research Council in South Africa to collect and import parasitoids for biological control in the US.

Bagrada Bug Moves into Central and Northern California

By Larry Godfrey[1], Shimat Joseph[2], Jhalendra Rijal[3], Surendra Dara[4], Richard Smith[2], and Ian Grettenberger[1]

[1]Dept. of Entomology and Nematology, Univ. of California, Davis; [2]Univ. of California Cooperative Extension Monterey County, Salinas; [3]Univ. of California Cooperative Extension Stanislaus, Merced, and San Joaquin County, Modesto; [4]Univ. of California Cooperative Extension San Luis Obispo, Santa Barbara, and Ventura County, San Luis Obispo

The bagrada bug was first found in California in 2008 and over the next few years adapted to the southern California/Arizona desert vegetable production system. Significant pest management concerns developed for this pest in Brassica crops, which are the favored hosts for bagrada bug. IPM programs based on well-designed research were put in place and losses to growers were largely mitigated.

This pest expanded its range northward and over the last 3-4 years has infested central and northern California. Vegetable production in the coastal production areas has been greatly impacted and the infestation has progressed as far north as Butte County in the Sacramento Valley. We started a project in Fall/Winter, 2014, funded by

(continued)

the Specialty Crop Block Grant program, to research and develop IPM programs for this pest in the Central Coast, particularly Salinas Valley, vegetable system. Specific objectives were 1.) to investigate bagrada bug biology in the Salinas Valley, 2.) to study the infestation and damage severity of bagrada bug on key crops, and 3.) to design management programs for bagrada bug on key Salinas Valley crops. This project was designed to build upon the significant research that had been conducted in southern California and Arizona, but the substantial differences in environmental conditions, cropping patterns, crop diversity, crop growth cycles, growing seasons, etc. dictated that adaptive research needed to be conducted.

During the winter and spring 2015, bagrada bug overwintering populations on key weed species--pepperweed and shortpod mustard--and early-season population development were monitored. In the summer, bagrada bugs were placed on emerging broccoli seedlings within cages in field plots. Various densities and timings of infestation were studied. Plant response, i.e., injury sites, plant mortality, growth, development, etc. were recorded. Finally, studies were conducted on perimeter trap crops for bagrada bug management in organic broccoli. Alyssum (either treated with organic insecticides, vacuumed or natural) and turnip (natural) were investigated as potential trap crops.

Similar studies are being conducted in the winter 2016 and planned for the 2016 summer and fall periods.

ARS-Albany Bagrada Bug Team In Place

By Paul Pratt, USDA/ARS/WRRC

The USDA Agricultural Research Service's Western Regional Research Center in Albany, California, has pulled together a group of scientists to work on biocontrol methods for managing bagrada bug in the coming year. Paul Pratt, Research Leader of the Exotic and Invasive Weeds Research Unit, announced that a new research entomologist, Dr. Brian Hogg, has been hired to lead the unit's research on developing biological control options for bagrada bug. Dr. Hogg has over 12 years' experience working in the field and will spend much of his time coordinating risk assessments of biological control agents of bagrada bug. Dr. Keith Stokes has also joined the USDA team in Albany as a postdoc researcher, and technician Adam Pepi has also been assigned to work on the project.

Bagrada Bug Proposal Moves Forward

By Charlie Pickett, CDFA

CDFA, University of California-Riverside, UC Cooperative Extension, and USDA-Agricultural Research Service entomologists collaborated on a successful pre-proposal submitted to the California Specialty Crop Block Grant Program. A full proposal will be submitted later this month. Investigators will find out in the fall whether their proposal was selected for funding. Here is the abstract of the proposal:

The bagrada bug is an invasive insect that has become a serious pest in cole crops throughout California. The purpose of this project is to provide a sustainable pest management strategy for suppressing this pest in this state.

First reported in 2008, the bagrada bug has spread throughout agricultural areas of Imperial and Riverside Counties, up through the Central Valley, and along the coast from San Diego to Monterey Bay. Currently the only means for controlling this pest is conventional pesticides. This leaves organic producers of cole crops at risk since there are no effective organically registered control measures.

A long term, self-sustaining solution is the introduction of parasitoids specialized in feeding on this pest. This proposal will evaluate a novel parasitoid for host specificity, determine if any resident natural enemies are attacking bagrada bug, and request field release permits from the appropriate authorities. The ultimate goal is the release of the new parasitoid.

Bagrada Bug Exploration Continues Abroad

By Paul Pratt and Link Smith, USDA-ARS

Dr. René Sforza of the USDA's European Biological Control Laboratory (EBCL) is, as of the writing, surveying for natural enemies of bagrada bug in South Africa. See photos on page 4 of this newsletter.

EBCL has established a colony of bagrada bug from Tom Perring's lab in anticipation of receiving egg parasitoids from foreign cooperators. EBCL plans to send prospective agents as soon as they are available to cooperating labs in the US for host specificity testing.

Marie-Claude Bon (USDA-ARS-EBCL) is planning to conduct DNA analysis of specimens of bagrada bug from cooperators to confirm that the target in the US is one species and to compare it to foreign populations.

In the Literature

A Note relevant to bagrada bug biocontrol was published in *the Journal of Entomological Science*: Mahmood, R., W. A. Jones, B. E. Bajwa, and K. Rashid. 2015. Egg Parasitoids from Pakistan as Possible Classical Biological Control Agents of the Invasive Pest *Bagrada*

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hilaris (Heteroptera: Pentatomidae). Journal of Entomological Science 50 (2): 147-149. Contact *Bagrada Bug News* editor Jane Sooby for a reprint.

Bagrada Bug Found in Hawai'i

By Randall T. Hamasaki, UHM College of Tropical Agriculture and Human Resources, Kamuela Extension Office

The bagrada bug was first discovered on the Island of Maui in late 2014. It was discovered on the Island of Hawaii in May 2015. Once it becomes established on-island, this insect seems to be dispersing fairly rapidly. On the Island of Hawaii, the bagrada bug seems to prefer weed hosts (like *Cleome gynandra* and *Brassica nigra*) than crops but this could change rapidly.

Bagrada images from South Africa



Photo by René FH Sforza

Showing South African farmers how to recognize bagrada bug in a cabbage field from a smartphone picture.



Bagrada hilaris on organic Raphanus sp. in South Africa. *Photo by René FH Sforza*

About the Bagrada Bug News

Numerous agencies are cooperating in the effort to discover effective organic management and biocontrol of bagrada bug.

Please refer any questions about this newsletter to editor Jane Sooby, jsooby@ccof.org. Design by Sarah Watters, CCOF



Bagrada Bug News

Issue 3 • September 15, 2016

Preparations Continue for Testing Parasitoids of Bagrada Bug at USDA-ARS in Albany, CA

By Brian Hogg and Keith Stokes

USDA-ARS, Exotic and Invasive Weeds Research Unit, Albany, CA

Classical biological control involves the introduction of natural enemies from an invader's native range to reduce populations of invasive pests to non-damaging levels. By establishing self-sustaining populations of natural enemies, biological control can be more cost-effective than other control methods, such as pesticides, which need to be continually reapplied. However, the candidate biocontrol agents must be thoroughly tested to ensure that they do not become pest species themselves. The possibility of detrimental effects of biological control is well known.

To demonstrate safety, candidate agents are exposed to species other than the pest species. Ideally, biocontrol agents are selected that have a high degree of specificity for the targeted pest species. The likelihood of non-target attack is typically determined by a combination of so-called choice and no-choice tests. In no-choice tests, the candidate is only offered either the pest or another species. In choice experiments, the candidate control agent is offered the opportunity to choose between attacking the pest species or another species.

The Hogg research laboratory at the USDA-ARS in Albany, CA, is maintaining laboratory cultures of bagrada bug and seven other stinkbug species for testing the

Natural enemies of crop pests must undergo rigorous assessment to ensure they don't become a pest themselves.

specificity of candidate control agents for bagrada bug, which will be conducted in coordination with Dr. Walker Jones at the USDA-ARS biological control laboratory in Stoneville, Mississippi, and Dr. Thomas Perring at UC Riverside. We recently received *Ooencyrtus* sp. and *Trissolcus* sp., and will soon receive *Gryon* sp., from Dr. Walker Jones. These are egg parasitoids (i.e., wasps that parasitize bagrada bug eggs). Parasitoids differ from parasites in that parasitoids typically kill their hosts relatively quickly, while parasites tend to kill their hosts

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Progress on Funding for Biological Control of Bagrada Bug

Parasitoid Preparations
(*continued*)

slowly, or not at all.

We have also started sampling for natural enemies of bagrada bug that may already be in California, by placing cardstock with killed (previously frozen) bagrada bug eggs in cole crop fields in northern California. Two laboratory technicians, Alex Gutierrez and Erica Pollard, recently joined the Hogg lab to assist in these efforts.

Report from Abroad
Rearing Egg Parasitoids of Bagrada Bug

By Lincoln Smith, René Sforza, and Marie Roche

USDA-ARS European Biological Control Laboratory

Colonies of two hymenopteran parasitoids of bagrada bug originating from Pakistan are being reared at the European Biological Control Laboratory. The species have been tentatively identified as *Trissolcus hyalinipennis* and *Gryon* nr. *gonikopalense* by Elijah Talamas (USDA-ARS-Systematic Entomology Laboratory).

The parasitoid colonies are being maintained as iso-female lines at room temperature (ca. 24°C, 50% RH and 12 h photoperiod). Individual females are exposed to fresh bagrada bug eggs (0-24 h old) for at least 1 day for oviposition.

We have established three colonies of hosts, one containing a mixture of California "inland" and "desert" colonies from Tom Perring's laboratory, one from South Africa, and one from Pakistan. Data from colony maintenance indicates that host eggs from both California and South Africa are suitable for parasitism by both species of parasitoids. *Gryon* nr. *gonikopalense* parasitized 95% of California and 97% of S. Africa host eggs, and *T. hyalinipennis* parasitized 84% of California and 88% of South Africa host eggs.

The parasitoids are able to parasitize eggs collected from bagrada bugs in California and South Africa.

Survivorship to adult stage was also high for both species. *Gryon* nr. *gonikopalense* emerged from 92% of California and 98% of South Africa host eggs that were parasitized, and *T. hyalinipennis* emerged from 92% of California and 98% of South Africa host eggs.

These preliminary results indicate that both these species have the potential to attack bagrada bug from the USA, and thus warrant further study of their host specificity and potential to control bagrada bug under natural conditions.

Importance of Weeds for Bagrada Bug Populations in the Salinas Valley

By Ian Grettenberger,[1] Larry Godfrey,[1] Richard Smith,[2] and Shimat V. Joseph[2]

[1]UC Davis Dept. of Entomology and Nematology; [2]UC Cooperative Extension Monterey County

A very similar version of this article was previously posted on the UC Weed Science blog Aug. 10, 2016.

Ed. Note: This field report contains specific scouting recommendations to growers, including:

- Shortpod mustard and perennial pepperweed are the two most important weeds for bagrada bug buildup in the Salinas Valley.
- Check weeds on the edges of fields and any large patches of weeds within 0.5 miles that may be likely sources of bagrada bugs.
- Bagrada bugs on weeds appear to be mainly a threat to crops once weed quality begins to decline, so observe the growth stage and overall condition of weeds.

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Progress on Funding for Biological Control of Bagrada Bug

By Charlie Pickett

California Department of Food and Agriculture

A Farm Bill "Suggestion" was submitted August 19 that would provide funding for one year of foreign exploration, host specificity testing, and survey work in California. The proposal is asking for $209,598 to be divided among four institutions: USDA Agricultural Research Service (ARS), University of California (UC) Riverside, California Dept. of Food and Agriculture (CDFA), and UC Cooperative Extension.

Funding will support host specificity work by USDA-ARS (Albany, CA) and UC Riverside, foreign exploration by USDA-ARS (European Biological

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Funding Progress
(*continued)*

Control Laboratory), and survey work in California for resident natural enemies by UC Cooperative Extension, USDA-ARS (Albany), and CDFA. We should hear back on whether or not the proposal is funded by March 2017.

With leftover funds from the USDA Animal and Plant Health Inspection Service 2015/2016 funding cycle, colonies of bagrada bug have been initiated and survey work has begun in California on the role of resident natural enemies in feeding on eggs of this pest. A similar proposal to above was submitted to CDFA's Specialty Crops Block Grant program last March. We will be notified around October 1 as to whether or not it is supported.



Figure 1. Adult and nymph bagrada bug on a still-green shortpod mustard plant after grasses have completely dried. Note the dead leaf tissue from bagrada bug feeding. All photos in this issue are by Ian Grettenberger.

Importance of Weeds
(*continued*)

Bagrada bug (*Bagrada hilaris*) was first observed in the Salinas Valley in October-November 2013. We started monitoring bagrada bug populations in non-crop habitat up and down the Valley starting in 2015 and since then have continued to do so. We have seen bagrada bug developing on the weeds in spring and summer months. Weeds are clearly a key factor for bagrada bug populations in our region. While cruciferous crops are available year-round in the valley, stands of weeds are typically where populations really build up during early- and mid-summer (Fig. 1).

In the Salinas Valley, shortpod mustard (Figs. 2 and 3) and perennial pepperweed (Figs. 4 and 5) appear to be the two most important weeds for buildup of bagrada bug populations. We have found bugs (in extremely high numbers) on perennial wall rocket, but this was very late in the year when temperatures were cooling and after the time when bagrada bugs are typically problematic. These three weeds are non-native and invasive, just like the bagrada bug.

For our survey, we have been surveying a number of sites that cover the length of the Salinas Valley (Salinas, Chualar, Gonzales, Soledad, Greenfield, King City, San Lucas, San Ardo, and Watsonville). These sites contain a stand of at least one of these weed species, although we focused on pepperweed and/or shortpod mustard at the majority of the sites. Each month, we search for damage and bagrada bugs on the weeds at each site for 20 minutes or until insects are counted on five plants of each species. When leaves are actively growing and not already damaged and worn out, damage is often easier to detect than insects (Figs. 6 and 7). This is similar to scouting in fields, where checking plants for fresh damage is the recommended method of scouting (Palumbo 2015). Unfortunately, fresh damage can be hard to find on older weeds because old damage obscures fresh damage, leaves are

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Importance of Weeds
(*continued*)

extremely tough, and bugs feed on stems or seed pods. We therefore use damage to detect the (likely) presence of bagrada bugs and use counts of actual bugs to track populations.

When we surveyed near the end of year was greater than in 2015, although what effect rainfall had on winter and spring bagrada bug populations is not clear. In 2016, we added a number of new survey sites, so some sites have already been surveyed during one period of population peaks, while others have only been surveyed since the beginning of this year.



Figure 2. Shortpod mustard growing in the shoulder.

June this year (2016), we did not find high populations of bagrada bugs or significant plant damage, although damage and/or insects were present at some sites. We were left wondering what would happen with bagrada bug populations this year. After our July and August sample dates, how 2016 populations compare with 2015 is still not clear, although we have now found enough bagrada bugs to suggest they may cause issues in at least some areas.

If anything, there may be a slight delay in bagrada bug movement into fields, although this is fairly speculative. The spring rainfall this

At the three sites we surveyed in 2015 with perennial pepperweed, we did not see populations jump until our survey time point in late August. This year, populations at one site are still very low. Last year, we found a large number of bugs at this site in August. Populations at another site have started to increase and were at 10 bugs per plant at the end of August. At some of the sites with shortpod mustard that we surveyed in 2015, we had already found a fair number of bagrada bugs by this time last year, including some large populations of nymphs (up to 3 to 5 adults per plant and 18 to 57 nymphs per plant). This year, we haven't seen the same populations yet at most of those sites. However, the same site that had 10 bugs per perennial pepperweed plant had populations on shortpod mustard averaging 25 adults and 15 nymphs

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Figure 3. Bagrada bugs feeding on shortpod mustard flowers.

Importance of Weeds
(*continued*)

per plant, clearly indicating bagrada bug populations at some sites are building.

Next, we have the sites that have only been surveyed in 2016. While the initial sites were chosen based on prior issues with bagrada bugs in nearby fields, the new sites were not necessarily chosen based on the same conditions. We chose these new sites to improve the coverage of our survey. Each site also contains at least one of the three weed species we have focused on (shortpod mustard, perennial pepperweed, or perennial wall rocket). A few sites were chosen knowing that bagrada bugs were present in 2015. A few of these sites have plenty of weeds available for bagrada bugs, but as of yet, we haven't seen any bugs. Some sites do have developing bagrada bug populations.



Figure 4. A stand of perennial pepperweed in the spring.

We found what appears to be growing populations of bagrada bugs on perennial pepperweed at one site near San Ardo on our last survey date (August 23). In the foothills near Gonzales, we found 1 to 26 bagrada adults and 0 to 22 nymphs on shortpod mustard plants. In addition, in July we were able to easily find bagrada bugs (0 to 8 adults, 0 to 3 nymphs) on shortpod mustard plants growing along US Hwy. 101 between Greenfield and King City (Fig. 8). Populations in this general area have since increased considerably and we have found a fair number of plants with > 50 adults or > 100 nymphs per plant. There are a lot of weeds in the roadside area on this stretch of road. This means that a handful of bagrada bugs on each plant can quickly add up to large populations when summed over thousands of plants. As the weeds senesce, bagrada bugs will likely concentrate on still-green plants, while continuing to reproduce, although this patch can only support the bagrada bugs for so long with plants continuing to senesce.

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Figure 5. A pair of bagrada bugs on perennial pepperweed flowers.

Importance of Weeds
(*continued*)

As we see it, the issue is when these growing populations of bagrada bugs run out of food in the patches of weeds and then go in search of new food sources. At this point, they can start finding their way into fields of cruciferous crops. This time of year, much of the shortpod mustard in the Valley is starting to set seed and will soon completely dry up if it has not already. In many locations, the vast majority of plants are almost dry. In the same area, some shortpod mustard plants will be completely senesced, while others are still green and flowering (see Figs. 9-13). Differences in growing conditions at a fairly small scale can therefore be very important. If all of the plants dry up, bagrada bugs will be forced to disperse, possibly triggering infestations in crop fields. If green plants remain, they may retain bagrada bugs, shifting the risk of infestation. Perennial pepperweed can persist late into the fall, but this is dependent on availability of water, damage by bagrada bugs, and disease pressure (pepperweed is often afflicted by white rust; Koike et al. 2011). The timing and severity of bagrada bug infestations in fields seems to be closely tied to what is happening on the weeds, so a better understanding of population dynamics on weeds will be needed to better predict an influx of bagrada bugs.

The next step will be to figure out how to incorporate bagrada

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Figure 6. Bagrada bug damage on perennial pepperweed. New lesions still appear green in color and with distinct lines or "fans" from the "lacerate and flush" feeding by bagrada bugs. Lesions turn white as they age and the leaf tissue becomes chlorotic.



Figure 7. Older bagrada bug damage on pepperweed. Lesions have developed into tattered holes.

Importance of Weeds
(*continued*)

bug populations in weeds into management and scouting plans. It is already common for pest control advisers (PCAs) to check weeds for bagrada bugs and we believe this to be a useful tactic. At this point, we suggest checking weeds on the edges of fields and any large patches of weeds within ~ 0.5 miles that seem to be likely sources of bagrada bugs. Consider which sides of crop fields often get infested the most and search for weeds on that side of the field. The dispersal ability of bagrada bugs has not been well characterized, but cases in which fields are colonized even when no cruciferous weeds or only bare ground is nearby show that bagrada bugs can move significant distances.



Figure 8. A typical roadside scene in the Salinas Valley (photo taken July 26). Some of the shortpod has completely senesced, but most plants still have green leaves, some flowers, and many pods.

While often seen walking, bagrada bugs readily fly, especially when temperatures are above 80°F (based on preliminary studies). When perennial pepperweed is green and leaves are growing, new or recent damage should be readily apparent. Damage on "old growth" shortpod mustard is not always readily apparent, so finding bagrada bugs themselves is necessary. Adults are often found feeding on flowers, buds, or seed pods, so these are the best plant structures to scan. We believe bagrada bugs on weeds are mainly a threat to crop fields once the quality of these plants starts to decline, so pay attention to weed phenology and damage severity on weeds from both bagrada bugs and disease.

Management of weeds is another option to limit the population growth potential of bagrada bugs. Sanitation of both weeds and crops has been a recommended cultural management tactic in the pest's Old World range (Palumbo et al. 2016). By removing nearby weeds, you may be able to prevent an economically significant infestation. If weeds are managed, the timing will be important. Even if nearby weeds didn't harbor bagrada bugs earlier in the season, they may serve as an intermediate bridge between the crop fields and weeds that are further away. Unfortunately, it is likely impossible to manage weeds far enough out from fields to eliminate the threat of bagrada bugs.

The landscape context is important, but exercising control over the entire landscape is not possible. For shortpod mustard, if it is possible to successfully manage weeds when they are still small, this may prevent buildup of bagrada populations from the very beginning. However, resurgence of the weeds may happen with sufficient soil moisture early in the year. A more efficient tactic may be to manage shortpod mustard once it has bolted and is flowering later in the season (~ late April to May). This will help prevent resurgence of weeds but will still intercept bagrada bug populations before they have a chance to build to a significant degree.

The timing of weed management could also be tied to the susceptibility of nearby crops, which could help if bagrada bugs are already present on the weeds. Adult bagrada bugs moving into a 40 day-old broccoli field because the weeds they were on were mowed or disked would likely not cause economic damage. However, managing weeds near a newly planted field could make matters worse and create a pest problem. Perennial pepperweed is a trickier weed to deal with given its phenology and ability to rapidly re-sprout.

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Importance of Weeds
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These weed species are not about to disappear from the landscape in the Salinas Valley, so they will continue to play an important role for developing bagrada bug populations.

See page 10 for literature citations.



Figure 9. Shortpod mustard growing in the roadside near Gonzales, CA. Plants further from the road have almost completely senesced. Bagrada bugs were not found at this time point. Photo taken March 26, 2016.



Figure 10. Shortpod mustard growing in the roadside near Gonzales, CA. Bagrada bugs were found on these plants. Photo taken July 26, 2016.

Importance of Weeds
(*continued*)



Figure 11. The same site near Gonzales, CA, further from the road. Plants are almost completely senesced. Bagrada bugs were found on these plants. Photo taken July 26, 2016.



Figure 12. Bagrada bugs feeding on the green pods on a shortpod mustard plant.

Importance of Weeds
(*continued*)

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Figure 13. Bagrada bugs on a nearly completely senesced shortpod mustard plant.

About the Bagrada Bug News

Numerous agencies are cooperating in the effort to discover effective organic management and biocontrol of bagrada bug. Please refer any questions about this newsletter to editor Jane Sooby, jsooby@ccof.org. Design by Sarah Watters, CCOF.



Bagrada Bug News

Issue 4 • December 9, 2016

Walking Behavior of Food-Deprived Bagrada Bug

By Shimat V. Joseph[1], Ian Grettenberger[2], and Larry Godfrey[2]

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In the Central Coast, growers of cruciferous crops usually have problems with bagrada bug starting in late July, and problems can extend into late November. Usually, bagrada bug populations build up on common cruciferous weeds such as shortpod mustard and perennial pepperweed in the general landscape surrounding the agricultural fields.

We hypothesize that bagrada bug move from those infested weeds and invade newly planted crucifer crops when quality of the weeds deteriorate (see photo next page) likely due to water stress or summer heat. At this time bagrada bug are susceptible to food deprivation and starvation.

We conducted experiments to determine if the degree of starvation has an effect on bagrada bug walking movement using mobility tracking software. Nymphal stages (younger nymphs: 2nd-3rd and older nymphs: 4th-5th instars) and adults (females and males) were starved in the laboratory for up to three days. In general, all bagrada bug life stages travelled farther and faster when starved in the laboratory.

In the field, walking pattern of starved bugs was not consistent with laboratory results because the bugs were exposed to varied environmental conditions, especially temperatures. It appears that only starved bugs moved farther as temperatures increased. Walking behavior of non-starved bugs did not appear to change with increase in field temperatures.

If weed quality declines in late summer or early fall, bagrada bugs are likely to travel longer distances for food.

We also examined if starved bugs oriented more strongly to food than non-starved bugs. We used broccoli crowns as food and provided a choice between food and nothing. It appears that both females and males chose broccoli over nothing

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Walking Behavior of Food-Deprived Bagrada Bug

Report from Abroad: Preliminary Results on the Geographic Origin of Bagrada Bug

California Bagrada Bug Scouting Report

Update on Bagrada Bug Populations in Non-Crop Areas of the Salinas Valley



Dead, dry weeds cause bagrada bugs to seek other food sources, such as brassica crops.

(*continued from previous page*)

when they were starved. Non-starved adults did not show preference for either broccoli or nothing.

This study suggests that bagrada bugs are likely to leave the weeds when their quality deteriorates. In the Central Coast, quality of the weeds in the agricultural landscape depends on sustained but intermittent winter rain events or how quickly weeds senesce in the heat of summers. These weeds have fairly deep root systems which can help them to stay alive beyond mid-summer. If the infested weeds dry early, it is likely that bagrada bug will appear early in the agricultural fields. Also, based on the data, if the weed quality is declining during the warmer time of the year (as in late summer or early fall), bagrada bugs are likely to travel longer distances.

Report from Abroad: Preliminary Results on the Geographic Origin of Bagrada

By Marie Claude Bon, René F.H. Sforza, and Lincoln Smith

USDA-ARS European Biological Control Laboratory

Marie Claude Bon (European Biological Control Laboratory, EBCL) has analyzed DNA from a variety of bagrada bug (*Bagrada hilaris*) specimens with the goal of determining the region of origin of the pest. Such information helps direct where to search for prospective biological control agents. A genetic "barcode" (a short sequence from a standard genetic locus of mitochondrial DNA, named *CO1* and commonly used for species identification) was sequenced to determine the relatedness of various populations of bagrada bug. We analyzed specimens from bagrada bug colonies provided by Darcy Reed, Brian Hogg, and Charlie Pickett that originated from Riverside, Coachella Valley, Davis, Gustine, and Monterey, CA, as well as specimens collected by Centre for Agriculture and Biosciences International (CABI) cooperators in Pakistan and by René Sforza (EBCL) in Morocco and South Africa. We compared these barcode sequences with those obtained from public databases such as the *BOLD* DNA Barcode Reference Library and the *GenBank* sequence database provided by the National Center for Biotechnology Information (NCBI), which included barcodes from Pakistan, Kenya, and Mexico.

It appears that all bagrada bugs in USA belong to one haplotype.

All the bagrada bug specimens from the USA share the same barcode sequence (haplotype). A similar pattern was observed with nine additional genes sequenced by Blake Bextine's group at University of Texas. Thus it appears that all bagrada bugs in USA belong to one haplotype. This haplotype is most closely related to one of the most prevalent haplotypes recovered from Pakistan (see figure). Specimens

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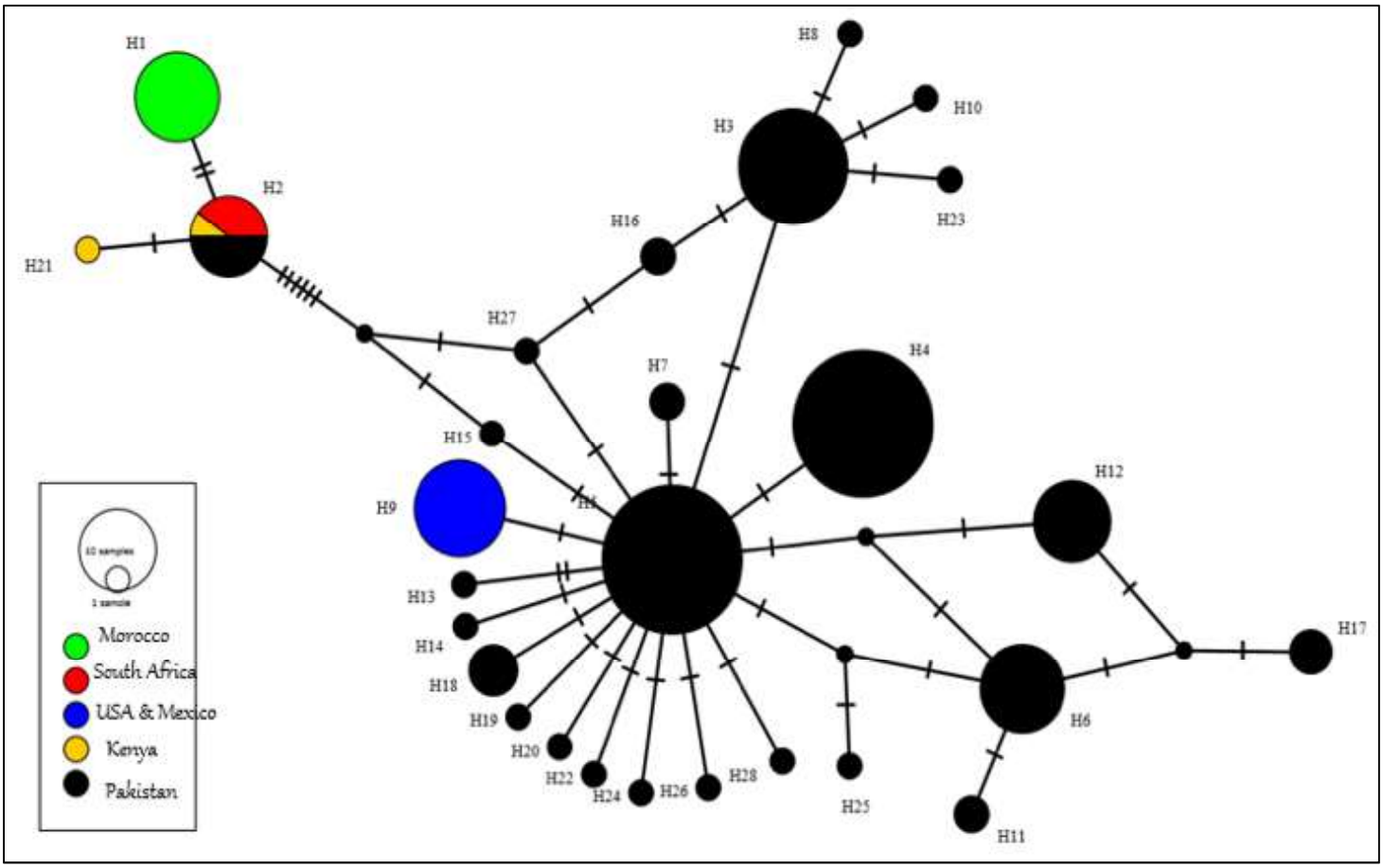

Evolutionary network depicting genetic relatedness among barcode haplotypes recovered from *Bagrada hilaris*. Each circle represents a different haplotype, the color corresponds to country, the diameter is proportional to abundance, and the cross hatches indicate the number of mutations (nucleotide changes) between haplotypes.

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from Kenya, South Africa, and Morocco are more distantly related to the USA specimens.

The present results suggest that the invasive populations in the USA originated from one population in the Pakistan region. We have yet not examined Indian samples, which might be similar to those from neighboring Pakistan. In any case, Pakistan appears to have a high genetic diversity, which further suggests that this would be a likely region for finding prospective biological control agents. The two species of parasitoids collected from Pakistan this year, *Trissolcus hyalinipennis* and *Gryon sp.*, should be prime candidates for host specificity testing.

California Bagrada Bug Scouting Report

By C.H. Pickett[1], B.N. Hogg[2], and K. Stokes[2]

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Work began in summer and fall 2016 to survey natural enemies of bagrada bug that may already be present in California. The major focus of our work was to develop a sentinel egg "trap" to identify parasitoids attacking bagrada bug eggs. Traps consisted of killed (frozen) bagrada bug eggs glued to waterproof index cards, which were placed on the ground, where bagrada bug lays most of its eggs, in organic cole crop fields and patches of known weedy hosts of bagrada bug (primarily shortpod mustard and perennial pepperweed).

From late July to October 2016, researchers at USDA-ARS and California Department of Food and Agriculture placed sentinel egg traps at a total of 18 sites in northern

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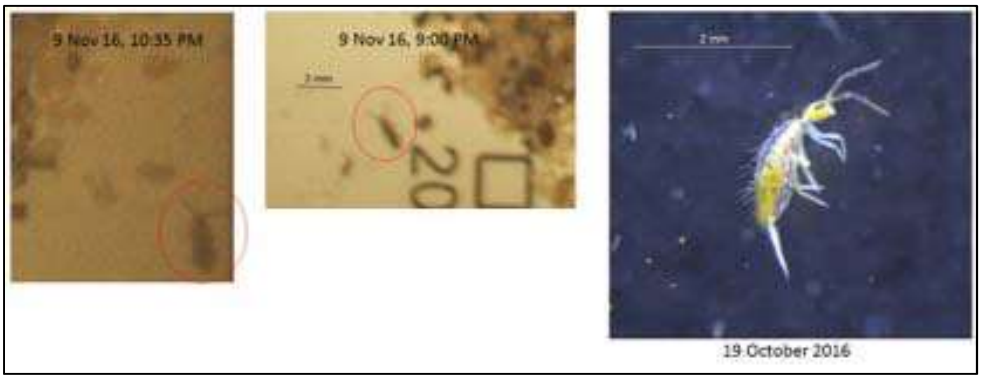

Soil Born Farms, Collembola in sentinel traps. Images to left from field camera, and to right collected species imaged through microscope.

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California in these counties: Monterey, San Benito, Fresno, Merced, San Joaquin, Marin, Sonoma, Contra Costa, Yolo, and Sacramento. Bagrada bug numbers were generally low in 2016; only eight of our sites (six cole crop fields and two weed patches) had significant bagrada bug populations.

We found four sites with high numbers of bagrada bugs in the Sacramento region where cole crops were being grown. Two were operated by Soil Born Farms, a non-profit educational organic production operation, and two sites managed by Terra Firma farms in Yolo and Solano counties, also organic production. Brown marmorated stink bug (BMSB) (*Halyomorpha halys*) pheromone-baited AgBio traps were set up to provide some baseline information on the relative size of the bagrada bug population. We know from having used this trap throughout California for monitoring BMSB that it also readily attracts bagrada bug.

We also sampled for bagrada bug by sweeping strips of alyssum at the two Terra Firma farms. They interplant alyssum strips with their cole crops for aphid control. This non-crop plant appears to be highly preferred by bagrada bug.

Sentinel bagrada bug eggs were readily fed on by predators. A time-lapse field camera was tested at one site for identification of predators that could be feeding on the sentinel eggs, although problems with fogging of the camera lens precluded its use at multiple sites. The organisms most commonly observed near sentinel egg cards were springtails (Collembola: most likely Isotomidae). See above image.

The creatures enclosed with a red circle in this image are probably Collembola (an order previously in Insecta).

Many species of Collembola are scavengers, but some are known to feed on other Collembola. In general there is very little known about these animals. Ants were also observed at several sites and are likely to prey on bagrada bug eggs.

Our traps sat just on top of the soil, however, and bagrada bugs lay the majority of their eggs just below the soil surface, where many predators may not find them.

Although we found no parasitism of sentinel bagrada bug eggs, no conclusions regarding findings can be made until season-long monitoring has taken place at multiple locations.

Update on Bagrada Bug Populations in Non-Crop Areas of the Salinas Valley

By Ian Grettenberger[1], Larry Godfrey[1], and Shimat V. Joseph[2]

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Here in the Salinas Valley, we have reached the end of our approximately two-year effort tracking bagrada bug populations in non-crop habitat. Countable populations have neared (or stayed at) zero at most of our sampling sites on the last sampling date the last week of November 2016. It is a good time to summarize what we have seen this year and how it compares to last year. Our assessments of bagrada bugs on weeds matches up with what we have heard in the Valley about populations in crops.

As a reminder, we have been following bagrada bug popula-tions at sites located in non-crop areas. These sites contained key cruciferous weeds, which were

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primarily shortpod mustard or perennial pepperweed, with some containing perennial wall-rocket. The sites we added at the inception of this study were chosen based on a previous history of bagrada bug infestations in nearby fields. The additional sites we added this year were chosen based on our knowledge that bagrada bugs had been on the weeds or simply based on habitat (i.e., great-looking weeds).

At the sites we have monitored for two years, populations were definitely lower than last year. We did still find bagrada bugs and saw populations tick up at some of the sites. However, these spikes were lower than last year. This seemed to be especially true for the nymphs. At our pepperweed sites that were monitored for two years (three sites), we found bagrada bugs both years, even if populations were a bit lower in 2016 than 2015.

Our two-year shortpod mustard sites were a bit different. A few of the sites had bagrada bug populations develop, although they didn't reach the size of populations in 2015. Notably, we did not find any bagrada bugs at a large number of these sites. This included sites that had fairly high populations of adults and/or nymphs in 2015. Shortpod mustard plants were present and looked healthy, but the insects were not.

We cannot compare populations in 2016 to those last year at the sites that were first scouted in 2016, although we do see some interesting trends when we look at the overall data for our study. Consistent with the general distribution of the weeds in the Valley, most of the sites were dominated by shortpod mustard versus pepperweed. None of the sites reached population levels that we saw at the two-year sites in 2015, although we did find decent populations at some of them.

Interestingly, while adult populations were not that much lower overall this year compared to last year (at new and old sites), nymph populations were much lower across sites both on shortpod mustard and pepperweed. A number of the shortpod mustard sites had very high spikes in populations of nymphs in 2015 (30-140 nymphs per plant), but our site with the most nymphs in 2016 (a new site) only had a maximum of 40 per plant. This suggests that either reproduction or mortality for nymphs was different between years. However, we don't have any evidence for what drove this pattern.

The complete lack of bagrada bugs (and damage on weeds) at some of the sites also shows how variable populations can be. The variation in bagrada bug populations between years could result from abiotic (temperature, precipitation) or biotic (weed hosts, predators) factors.

It remains to be seen what will happen with populations next year in both non-crop areas and in fields. It doesn't seem like we have high populations of bagrada bugs going into the winter. However, we will have to wait until the temperatures start to rise in late spring and early summer before we start to get a handle on what populations will look like in 2017. 

About the Bagrada Bug News

Numerous agencies are cooperating in the effort to discover effective organic management and biocontrol of bagrada bug. Please refer any questions about this newsletter to editor Jane Sooby, jsooby@ccof.org. Design by Sarah Watters, CCOF.

An Evaluation of the Flora Adjacent to Wine Grape Vineyards for the Presence of Alternative Host Plants of Grapevine red blotch-associated virus

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Abstract

Bahder, B. W., Zalom, F. G., and Sudarshana, M. R. 2016. An evaluation of the flora adjacent to wine grape vineyards for the presence of alternative host plants of Grapevine red blotch-associated virus. Plant Dis. 100:1571-1574.

Grapevine red blotch-associated virus (GRBaV) is a recently discovered virus of concern to wine grape production in North America. While the vector of this virus is unknown, other elements of virus epidemiology are essential to develop guidelines for the management of the virus as well as to assist in the search for its vector. The objective of this study was to evaluate vegetation within and surrounding GRBaV-infected vineyards to identify potential virus reservoirs that may serve as sources of inoculum. In this study, 13 plant species were sampled throughout the year and were tested for the presence of GRBaV. Of the 13 species tested, two species, *Rubus armeniacus* and wild grapes (*Vitis californica* × *V. vinifera*), tested positive by quantitative PCR. Of these two species, only wild grapes were determined to be a true host. This study documents the first time GRBaV has been confirmed in an alternative host or in a species outside of a commercial vineyard and suggests that a mechanism exists by which GRBaV moves between plant species that is not human-mediated. The precise role that wild grapes play in the epidemiology of GRBaV remains unknown.

Grapevine red blotch-associated virus (GRBaV) is a recently discovered virus associated with red blotch disease of grapevines (Al Rwahnih et al. 2013; Krenz et al. 2012; Sudarshana et al. 2015) that has been reported in various cultivars of *Vitis vinifera* in North America (Krenz et al. 2014). The genome of GRBaV is comprised of a single-stranded, positive-sense, circular DNA of 3,206 kilobases (kb) in size (Al Rwahnih et al. 2013; Krenz et al. 2012). Due to similarity of genome size, sequence identity, and the presence of a nonanucleotide sequence of TAATATT↓AC that serves as the origin of replication (ori), GRBaV has been proposed to be placed in the family *Geminiviridae*. The presence of GRBaV has been confirmed from Arkansas, California, Georgia, Idaho, Maryland, New Jersey, New York, Oregon, Pennsylvania, Texas, Virginia, and Washington within the United States (Brannen et al. 2013; Krenz et al. 2014; Sudarshana et al. 2015) and from Ontario in Canada (Sudarshana et al. 2015). This widespread distribution is likely due to the dissemination of infected material prior to the discovery of the virus. While GRBaV wasn't discovered until 2012, herbarium specimens of wine grape cultivars dating to 1940 were confirmed to be infected by GRBaV (Al Rwahnih et al. 2015a) and several table grape cultivars at the National Clonal Germplasm Repository in California were also found to be infected with GRBaV (Al Rwahnih et al. 2015b).

Negative impacts of red blotch disease on grapevines have been documented by Calvi (2011) and red blotch is currently a major concern of the wine grape industry in California and elsewhere in the United States. Poojari et al. (2013) implicated the Virginia creeper leafhopper, *Erythroneura ziczac*, as a vector of GRBaV under greenhouse conditions. However, repeated attempts to confirm this transmission have failed thus far, leaving the vector of GRBaV under vineyard conditions unknown (B. Bahder, F. Zalom, and M. R. Sudarshana, *unpublished*). While establishing the vector species for GRBaV is essential for developing effective guidelines for managing the spread of GRBaV in vineyards, another important variable for the epidemiology of GRBaV is the host range of the virus. Establishing the presence of GRBaV in plant species besides *V. vinifera* is important not only for determining natural reservoirs of GRBaV but, also, to provide leads in the search for one or more vectors of the virus.

The primary objective of this study was to survey woody and herbaceous plant species within and surrounding GRBaV-infected vineyards in northern California to help assess the risk of natural reservoirs for infection.

Materials and Methods

Site selection. Three vineyard sites were selected to sample associated vegetation, two (NC-01 and NC-02) located in Napa County, California, and one (SC-01) located in Sacramento County, California. Both NC-01 and NC-02 were known to be infected with isolates belonging to both clades of GRBaV (CS-337-1 and CF-214-1), while SC-01 was infected with clade I (CS-337-1) isolates only. An additional location in Napa County representing undisturbed riparian habitat, about 2 km from the nearest vineyards, was also surveyed. Vineyard NC-01 is an experimental vineyard of the Department of Viticulture and Enology, University of California, Davis, at Oakville in the Napa Valley that was established with cultivar Cabernet Sauvignon 7 (CS-7) on rootstock 101-14. Vineyards NC-02 and SC-01 are commercial vineyards that were sampled with grower permission in Napa and Sacramento counties, respectively. Site NC-02, the second vineyard in Napa County, is comprised of Cabernet Franc. The SC-01 vineyard is an increase block consisting of rootstock 420A and self-rooted Cabernet Sauvignon. The riparian area sampled was located at the northern end of the Napa Valley at coordinates 38.6488444°, 122.7402806°, and was isolated from commercial vineyards with a high abundance of wild grapes.

Sample selection and collection. For sampling plant species in and around vineyards, the most abundant woody and herbaceous plant species were sampled. Abundant is defined here as plants where 10 individuals could be sampled. A total of 10 samples were taken of each of the 13 species (Table 1). For small, herbaceous plants, the whole plant was sampled, while all woody plants were sampled by removing five leaves and a portion of the stem to extract DNA from bark scrapings. All species selected were sampled and tested in the winter, spring, summer, and fall. In the case of woody plants, all sampled plants were marked so that the same plants were sampled repeatedly. Additionally, in a small vegetable garden present at the Oakville station, tomato and pepper plants were randomly collected and tested

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Accepted for publication 25 March 2016.

http://dx.doi.org/10.1094/PDIS-02-16-0153-RE
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for the presence of GRBaV. All field samples were stored at 4°C until processed for nucleic acid extraction.

DNA extraction and virus detection. Total DNA was extracted from samples using the DNeasy plant mini kit (Qiagen Inc., Valencia, CA). To verify the presence of GRBaV in plant tissue, quantitative polymerase chain reaction (qPCR) assays were conducted, using primers GVGF1 (5′-CTC GTC GCA TTT GTA AGA-3′) and GVGR1 (5′-ACT GAC AAG GCC TAC TAC G-3′) (Al Rwahnih et al. 2013). qPCR assays were performed in a 20-µl reaction, containing 0.15 µM of each of the primers, 2% polyvinyl pyrrolidone, 0.3 µl Stratagene reference dye (1:500), 10 µl of SsoFast EvaGreen supermix (BioRad Inc., Hercules, CA), and 1 µl of DNA template, with the remaining volume made up with nuclease-free water. Thermal cycling conditions were as follows: initial denaturation at 95°C for 2 min, 35 cycles of 95°C for 30 s, 62°C for 1 min, 72°C for 1.5 min, on a Stratagene Mx3000P thermal cycler (www.genomics.agilent.com). Following amplification, high resolution melting analysis was performed to confirm the identity of the product amplified. Conditions for melting point analysis were 95°C for 1 min, 55°C for 30 s, and 95°C for 30 s with continuous measurement of fluorescence. Samples were scored positive when the accumulated fluorescence signal crossed the threshold (Ct) and the amplicon had a melting temperature comparable to that produced by a product amplied from a plasmid cloned with a GVGF1/GVGR1 PCR product and a GRBaV-infected grapevine source plant maintained in a greenhouse.

RNA extraction and reverse transcriptase (RT)-PCR. Plant samples that were confirmed positive by analysis of sequence data were subsequently re-extracted, using the RNeasy plant mini kit (Qiagen, Valencia, CA) to isolate total RNA. Plant samples were initially ground in guanidine buffer (Osman et al. 2012) and were treated with DNase I at 37°C for 25 min, and the enzyme was inactivated at 70°C for 10 min and, then, processed according to manufacturer instructions. To establish if GRBaV was replicating in the plants that tested positive, RT-PCR was performed on the RNA extract. Reactions performed were 25 µl in volume, consisting of 2 µl of RNA template, 0.5 µM of each primer, 5% 0.1 M dithiothreitol, 8% 25 mM $MgCl_2$, 20% 5× Green GoTaq Flexi buffer, 4% 10 mM dNTP mix, 4% RNasin, 180 U Superscript III RT, and 0.75 U GoTaq Flexi DNA polymerase. Thermal cycling conditions were 40 min at 52°C for initial reverse transcription, followed by 35 cycles of denaturation at 95°C for 30 s, 30 s at 62°C for annealing, and 1.5 min at 72°C for extension, followed by a final extension period of 7 min at 72°C. Amplified products were visualized by electrophoresis on a 1.5% agarose gel, using 1× Tris-acetat-EDTA buffer and staining with GelRed.

DNA sequencing and sequence analysis. To obtain sequence data from positive samples, standard PCR was re-conducted on samples testing positive by qPCR, using the aforementioned primers. PCR was performed in 25-µl reactions with 0.5 µM of each primer, 200 µM dNTPs, 5× Green GoTaq Flexi buffer, 25 mM $MgCl_2$, and 1.5 U GoTaq Flexi DNA polymerase with the remaining volume made up with diethylpyrocarbonate-treated water. Two microliters of DNA template were used for each reaction. Thermal cycling conditions were the same as used by Al Rwahnih et al. (2013). PCR product was visualized, as described above, on a 1.5% agarose gel. PCR products were purified using the QIAquick PCR purification kit (Qiagen, Inc, Valencia, CA) and were sequenced at the University of California, Davis, DNA Sequencing Facility on an ABI Prism 3730 genetic analyzer. Contiguous files were created using Vector NTI v. 11.5 (Life Technologies, Benicia, CA), aligned using MEGA 5.2 (Tamura et al. 2011), and were BLAST searched against the GenBank database to verify the identity of GRBaV isolates.

Results

Plant sampling and virus detection. A total of 13 different plant species were systematically surveyed throughout 2015 (Table 1). Eight of the 13 species were herbaceous plants and five species were woody plant species. Of the plant species tested for the presence of GRBaV, using qPCR, wild grapes (*Vitis californica* × *V. vinifera*) and *R. armeniacus* (Himalayan blackberry) tested positive and all other species were negative for GRBaV in the initial screening (Table 1). Wild grapes that tested positive for GRBaV in winter also tested positive for GRBaV in other seasons, while the *R. armeniacus* plants that were positive in winter and spring were negative for GRBaV in the summer and fall (Table 1). Two of the positive wild grapes were from the isolated riparian habitat, two were from NC-01, and one from NC-02. One of the infected wild grapevines also appeared to develop symptoms late in the year, consisting of reddened veins and mild reddening of the leaf blade (Fig. 1) that were not as pronounced as the symptoms seen in red-fruited wine grape cultivars of *V. vinifera*. Other wild grapes nearby the symptomatic vine that tested negative by PCR were asymptomatic, whereas the wild grape with symptoms was PCR positive (Fig. 1). Due to unknown parentage of this wild grape, it cannot be said if reddening was solely due to GRBaV infection, however, this reddening in PCR was absent in wild grapes that tested negative for the virus.

PCR products amplified from these samples were subsequently sequenced and were confirmed as GRBaV sharing homology with CS-337-1 (KC896624.1) and CF-214-1 (NC_022002.1) isolates in GenBank, belonging to clades 1 and 2, respectively. Sequence data obtained from the three *R. armeniacus* (KM389994, KM389996, and KM389997) testing positive for GRBaV shared 99% nucleotide identity with isolate CF-214-1 (Fig. 2), and sequence data obtained from the five positive wild grape specimens (KU244025 to KU244029)

Table 1. Common species of plants found in and adjacent to vineyards with grapevines that tested positive for Grapevine red blotch-associated virus in northern California

Species	Common Name	Winter[a]	Spring[a]	Summer[a]	Fall[a]	Site
Herbaceous plants						
Cynodon dactlyon	Bermuda grass	0/10	0/10	0/10	0/10	NC-01, NC-02, SC-01
Eschscholzia californica	California Poppy	0/10	0/10	0/10	0/10	NC-01, NC-02, SC-01
Kickxia elatine	Sharppoint Fluvellin	0/10	0/10	0/10	0/10	NC-01, NC-02, SC-01
Malva neglecta	Common Mallow	0/10	0/10	0/10	0/10	NC-01, NC-02, SC-01
Plantago lanceolata	Buckhorn	0/10	0/10	0/10	0/10	NC-01, NC-02, SC-01
Tribulus terrestris	Puncture Vine	0/10	0/10	0/10	0/10	NC-01, NC-02 SC-01
Woody plants[b]						
Rosa sp.	Rose	0/10	0/10	0/10	0/10	NC-01, NC-02
Rubus armeniacus	Himalayan Blackberry	3/10	3/10	0/10	0/10	NC-01, SC-01
Heteromeles arbutifolia	Toyon	0/10	0/10	0/10	0/10	NC-01, NC-02
Ilex sp.	Holly	0/10	0/10	0/10	0/10	NC-01, NC-02
Quercus lobata	Valley Oak	0/10	0/10	0/10	0/10	NC-01
Quercus suber	Cork Tree	0/10	0/10	0/10	0/10	NC-01
Vitis californica × *V. vinifera*	Wild Grape	5/10	5/10	5/10	5/10	NC-01, NC-02, RH[c]

[a] The numerator is the number of infected plants positive for GRBaV byPCR and the denominator is the total number of plants analyzed.
[b] All woody plant species tested were the same 10 individuals tested at different times of the year.
[c] RH = Riparian habitat.

shared 99% identity with isolate CF-214-1 (Fig. 2). Based on these data, all isolates obtained from *R. armeniacus* and wild grapes were more closely related to the genotype represented by CF-214-1 (Fig. 3). All wild grape samples amplified also generated PCR products of expected size by RT-PCR (Fig. 4), while all of the *R. armeniacus* samples that tested positive using PCR and qPCR subsequently tested negative by RT-PCR (Fig. 4). Due to the ambiguous nature of the *R. armeniacus* results, 10 additional plants were sampled and anlayzed by PCR. One plant also tested positive for the CS-337-1 strain of GRBaV but exhibited the same pattern as the other *R. armeniacus*, in that viral RNA was not detectable by RT-PCR (data not shown). All plant samples from a vegetable garden also tested negative for the presence of GRBaV.

Discussion

This study provides the first evidence of GRBaV infection of an alternative host, a wild grape (*V. californica* × *V. vinifera*) outside of a vineyard. Finding GRBaV in wild grapes was not surprising, due to the presence of GRBaV in table grapes (Al Rwahnih et al. 2014) as well as the documented occurrence of other grapevine viruses occurring in other *Vitis* species and hybrids, both cultivated (Bahder et al. 2013; Soule et al. 2006) and wild (Klaassen et al. 2011). Due to the relatively recent discovery of GRBaV, lack of information on its biology and epidemiology, and the unknown status of the vector, the identification of the virus in naturally occurring flora outside of vineyards is important from an epidemiological perspective, because it demonstrates that there is a mechanism by which GRBaV can move between plants without human intervention. The presence of the same genotype of GRBaV in wild grapes immediately adjacent to vineyards and at a greater distance is indicative of a flying insect vector, because geminiviruses are not seed- or pollen-borne (Muhire et al. 2013; Sudarshana et al. 1998), with the exception of *Tomato yellow leaf curl virus* (Kil et al. 2016), and the observed distances are likely too great to suggest involvement of soil-borne vectors such as nematodes. Based on our data, it is unclear if GRBaV was present in wild grapes and subsequently moved into *V. vinifera* or if vineyards with infected material were the source for infection of wild grapes. However, after the first report of red blotch disease and GRBaV (Al Rwahnih et al. 2012), there has been no report of the presence of this virus in other countries, with the exception of Switzerland in grapevines imported from California in the 1980s (Reynard 2015; Reynard and Gugerli 2015). In the absence of reports of spread from the old world, it is likely that GRBaV moved from wild *Vitis* spp. in North America into *V. vinifera*.

The presence of GRBaV in *R. armeniacus* is intriguing, because blackberry brambles are common in vineyards in the North Coast of California. Some viruses are known to infect both grapes and blackberries (Martin et al. 2013). *Grapevine Syrah virus 1* (genus: *Marafivirus*; family: *Tymoviridae*) and *Tomato ringspot virus* (genus: *Nepovirus*; family: *Secoviridae*) have been detected in both blackberry plants and grapevines. Recently, it was reported that *E. ziczac* could transmit GRBaV under greenhouse conditions (Poojari et al. 2013) and *E. ziczac* infestation of both blackberries and grapevines had been seen at site SC-01. Because of this, we examined the presence of GRBaV in *R. armeniacus*. Observations over a full year indicated that, while the same wild grapevine plants tested positive in all four seasons for

		1	2	3	4	5	6	7	8	9
1	CS-337-1	-								
2	CF-214-1	6.7								
3	WG-128D	6.9	0.4							
4	WG-128E	6.9	0.2	0.2						
5	WG-128SS	6.5	0.2	0.4	0.4					
6	WG-128Fr	7.4	0.6	1.0	0.8	0.8				
7	WG-128De	6.5	0.2	0.4	0.4	0.0	0.8			
8	RA-NC1	7.1	0.4	0.8	0.6	0.6	1.0	0.6		
9	RA-NC2	7.1	0.4	0.8	0.6	0.6	1.0	0.6	0.0	
10	RA-SC1	7.1	0.4	0.8	0.6	0.6	1.0	0.6	0.0	0.0

Fig. 2. Pairwise comparison showing percent difference at the nucleotide level between the V2 open reading frame (ORF) of known genotypes of Grapevine red blotch-associated virus (GRBaV), CF-214-1 (clade 2) and CS-337-1 (clade 1) from California, and V2 ORF of isolates from wild grapevines and *Rubus armeniacus*.. RA = *Rubus aremeniacus*, WG = wild grapevine (*Vitis californica* × *V. vinifera*), CF = Cabernet Franc, CS = Cabernet Sauvignon. Values represent percent difference.

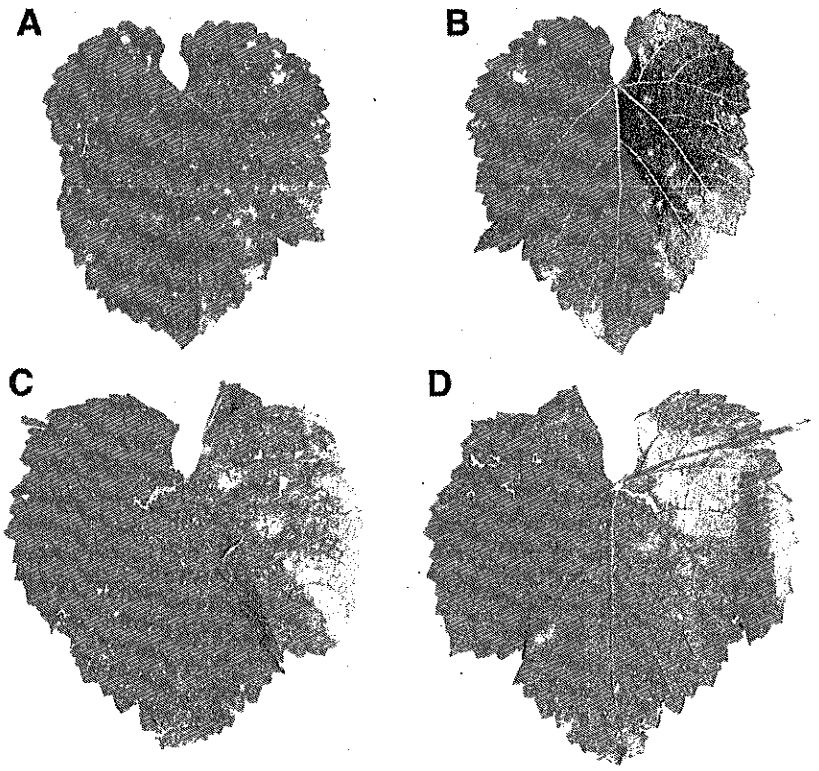

Fig. 1. A and **B**, Adaxial and abaxial surface of leaf blades of a specimen of a wild grapevine (*Vitis californica* × *V. vinifera*) that tested negative and **C** and **D**, positive for Grapevine red blotch-associated virus (GRBaV) in quantitative PCR. Note pinkish veins in the leaf from GRBaV-infected wild grapevine.

GRBa V, the virus was detected only in winter and spring and not in the new growth in summer and fall (Table 1). To examine if the virus was replicating in blackberries, RT-PCR assays were conducted to detect transcripts of predicted virus genes. Tests for transcripts of the V2 gene (Fig. 4) indicated that GRBaV did not replicate in *R. armeniacus* and, thus, the virus did not become systemic in this host. The detection of GRBa V in these plants suggests a form of environmental contamina-tion as a result of vector feeding in which the virus was introduced at the feeding site.

While GRBaV was not shown to be replicating in *R. armeniacus*, these plants may still be of epidemiological importance for GRBaV in that they likely serve as an alternative host for the vector species. The impact that *R. armeniacus* and wild grapes have on the epide-miology of GRBaV cannot be fully understood until the vector is identified. Among grapevine viruses, all known grapevine leafroll-associated viruses are largely restricted to *Vitis* species. In the case of GLRaV-3, a natural vector has been known for33 years and its pres-ence in wild grapes is not surprising. However, for GLRa V-2, a natural vector has not been found and, thus, the finding of this virus in *V. cal-ifornica* by Klaassen et al. (201 1) suggests an obscure vector thriving in isolation. In the case of GRBa V, once the vector is discovered, more detailed studies of its life history and movement behavior will help as-sess the risk that wild grapevines pose as virus reservoirs for potential infection and the significance that *R. armeniacus* plays as an alterna-tive host for the vector, if any.

Acknowledgments

This work was supported by USDA-ARS CRIS 5306-220000-014-00D. Ad-ditional funding for this research was provided by grants from the California Grapevine Rootstock Improvement Commission, and the California Tree Fruit and Nut Crops and Grapevine Industry Board. The authors thank Michael Bollinger and Meredith Castillo, for assistance in sample collection and processing. This publication was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

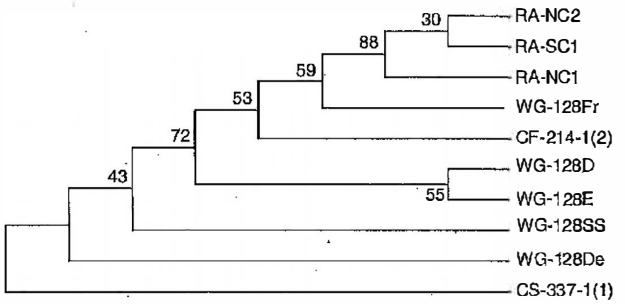

Fig. 3. Neighbor-joining tree showing relationship of Grapevine red blotch-associated virus (GRBaV) isolates from wild grapevines and *Rubus armeniacus* to GRBaV genotypes belonging to two clades from California, based on the nucleotide sequence of the V2 open reading frame. Values above the nodes represent boot strap values. RA = *Rubus aremeniacus*, WG= wild grapevine (*Vitis californica* × *V. vinifera*), CF = Cabernet Franc, CS = Cabernet Sauvignon.

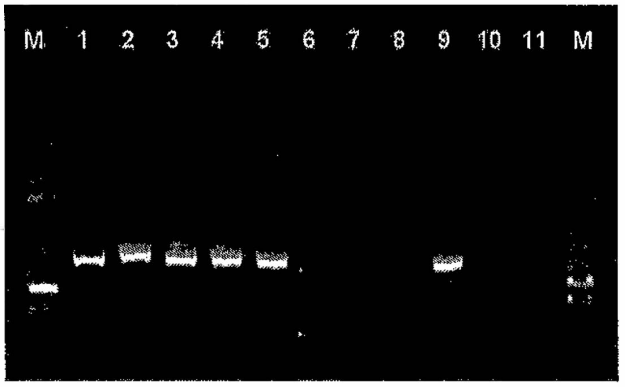

Fig. 4. Agarose gel (1.5%) stained with GelRed visualizing reverse transcriptase-PCR product for Grapevine red blotch-associated virus (GRBaV) isolates from wild grapevines (*Vitis californica* × *V. vinifera*) (lanes 1 to 5) and *Rubus armeniacus* (lanes 6 to 8); lane M, 1 kb+ Ladder (Invitrogen Inc.), lane 9, GRBaV-Infected *Vitis vinifera*. Lanes 10 and 11, healthy grapevine and water control, respectively.

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SCB14051 Attachment 2

Phylogeny of Geminivirus Coat Protein Sequences and Digital PCR Aid in Identifying *Spissistilus festinus* as a Vector of Grapevine red blotch-associated virus

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Accepted for publication 18 April 2016.

ABSTRACT

Bahder, B. W., Zalom, F. G., Jayanth, M., and Sudarshana, M. R. 2016. Phylogeny of geminivirus coat protein sequences and digital PCR aid in identifying *Spissistilus festinus* as a vector of Grapevine red blotch-associated virus. Phytopathology 106:1223-1230.

Grapevine red blotch-associated virus (GRBaV) is a single-stranded DNA virus, proposed to be a member of the family *Geminiviridae*, and is associated with grapevines showing red blotch symptoms in North America. The existence of the virus was reported in 2012, and subsequently detected in grapevines in major grape production regions. We investigated if a vector exists that can transmit GRBaV in vineyards. Phylogenetic analysis of the predicted amino acid sequence of coat protein (CP) of GRBaV with the CP of 23 geminiviruses representing all seven genera of the family *Geminiviridae* revealed that GRBaV-CP was most similar to that of *Tomato pseudo-curly top virus*, a geminivirus known to be transmitted by a treehopper (Membracidae), a family that is closely related to leafhoppers (Cicadellidae). To identify vectors of GRBaV, hemipteran species within and nearby wine grape vineyards where virus spread was suspected were collected and transmission assays were conducted. Among the species tested, the three-cornered alfalfa hopper *Spissistilus festinus* (Hemiptera: Membracidae) was able to both acquire the virus from a grapevine infected with GRBaV and transmit the virus to healthy grapevines in the laboratory. In commercial vineyards, lateral shoots of grapevines girdled due to feeding injury by the adult three-cornered alfalfa hopper also tested positive for the virus using digital PCR. These findings represent an important step in understanding the biology of GRBaV and develop management guidelines.

Additional keywords: *Erythroneura elegantula*, *E. variabilis*, *E. ziczac*.

Grapevine red blotch disease (GRBD) is a recently recognized disease of grapevines (Calvi 2011; Sudarshana and Fuchs 2015; Sudarshana et al. 2015). Symptoms of GRBD include reddening of primary, secondary, and tertiary veins as well as a red blotch pattern on the leaf surface in red-fruited varieties. In white-fruited varieties, symptoms include irregular chlorosis on leaf blades that may become necrotic in the autumn months (Sudarshana et al. 2015). Disease symptoms may resemble those of grapevine leafroll disease (GLD) and GRBD has also been referred to in the literature as simply a red leaf disease (Calvi 2011; Poojari et al. 2013).

Grapevine red blotch-associated virus (GRBaV) is a DNA virus that was discovered in symptomatic grapevines in California using a metagenomic approach (Al Rwahnih et al. 2012; Al Rwahnih et al. 2013). This virus has also been referred to as Grapevine Cabernet franc-associated virus (Krenz et al. 2012); Grapevine red leaf-associated virus (Poojari et al. 2013), and Grapevine geminivirus (Seguin et al. 2014). Despite its slightly larger genome size (~3,206 nucleotides), GRBaV shares several features of monopartite geminiviruses and has been proposed to be a member of the family *Geminiviridae*. Even though the virus was first reported from field samples in 2012, it was detected in herbarium specimens archived as early as 1940 (Al Rwahnih et al. 2015a).

Negative impacts of GRBD on wine grape quality have been reported (Calvi 2011; Poojari et al. 2013). Because of the potential economic impact of the disease and the presence of GRBaV in grapevines previously thought to be affected by leafroll disease but tested negative for all known leafroll-associated viruses (Sudarshana et al. 2015), GRBaV has become a major concern for wine grape producers in the United States. This virus also has been found in table grape accessions at the National Clonal Germplasm Repository in Winters, CA (Al Rwahnih et al. 2015b), but its significance to table grape producers is not known. Recently, GRBaV was detected in wild grapes relatively close to vineyards affected by GRBD in California, indicating the likelihood of plant-to-plant spread in nature (Bahder et al. 2016; Perry et al. 2016).

Members of the family *Geminiviridae* are transmitted by hemipteran insects. While members of the largest genus *Begomovirus* are transmitted by whiteflies (*Bemisia tabaci*, family Aleyrodidae), members of the other genera are transmitted by leafhoppers (Cicadellidae) and in one case, a treehopper (Membracidae) (Briddon et al. 1996). The only other geminivirus-like DNA virus that infects a woody plant and is known to exhibit horizontal transmission is *Citrus chlorotic dwarf-associated virus*, transmitted by the whitefly *Parabemisia myricae* (Loconsole et al. 2012). For GRBaV, Poojari et al. (2013) implicated the Virginia creeper leafhopper, *Erythroneura ziczac* Walsh, as a vector. However, the lack of reports of GRBaV spread in other regions of North America besides California, where *E. ziczac* is well-established together with the propensity of *E. ziczac* to feed on mesophyll, and the phloem limited nature of monopartite geminiviruses, suggests the more likely possibility for other insect species to transmit GRBaV under field conditions. *E. elegantula* Osborn and

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*The *e*-Xtra logo stands for "electronic extra" and indicates that one supplementary figure and one supplementary table are published online.

http://dx.doi.org/10.1094/PHYTO-03-16-0125-FI
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E. variabilis Beamer, two other leafhopper species in the same genus as *E. ziczac*, are widespread in California vineyards, but their ability to transmit GRBaV has not been evaluated.

The primary objective of this study was to evaluate the ability of the three leafhopper species, *E. elegantula*, *E. variabilis*, *E. ziczac*, and other hemipteran insects that are commonly found in California vineyards to transmit GRBaV under greenhouse conditions.

MATERIALS AND METHODS

Evaluation of potential hemipteran vectors. To evaluate potential vectors of GRBaV, a phylogenetic analysis was conducted on the amino acid sequence of the coat protein (CP) of 23 geminiviruses from the seven genera of the family *Geminiviridae* (Supplementary Table S1) to determine the relationship of GRBaV to other geminiviruses. Sequence data were aligned using MEGA6 (Tamura et al. 2013) and the phylogenetic tree was constructed using the neighbor-joining method.

Plant material and virus isolates. Potted plants of cultivar Cabernet Sauvignon (CS) grafted on rootstock Freedom (courtesy Casa Cristal Nursery, Inc., Delano, CA) were used for insect colony establishment and as recipient plants in transmission assays. These plants were maintained in a greenhouse under a 16 h photoperiod at 26°C. Virus-infected source material used for virus acquisition were propagated from grapevines infected with the isolate CF214-1 (NC022002.1) (Al Rwahnih et al. 2013). This isolate represents clade II, one of two common GRBaV variants (Al Rwahnih et al. 2015b; Krenz et al. 2014). All GRBaV-free plants and insect colonies designated for transmission assays were maintained in insect-proof cages (MegaView Science, Taipei, Taiwan) in a greenhouse separate from that used to maintain virus-infected source plants.

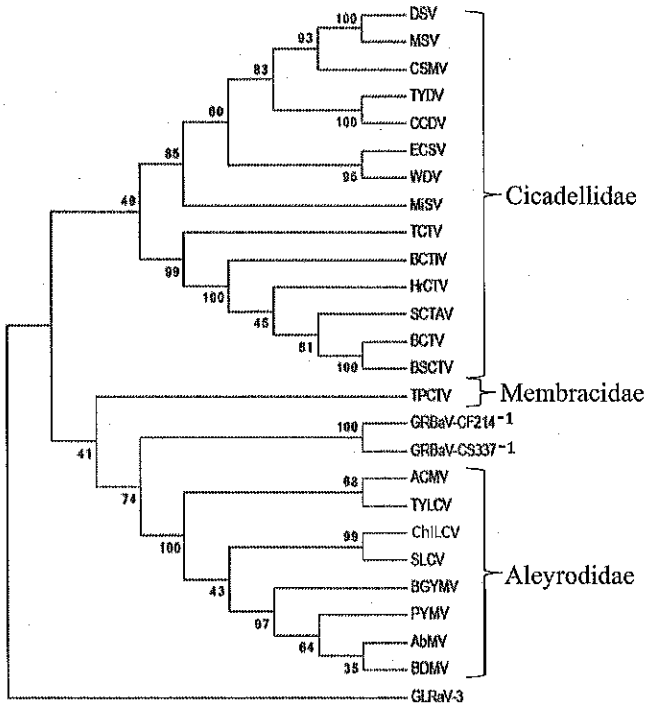

Fig. 1. Neighbor-joining tree indicating the relationship of amino acid sequence of coat protein (CP) of geminiviruses with Grapevine red blotch-associated virus (GRBaV). Isolates GRBaV-CF214-1 and GRBaV-CS337-1 represent two clades of GRBaV. CP of *Grapevine leafroll-associated virus 3* (GLRaV-3) was used as an outlier. Other viruses in the tree are as follows: *Abutilon mosaic virus* (AbMV), *African cassava mosaic virus* (ACMV), *Bean dwarf mosaic virus* (BDMV), *Bean golden mosaic virus* (BGYMV), *Beet curly top Iran virus* (BCTIV), *Beet curly top virus* (BCTV), *Beet severe curly top virus* (BSCTV), *Chickpea chlorotic dwarf virus* (CpCDV), *Chili leaf curl virus* (ChiLCuV), *Chloris striate mosaic virus* (CSMV), *Digitaria streak virus* (DSV), *Eragrostris curvula streak virus* (ECSV), *Horseradish curly top virus* (HrCTV), *Maize streak virus* (MSV), *Micanthus streak virus* (MiSV), *Potato yellow mosaic virus* (PYMV), *Spinach curly top Arizona virus* (SCTAV), *Squash leaf curl virus* (SLCV), *Tobacco yellow dwarf virus* (TYDV), *Tomato pseudo-curly top virus* (TPCTV), *Tomato yellow leaf curl virus* (TYLCV), *Turnip curly top virus* (TCTV), and *Wheat dwarf virus* (WDV).

Nucleic acid extraction and virus detection; standard PCR, qPCR, and digital PCR (dPCR) assays. Total DNA was extracted from insects and plants using the DNeasy Blood & Tissue Kit and DNeasy Plant Mini Kit (Qiagen Inc., Valencia, CA), respectively. For cohorts of recipient plants being extracted together, cross-sections of petioles were taken from each of the 15 leaves until approximately 100 mg of tissue was obtained.

Standard PCR assays to verify GRBaV in source plants and final tests on recipient plants were performed in 25-µl reactions using primers GVGF1 and GVGR1 as described previously (Al Rwahnih et al. 2013). The amplicons were visualized by running 2 µl of the PCR product on a 1% agarose gel. Amplicons of the expected size (556 bp) were purified using the QIAquick PCR Purification Kit (Qiagen Inc.) and sequenced using primers GVGF1 and GVGR1 at the DNA sequencing facility, University of California, Davis. The identity of the sequenced products was determined by BLAST searches against the GenBank database.

Detection of GRBaV by qPCR was performed in 20 µl reactions comprised of 1 µl of DNA extract, 0.15 µM of each of the primers GVGF1 and GVGR1, 2% polyvinyl pyrollidone-40, 0.3 µl of Stratagene Reference Dye (1:500), 10 µl of SoFast EvaGreen Supermix (Bio-Rad Inc., Hercules, CA) with the remaining volume made up with nuclease free water. Thermal cycling conditions were as follows: initial denaturation at 95°C for 2 min; 35 cycles of 95°C for 30 s, 62°C for 1 min, and 72°C for 1.5 min; on a QuantStudio 6 Flex Real-Time PCR System (ThermoFisher Scientific Inc., Waltham, MA). Following amplification, high-resolution melting analysis was performed to confirm identity of the product amplified. Conditions for melting point analysis were 95°C for 1 min, 55°C for 30 s, and 95°C for 30 s with continuous measurement of fluorescence. Samples were scored positive if a measureable cycle threshold (Ct) value was generated and the amplicon had a melting temperature comparable to that produced by a cloned GRBaV fragment (GVGF1/GVGR1 product) and a positive control source plant. The same procedure was used to detect GRBaV in insect specimens.

The dPCR assays were performed on plant cohorts at monthly intervals using TaqMan assays on a QuantStudio 3D Digital PCR System (www.thermofisher.com/us/en/home.html). The assays were performed using 6 µl of DNA template and 9.5 µl of reaction mixture (76.3% QuantStudio 3D Master Mix, 7.6% TaqMan Assay, and remaining volume made up with DEPC-treated water). The TaqMan probe used in the assay is 5′-FAM -AGA ACT GAA GTT GAA GAA TT-3′ and primers 5′-AAG AAT TGC ATT GAC TGA ACC TGA-3′ (forward) and 5′-CCT AGC TCC AGG TCC AGA CG-3′ (reverse). The reaction mix was loaded on a chip using QuantStudio 3D Digital PCR Chip Loader and run on a ProFlex Base PCR System. Thermal cycling conditions consisted of an initial denaturation at 95°C for 2 min; followed by 35 cycles of denaturation at 95°C for 30 s, annealing at 65°C for 30 s, and extension at 72°C for 30 s, with a final extension step at 72°C for 5 min. End point fluorescence data were collected and analyzed using QuantStudio 3D AnalysisSuite Cloud Software (https://www.thermofisher.com/us/en/home/life-science/pcr/digital-pcr/quantstudio-3d-digital-pcr-system/quantstudio-3d-software.html). The FAM calculated threshold for establishing positive fluorescence reactions was set at 3,000 relative fluorescence units based on a positive control, a cloned fragment of GRBaV genome, at a concentration of 10 copies/µl.

Insect collection, colony establishment, and test for virus in insects. Vineyard plots where GRBaV-infected grapevines were present and disease incidence was observed to increase over time, as well as vineyards where no noticeable increase in GRBD incidence was observed, were sampled over a 2-year period from March 2014 to November 2015. Yellow sticky traps were deployed and sampled weekly throughout the study period to determine what insect species

were present at each field site. Sweep-netting was also conducted biweekly to collect live individuals for colony establishment.

Live insect specimens collected from vineyards where GRBD was not observed were reared on grapevines, tested to be free from GRBaV in a greenhouse at 26°C under a 16 h photoperiod until used in transmission bioassays. Following failed attempts to rear *S. festinus* on Cabernet Sauvignon grapevines, *S. festinus* insects were collected from alfalfa fields on the University of California (UC)-Davis Agronomy Farm using sweep nets and maintained on alfalfa grown from seeds (AMERISTAND 901TS) in the greenhouse to establish a permanent colony of *S. festinus*. Subsets of 20 live individuals for each insect species were exposed to GRBaV-infected grapevines for 48 h and subsequently tested for the presence of the virus.

Collection of girdled grapevine shoots in vineyards. Grapevines in vineyards with apparent spread exhibited feeding damage in the form of girdled petioles and stems. A set of 10 girdled regions were sampled from one vineyard that had recent feeding damage and where the girdled region had not yet become necrotic, and were subsequently evaluated for the presence of GRBaV by dPCR.

Virus transmission assays. For all transmission assays, insects were exposed to GRBaV-infected source plants for an acquisition access period of 48 h and 15 individuals of each species were subsequently transferred to individual healthy recipient CS plants for an inoculation access period of 48 h. For each species, five individuals were moved directly from proven healthy plants to healthy recipient plants to serve as controls. After 48 h of feeding on recipient plants, insects were collected and preserved in 85% ethanol at room temperature to serve as vouchers.

Transmission efficiency of the insects was assessed by extracting DNA from the recipient plants and testing for GRBaV using dPCR at 2 weeks, and then at monthly intervals for up to 5 months postinoculation. To test for the presence of GRBaV in the recipient plants, single new-growth/terminal leaves of all plants were collected and pooled into a composite sample for analysis. DNA was extracted and tested for the presence of GRBaV using dPCR. When a composite sample tested positive for GRBaV, all the plants within that composite were tested individually at 5 months postinoculation using standard PCR to determine the number of plants infected by GRBaV. Amplicons from individual recipient plants testing positive for GRBaV were sequenced at the UC-Davis DNA sequencing facility to verify the nucleotide identity of the GRBaV isolates in the recipient plants.

RESULTS

Evaluation of potential vectors. Based on the neighbor-joining tree produced using CP amino acid sequences of geminiviruses representing all seven genera of the family *Geminiviridae*, GRBaV

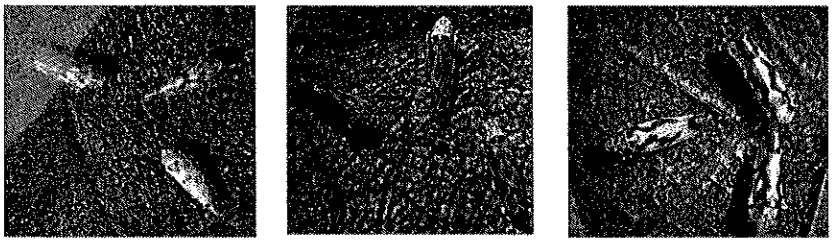

Fig. 2. *Erythroneura* leafhoppers evaluated for their ability to transmit Grapevine red-blotch associated virus: *Erythroneura elegantula* (left), *E. variabilis* (middle), and *E. ziczac* (right).

TABLE 1. Status of grapevine red blotch-associated virus (GRBaV) spread in vineyards in California counties and occurrence of candidate insect vectors

Site	County	Spread of GRBaV in vineyard	*Spissistilus festinus*	*Erythroneura elegantula*	*E. variabilis*	*E. ziczac*
1	Amador	+	+	+	+	+
2	Mendocino	+	+	+	+	+
3	Napa	+	+	+	+	–
4	Napa	–	–	+	+	–
5	Napa	–	–	+	–	–
6	Napa	+	+	+	+	–
7	Sacramento	–	–	+	+	+

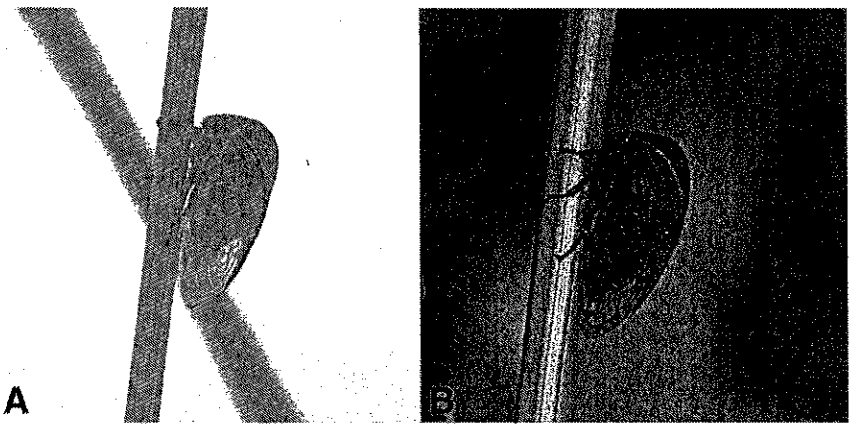

Fig. 3. *Spissistilus festinus* adult **A,** male and **B,** female feeding on alfalfa plants.

was most closely related to *Tomato pseudo-curly top virus* (TPCTV) (Fig. 1). The vector of TPCTV is the nightshade treehopper (*Micrutalis malleifera*, family Membracidae). The phylogenetic tree presented in Figure 1 shows four clades, with the top clade containing geminiviruses transmitted by leafhoppers (Cicadellidae), the two middle clades containing TPCTV, vectored by a membracid, and GRBaV. The last clade contains geminiviruses transmitted by whiteflies and have bipartite genomes with the exception of *Tomato yellow leaf curl virus*, which has a monopartite genome. These data show geminiviruses are transmitted by hemipteran insects that belong to either the Auchenorrhyncha (leafhoppers and treehoppers) or Sternorrhyncha (whiteflies) and GRBaV belongs to a clade of geminiviruses that is closest to a clade transmitted by Auchenorrhyncha.

Insect collection, colony establishment, and virus detection after feeding. The three *Erythroneura* leafhoppers of interest here (Fig. 2) were collected from vineyards and reared on healthy Cabernet Sauvignon vines in the greenhouse. Both *E. elegantula* and *E. variabilis* were common in most of the vineyard sites that were sampled over a 2-year period, while *E. ziczac* was found in three of these vineyards (Table 1). However, a membracid, *Spissistilus festinus* (Say) (Fig. 3) was found in all vineyards where virus spread was suspected, and absent from vineyards where there was no evidence of spread. Live specimens of *S. festinus* were collected from vineyards with no incidence of GRBaV and were reared on healthy grapevines for colony establishment, but *S. festinus* was unable to reproduce on them.

When testing for the presence of GRBaV in insects after feeding on GRBaV-infected plants, the three leafhopper species and *S. festinus* all tested positive, with *S. festinus* providing the lowest Ct values (higher virus concentration) as well as highest percentage (75%) of positive individuals (Table 2). None of the species exposed to healthy grapevines tested positive for GRBaV. All three *Erythroneura* species that tested positive for GRBaV but had much higher Ct values (lower viral titer) and a lower percentage of positive individuals (Table 2).

Lateral shoots of grapevines that had girdling injury caused by *S. festinus* (Fig. 4) at vineyards with suspected spread of GRBaV also tested positive using dPCR. Out of the 10 shoot samples tested, two had weak, but detectable levels of GRBaV at the injured site (Fig. 5).

Transmission assays. All composite samples of recipient plants from transmission assays for the three *Erythroneura* species did not test positive for GRBaV throughout the study period using dPCR (Table 3). Also, all recipient plants exposed to *Erythroneura* leafhoppers tested

TABLE 2. Number of insects testing positive for the presence of Grapevine red blotch-associated virus (GRBaV) in qPCR tests after feeding on GRBaV-infected grapevine plants

Species	Number of positive/number tested	Mean cycle threshold (Ct) ± SE	Mean virus quantity/µl ± SE	Mean melting temperature (°C) ± SE
Erythroneura elegnatula	2/20	28.9 ± 0.81	1.79E + 01	83.3 ± 0.0
E. variabilis	1/20	32.1 ± 0.0	1.00E + 01	83.3 ± 0.0
E. ziczac	1/20	26.5 ± 0.0	1.55E + 01	83.3 ± 0.0
Spissistilus festinus	15/20	16.1 ± 0.34	1.86E + 05	83.3 ± 0.02
GRBaV-infected grapevine[a]	5/5	14.1 ± 0.63	1.34E + 06	83.3 ± 0.03
Healthy grapevine[a]	0/5	No Ct	N/A	52.4 ± 2.4
Buffer control[a]	0/5	No Ct	N/A	62.1 ± 5.4

[a] Plant and buffer controls used in qPCR tests.

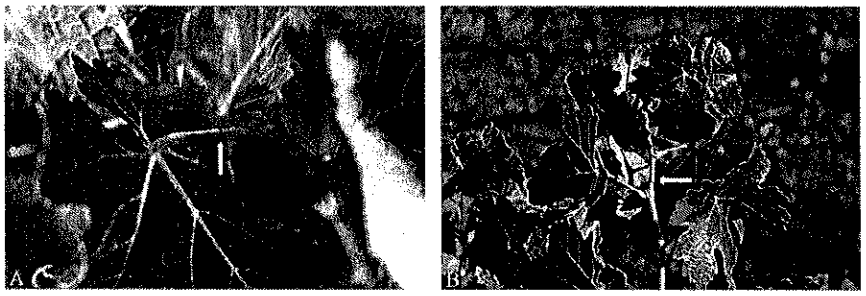

Fig. 4. Grapevine **A,** leaf petiole and **B,** shoot girdled due to feeding injury by *Spissistilus festinus* in vineyards.

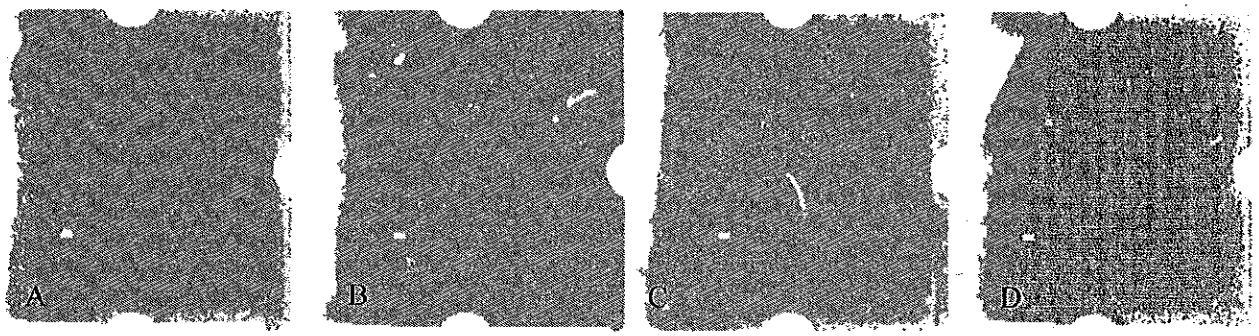

Fig. 5. Scans of chips used for digital PCR assay using QuantStudio 3D digital PCR system for the detection of Grapevine red blotch-associated virus (GRBaV) in the girdled regions of grapevines. **A and B,** Nucleic acid extracts from girdled shoot samples testing positive for GRBaV; **C,** nucleic acid extract from grapevines infected with GRBaV diluted to 0.001% of original extract; and **D,** nucleic acid extract from healthy grapevine control. Dots are reactions positive for GRBaV.

negative by standard PCR at 6 months (data not shown). Plant cohorts exposed to *S. festinus* that had been feeding on virus-infected source material began testing positive by dPCR for GRBaV at 3 months postinoculation (Table 3, Fig. 6). The percentage of positive reactions in this plant cohort increased at both 4 and 5 months postinoculation (Table 3, Fig. 6). The virus also was detectable using standard PCR at 5 months postinoculation (Fig. 7). Of the 15 receiving plants exposed to *S. festinus*, three plants were found infected with GRBaV at 5 months postinoculation, and two of these three recipient plants also exhibited mild red blotch leaf symptoms (Fig. 8). The negative control samples for *S. festinus* tested negative throughout the study period by dPCR, and all control plants tested negative using standard PCR after 5 months postinoculation (Fig. 6). The amplicons obtained from the three recipient plants matched the nucleotide sequence of the amplicon obtained from the corresponding source plant (Supplementary Fig. S1).

TABLE 3. Digital PCR results for monthly testing of recipient plant cohorts for the presence of Grapevine red blotch-associated virus

Species	Percentage of positive wells in dPCR assay		
	3 months	4 months	5 months
Erythroneura ziczac	0.0%	0.0%	0.0%
E. elegantula	0.0%	0.0%	0.0%
E. variabilis	0.0%	0.0%	0.0%
Spissistilus festinus	0.1%[a]	0.3%[b]	1.6%[c]

[a] 21/18,874 positive.
[b] 47/16,216 positive.
[c] 248/15,768 positive.

DISCUSSION

GRBaV is an emerging problem to grape production in North America (Sudarshana et al. 2015). While its exact taxonomic status has not been determined, it is most likely to be included in the family *Geminiviridae* based on the size and genome organization. Year-to-year increase in new GRBaV infections has been noticed in vineyards affected by GRBD in California (M. R. Sudarshana, *unpublished data*) indicating the prevalence of a vector that can transmit GRBaV in vineyards. The Virginia creeper leafhopper (*E. ziczac*) was reported to be a vector in greenhouse conditions (Poojari et al. 2013). However, *E. ziczac* is not widely distributed in California, and was not always found in vineyards where GRBD appeared to be spreading (Table 1). As a result, we revisited the possible transmission of GRBaV by this species and two more common *Erythroneura* leafhoppers frequently found in California vineyards, as well as by other hemipteran insects present in the vineyards where GRBaV spread was suspected.

Specificity between the CP of plant viruses and their insect vectors reflects an evolutionary history between the vector and the virus such as seen with the *Grapevine leafroll-associated virus* complex and the Coccoidea (Tsai et al. 2010). It seems likely that this would also be the case for geminiviruses, including GRBaV, and their vectors. We first examined the phylogenetic relationship of the putative CP of GRBaV with the CP of 23 geminiviruses, representing all seven genera of the family *Geminiviridae* (Fig. 1). The CP was selected because this is the protein encoded by the virus that determines vector specificity (Briddon et al. 1990). It is likely this protein interacts with a receptor protein(s) lining the insect gut

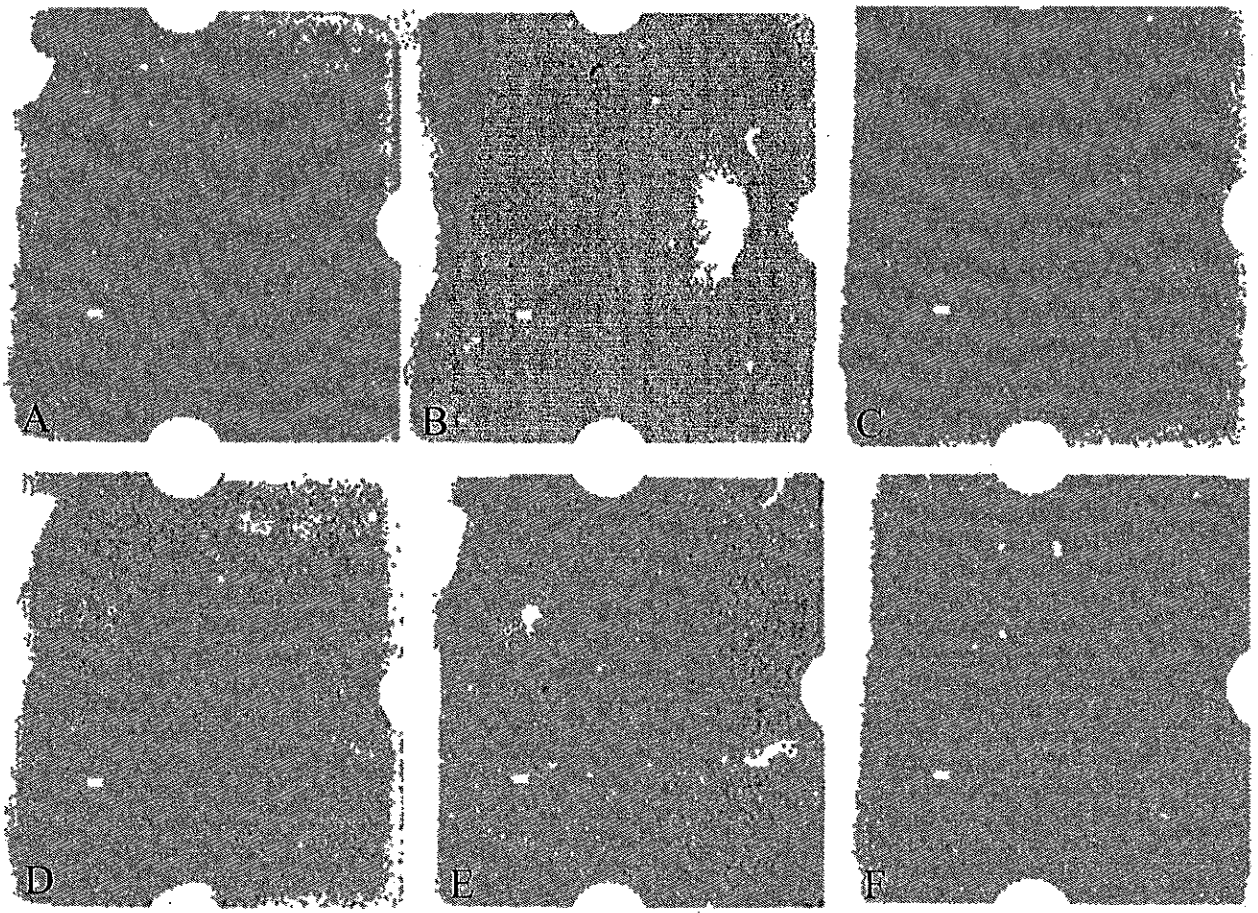

Fig. 6. Digital PCR results for cohorts of recipient plants exposed to *Spissistilus festinus*. **A,** Baseline test pre-inoculation; **B,** 3 month test; **C,** 4 month test; **D,** 5 month test; **E,** positive control diluted to 0.001% original concentration; and **F,** water control.

and salivary gland, and thus determines the specificity of insect vector–viral interactions. The close relationship of GRBaV to TPCTV based on CP amino acid sequence is consistent with findings by Varsani et al. (2014), which illustrated that GRBaV is closely related to TPCTV and belonged to the clade of geminiviruses that are vectored by auchenorrhychan insects. Based on this, it may be expected that GRBaV would be transmitted by an insect species within this suborder.

For the detection of GRBaV in receiving plants, new growth was selected because (i) the exact feeding sites could not be observed, (ii) removal of new growth relative to inoculation date would ensure inoculum was not removed before GRBaV became systemic, and (iii) the potential for contamination due to residual virions in fecal matter on the plant surface could be avoided. Adults of *S. festinus* were allowed to feed freely on recipient plants rather than being restricted to individual leaves. This is because the feeding behavior that causes girdling is a mechanism to block photosynthates and create a nutrient sink (Andersen et al. 2002) that could cause the virus to be isolated on the inoculated leaf, thus preventing it from infecting the plant systemically.

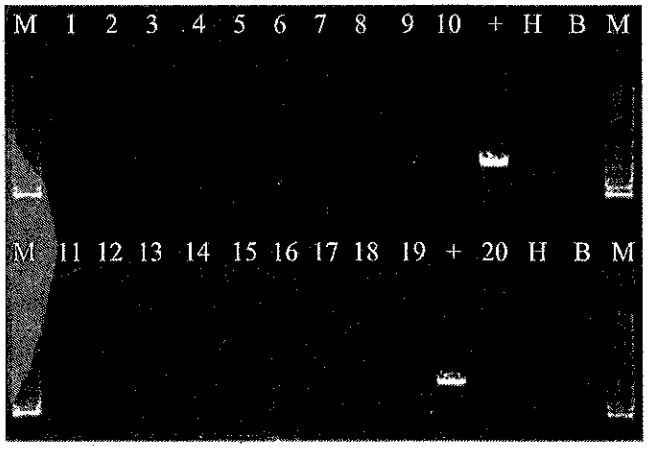

Fig. 7. Agarose gel image for recipient plants exposed to *Spissistilus festinus* at 5 months postinoculation; Lane M, 1-kb+ ladder; lanes 1 to 15, transmission assays from virus-infected plants; lanes 16 to 20, negative control transmission assays from healthy plants; lane +, positive control from virus-infected source plant; lane H, healthy control; and lane B, buffer control.

In 2013, it was reported that GRBaV was detectable in all recipient plants at 4 months postinoculation as well as in individuals of *E. ziczac* tested for the presence of GRBaV by standard PCR (Poojari et al. 2013). Five percent of *E. ziczac* in our study tested positive for GRBaV as well; however, our results did not confirm the successful transmission of GRBaV by *E. ziczac*. Regardless of percentage, detection of GRBaV in *E. ziczac* does not provide any evidence that it is a vector, merely that it was feeding on an infected plant and residual virions passing through the gut are likely what is being detected (Lett et al. 2002). Poojari et al. (2013) stated that leaves where *E. ziczac* had fed, as well as newly emerging leaves tested positive for GRBaV. Presence of GRBaV at the feeding site as reported by Poojari et al. (2013) could be explained by residual viral particles being excreted by *E. ziczac* onto the leaf surface, a phenomenon documented in the whitefly *Bemisia tabaci* and another geminivirus, *Squash leaf curl virus* by Rosell et al. (1999). We also found no evidence of GRBaV transmission by *E. elegantula* and *E. variabilis* which are more widespread in California vineyards, although very low numbers of both species tested positive for the virus.

While transmission of GRBaV under greenhouse conditions with the *Erythroneura* leafhoppers failed, we confirmed successful transmission of GRBaV by the membracid *S. festinus*. It is interesting to



Fig. 8. A, Symptomatic leaves from recipient plant testing positive for Grapevine red blotch-associated virus after exposure to viruliferous *Spissistilus festinus* and **B,** healthy leaf from negative control transmission assay.

note the close phylogenetic relationship of GRBa V with TPCTV, and the transmission of both geminiviruses by membracids. *S. festinus* is native to the southeastern United States, and a common though usually minor pest of alfalfa, soybean, peanut, and various vegetable crops (Andersen et al. 2002). Its range extends throughout the southern United States to California, but can also be found in Northeastern United States extending as far north as Canada. The greater incidence of *S. festinus* in California (Wistrom et al. 2010), relative to other major grape growing regions in North America, is con-sistent with the lack of GRBD spread in regions such as New York (M. Fuchs, Cornell University, NY, *personal communication*) and Washington (D. Walsh, Washington State University, WA, *personal communication*) states. The fact that *S. festinus* is native to North America and not reported from other countries where wine grapes are produced and GRBD incidence is extremely low, also supports that it is the most likely vector of GRBaV in California. Despite successful transmission of GRBa V under greenhouse conditions by *S. festinus* and its absence from regions where no spread is documented, it is not yet known if *S. festinus* is the only species capable of transmitting GRBa V, whether in the greenhouse or in a natural setting. Other species within the genus *Spissistilus* as well as other closely related taxa of treehoppers that feed on grapes may still be competent vectors as well and should be the focus of future research on the epidemiology of GRBa V. While not considered a serious pest of wine grapes, *S. festinus* is known to cause feeding damage on leaf petioles and lateral shoots that results in a characteristic girdle (Fig. 4), blocking photosynthates, and ultimately turning the affected leaf red (Smith 2013). The detection of low levels of GRBa V by dPCR in girdled regions from vineyards exhibiting GRBD supports the hypothesis that *S. festinus* may be responsible for spread of the virus under field conditions. That only low levels of virus was detected in girdled areas of the petiole is not surprising because once virus is released into the phloem, virus particles that reach the sieve tubes would likely be quickly translocated through the phloem network, and the damaged tissue associated with the girdling might fail to support virus replication.

The ability of dPCR technology to detect extremely low amounts of virus greatly assisted in demonstrating GRBaV transmission by *S. festinus*. While this technology is just beginning to gain entry in plant virus diagnostics, it is becoming increasingly popular in the detection of human viral pathogens (Sedlak et al. 2014; Strain et al. 2013). dPCR has also been found to be more sensitive than qPCR in the detection of *Human immunodeficiency virus* and it can provide absolute quantitation without a need for standards (Strain et al. 2013).

Based on our results, *S. festinus* is a vector of GRBaV under strict laboratory conditions with some evidence to support its transmission in the field. Conversely, under the same conditions, *E. elegantula*, *E. variabilis*, and *E. ziczac* failed to successfully transmit GRBaV and could not be confirmed as vectors of GRBaV. These findings represent an important step in the understanding of the epidemiology of red blotch disease, and serve as a baseline for approaching management of the pathogen in the environment. Future studies to provide direct evidence for transmission of GRBaV by *S. festinus* under field conditions and understand the biology of *S. festinus* behavior in vineyards are needed to develop successful GRBD management programs.

ACKNOWLEDGMENTS

This work was supported by USDA-ARS CRIS 5306-220000-014-00D. We thank D. Fravel, National Program Leader–Plant Health, for providing assistance from ARS Project 0500-00082-001-00D, National Plant Disease Recovery System to M. R. Sudarshana. Additional funding for this research was provided by grants from California Grapevine Rootstock Improvement Commission, and the California Tree Fruit and Nut Crops and Grapevine Industry Advisory Board to M. R. Sudarshana and F. G. Zalom. We thank J. Jackson, Casa Cristal Nursery, Inc., Delano, CA, for providing potted Cabernet Sauvignon grapevines for the transmission studies; M. Castillo and M. Bollinger for assistance in the field and laboratory; and our collaborators L. Wunderlich, UC Cooperative Extension Central Sierra Region, M. Anderson, UC Davis Department of Viticulture and Enology, and R. Smith, UC Cooperative Extension Sonoma County, for help in identifying vineyards for the study. We appreciate helpful suggestions and comments on the manuscript made by D. Kluepfel, Research Leader, USDA-ARS, Davis, CA. Mention of a trademark, proprietary product, or vendor does not constitute guarantee or warranty of the product by the USDA, and does not imply its approval to the exclusion of other products and vendors that might also be suitable. This publication was also supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

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INVESTIGATING THE SPREAD AND EFFECT OF *GRAPEVINE RED BLOTCH VIRUS* IN CALIFORNIA-GROWN ZINFANDEL

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ABSTRACT

Grapevine red blotch virus (GRBV) is a major concern for California winegrape growers since its discovery in 2012. Negative impacts on juice have been reported, though inconsistent. A treehopper, *Spissistilus festinus*, transmitted GRBaV in strict laboratory studies, but field evidence of transmission is lacking. Many GRBaV-infected vines originate from the nursery and are being removed. Our goal is to study GRBaV spread and its effects on juice quality in a dry-farmed own-rooted Zinfandel (*Vitis vinifera*) vineyard in Amador County. The vineyard was field grafted from a block that, in turn, was grafted from a 1923 planting. Between 2015 and 2016, 1224 vines from three blocks were visually mapped for symptoms, and petioles were collected from a subset of vines for confirmation of GRBV infection by qPCR. Overall infection in 2015 was rated 24.7%; and increases observed visually in 2016 were 18.2%, 19.9%, and 7.1% for blocks 1, 2 and 3, respectively. Girdled vines were observed in fall and *S. festinus* were collected. Prior to harvest, thirty berries from ten healthy and ten GRBV-infected vines were collected. Berry weight, pH and total soluble solids (TSS) of juice were measured. Infected berries were heavier and mean pH slightly lower in 2015. Mean TSS was 7.75 and 4.34 °Brix lower in berry juice from infected vines compared to healthy in 2015 and 2016, respectively.
Key words: Grapevine red blotch virus, Zinfandel

INVESTIGACIÓN DE LA PROPAGACIÓN Y EFECTO DE LA '*GRAPEVINE RED BLOTCH VIRUS*' EN CALIFORNIA-CULTIVADO ZINFANDEL

RESUMEN

Los productores de vino de California tienen una preocupación cada vez mayor por el virus denominado *Grapevine red blotch virus* (GRBV), descubierto en 2012. Se han detectado efectos negativos, aunque inconsistentes, en el zumo. Un insecto, *Spissistilus festinus*, transmitió GRBaV en estrictos estudios de laboratorio, pero falta evidencia de la transmisión en el campo. Muchas de las viñas infectadas con GRBaV se originaron en viveros y actualmente están siendo eliminadas. El objetivo de este trabajo es estudiar la propagación de GRBV y sus efectos sobre la calidad del zumo en un viñedo sin riego sobre raíz propia Zinfandel (*Vitis vinifera*) en el condado de Amador. El viñedo fue injertado en una parcela que, a su vez, fue injertado de una plantación de 1923. Entre 2015 y 2016, 1224 parcelas fueron visualmente cartografiados para los síntomas, y se recogieron los pecíolos de un subconjunto de vides para la confirmación por qPCR. En 2015, la infección total fue de 24,7%; los incrementos observados visualmente en 2016 fueron 18,2%, 19,9% y 7,1% para las parcelas 1, 2 y 3, respectivamente. En el otoño, se observaron viñedos dañados y se recopiló *S. festinus*. Antes de la cosecha, se recogieron treinta bayas de diez viñas sanas y diez infectadas con GRBV, confirmadas por qPCR. Se midieron el peso de las bayas, el pH y los sólidos solubles totales (TSS) del jugo. Las bayas infectadas fueron más ligeras y el pH

medio ligeramente inferior en 2015. El TSS medio fue de 7,75 y 4,34 °Brix inferior en el jugo de bayas de viñas infectadas en comparación con las sanas en 2015 y 2016, respectivamente.
Palabras clave: Grapevine red blotch virus ("Enfermedad de la mancha roja en vid"), Zinfandel

INTRODUCTION

Grapevine red blotch virus (GRBV) is a recently identified virus species affecting the health and productivity of many California vineyards. GRBV was discovered after grapevines with grapevine leafroll disease (GLD) like symptoms but testing negative for the GLD virus led researchers to perform deep sequencing genetic analysis, revealing the red blotch ssDNA virus (Al Rwahnih et al., 2013). GRBV symptoms first appear approximately mid-summer, starting on the basal leaves and moving up the shoot. In red-fruited cultivars, red blotches form on the leaf margin or within the leaf blade and primary and secondary veins often turn red. In white fruit cultivars, leaf symptoms appear as pale green to pale yellow patches. The effect on fruit varies with environment and year; there is typically a reduction in juice total soluble solids (Brix) and a reduction in fruit color (anthocyanins). Effect on juice pH and titratable acidity also varies (Smith et al., 2014; Sudarshana et al., 2015; Zalom et al., 2016).

GRBV has been found in all major California and U.S. wine growing regions (Krenz et al., 2014), and appears to have been widely spread through infected nursery material used for propagation. Commercial testing using a PCR test is available from several U.S. laboratories and University of California outreach efforts have focused on educating growers to test nursery material before installing new plantings. In 2016, GRBV was added to the voluntary California Department of Food and Agriculture's regulation for registration and certification of grapevine planting material (CDFA, 2016). It is anticipated that the new regulation and education of the industry will greatly reduce GRBV impacts; however, there is concern over recent evidence of vector spread of GRBV.

An observed increase of 4.2 to 6.2% annually in GRBV infections at a UC research vineyard from 2011 to 2014 provided the first evidence of spread by a vector (Sudarshana, M.R. et al., unpublished). More recently, GRBV infected vines increased from 5.7% (2014) to 59.8% (2016) in an Oregon vineyard (Dalton et al., 2017). Suspect vectors were collected from vineyards exhibiting GRBV spread, and laboratory testing showed GRBV can be transmitted by a membracid, the three-cornered alfalfa hopper, *Spissistilus festinus* Say (Bahder et al., 2016); however, field transmission has yet to be shown. *S. festinus* is considered a minor pest since its feeding results in mild girdling of shoots and petioles. Little is known about its biology in vineyards.

Although much has been learned in the short time since GRBV's discovery in 2012, many questions remain about its spread by vector(s), its effect on winegrape composition in different varieties and growing environments, and economical disease management. Our goal is to study GRBV spread and its effects on juice quality in a dry-farmed own-rooted Zinfandel (*Vitis vinifera*) vineyard in Amador County.

MATERIALS AND METHODS

Site identification. In August 2015, prior to the announcement that *S. festinus* transmits GRBV, an Amador County grower sent *V. vinifera* cv. Zinfandel leaf samples exhibiting symptoms including red patches and marginal and interveinal burning in to our office and were tested positive for GRBV. Upon visiting the site, we observed a pattern of GRBV symptoms across the vineyard that suggested spread. None of the vines were planted using nursery material. Three of the blocks had been planted as "own root" in 1998 from canes grown in adjacent blocks that, in turn, were planted "own root" in 1987 using canes from a 1923 vineyard planting located approximately 0.4 km N. Vines are head-trained and spaced 2.74 x 2.74m. The entire 1.8 ha vineyard is dry-farmed (without irrigation).

GRBV mapping. On 24 August 2015 and 31 August 2016, a total of 1224 vines from three blocks (1998 planting) were visually inspected for GRBV symptoms and mapped. Volunteers were trained immediately prior to the visual rating to distinguish GRBV symptoms from other diseases (i.e. Esca). A subset of 89 (2015) and 85 (2016) of the rated vines, both healthy and GRBV +, were confirmed with qPCR for GRBV presence or absence. Tested vines included those used for berry sampling; these vines were also tested for *Grapevine leafroll associated virus* (GLRaV) -1, -3, and -4, using qRT-pCR to detect GLRaV strains -1 and -3, and using conventional RT-PCR to detect GLRaV-4 strains. Different primers were used to detect strains currently included within GLRaV- 4, (GLRaV strains -4, -5, and -9). For GRBV and GLRaV-1, -3, and -4 testing, six leaves with petioles were collected from each vine, placed in a labelled plastic bag and kept cool while transported to the lab. Petioles were removed from the leaves and processed and nucleic acid was extracted as by Al Rwahnih et al., 2013. qPCR and qRT-PCR assays were conducted for GRBV and GLRaV-1 and -3 using primers (Sudarshana et al., unpublished). For GLRaV -4 virus strains -4, -5, and -9, primers and protocols were as described by Osman et al., (2008).

Berry sampling. Commercial harvest dates were 1-Sept 2015 and 6-Sept 2016. Prior to commercial harvest, on 31 Aug 2015 and 5 Sept. 2016, 30 berries were collected from each of ten healthy and ten GRBV (+) vines. Avoiding dehydrated fruit, berries were randomly collected from the top, middle and bottom of bunches around the entire vine, placed in a labelled plastic bag and kept cool until transport to the lab that day. Berries were recounted and weighed before manually crushing and straining the juice from the pulp. Juice total soluble solids and pH were measured in the laboratory using a calibrated refractometer (Atago Handheld Master Alpha refractometer) and handheld pH meter (Fisher Scientific Acumet AP110 pH meter).

Analysis. Maps of the vineyard blocks illustrating each vine rated from blocks 1, 2 and 3 as GRBV (+) or GRBV (-) in 2015 and in 2016 were created and a single factor ANOVA test was performed on all berry and juice data using Microsoft Excel.

RESULTS AND DISCUSSION

GRBV spread. Overall GRBV infection in 2015 was rated at 24.7%; and increases observed visually in 2016 were 18.2%, 19.9%, and 7.1% for blocks 1, 2 and 3, respectively (Fig. 1). The difference between visual rating and qPCR results were 13.5% and 8.2% in 2015 and 2016. A few vines were rated "healthy" in 2016 after previously rated "GRBaV +" in 2015 and will be retested in 2017. Girdling of shoots was observed and *S. festinus* was collected on the mapping dates.

Juice. No leafroll was detected in any of the vines sampled for juice. In 2016, one vine visually rated as "healthy" tested positive for GRBV after berry sampling so that data was not included in the analysis. GRBV infected berries were heavier and mean pH slightly lower in 2015 (Fig. 2, 2A and 2B). Mean TSS was 7.75 and 4.34 °Brix lower in berry juice from infected vines compared to healthy in 2015 and 2016, respectively (Fig. 2, 2C). In 2015, mean TSS in healthy vines was unusually high, 29.5°Brix, reflecting seasonal conditions. 2015 was noted as an exceptionally early harvest year and the fourth year of drought in California. Yields were lower and fruit ripening was uneven. Sugars elevated quickly in August and compressed harvests, causing a lack of available labor crews for some growers, which led to delayed harvests and higher TSS in fruit than normal (Wunderlich, 2016). In 2016 mean TSS in healthy vines was 27.1°Brix, closer to typical harvest targets of 25-26°Brix for irrigated Zinfandel grown in this region.

There is little other published work on the effect of GRBV on juice quality conducted on grapevines infected by GRBV only and not coinfected by other grapevine viruses. Smith et al. (2014) reported a significant reduction in °Brix in juice from Chardonnay, Merlot and Cabernet Sauvignon GRBV positive vines as compared to GRBV negative vines. In their study, vines were determined to be GRBV positive or negative by qPCR assay and negative for all grapevine leafroll associated viruses, vitiviruses, and

nepoviruses. They found pH was higher in GRBV positive Chardonnay but not significantly different in Merlot or Cabernet Sauvignon. Smith et al. (2014) also tried significantly reducing crop load to improve °Brix in juice from GRBV positive vines but found no effect.

CONCLUSION

Grapevine red blotch virus disease incidence increased dramatically in the monitored blocks from 2015 to 2016. In late summer, the treehopper *S. festinus* and its girdling was observed at this site, although we have no evidence that *S. festinus* is responsible for the spread of red blotch here. Other, yet unidentified vectors, may also be present and contributing to disease spread. Studies of *S. festinus* biology and management are currently underway and bi-weekly monitoring of *S. festinus* at this site was begun in 2017. Absence of grapevine leafroll disease made visual rating at this site relatively easy, although visual identification alone is not completely reliable. Recently infected vines may not exhibit symptoms, or symptoms may be confused with other diseases or disorders present in the vineyard, so laboratory testing is always recommended to confirm infection by GRBV. It is not clear why some vines were rated positive based on symptoms in 2015 and negative in 2016; more testing of vines needs to be done to confirm our results. The GRBV-infected Zinfandel vines in our dry-farmed study site had visual leaf symptoms of red blotches and necrosis over time; the leaf necrosis appeared worse in 2015 (the end of the four- year drought) than in 2016. At present, there is little to recommend to growers to improve the effects of GRBaV infection on juice quality. The dry-farming practices used appear to increase the severity of symptoms, especially the decrease in TSS; and the environmental effects of weather are likely responsible for the variation in juice results from 2015 (a dryer year) to 2016. A more thorough evaluation of GRBV effects on juice and wine quality in vineyards such as this, where water stress will be greater in low rainfall years, would be beneficial to the industry.

ACKNOWLEDGEMENTS

We thank and acknowledge the grower-cooperator and all student volunteers and staff who helped with this project. This work was supported by USDA-ARS CRIS 5306-220000-014-00D. This publication was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture (USDA) through Grant 14-SCBGP-CA-0006. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA. Additional funding for this research was provided by grants to MRS and FGZ.

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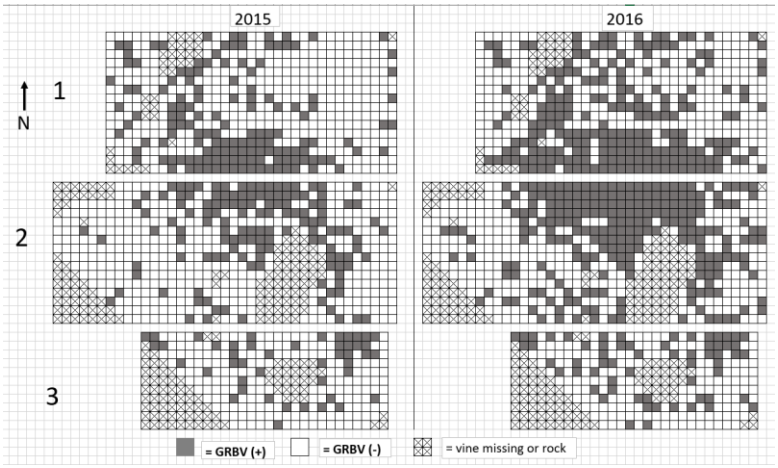


Figure 1. Comparison maps of GRBV (+) and healthy GRBV (-) vines in blocks 1, 2 and 3 of an Amador, California dry-farmed Zinfandel vineyard in 2015 (left) and in 2016 (right). Each square represents a vine; darkened squares represent GRBV (+) vines. Overall infection in 2015 was rated 24.7%; and increases observed visually in 2016 were 18.2%, 19.9%, and 7.1% for blocks 1, 2 and 3, respectively.

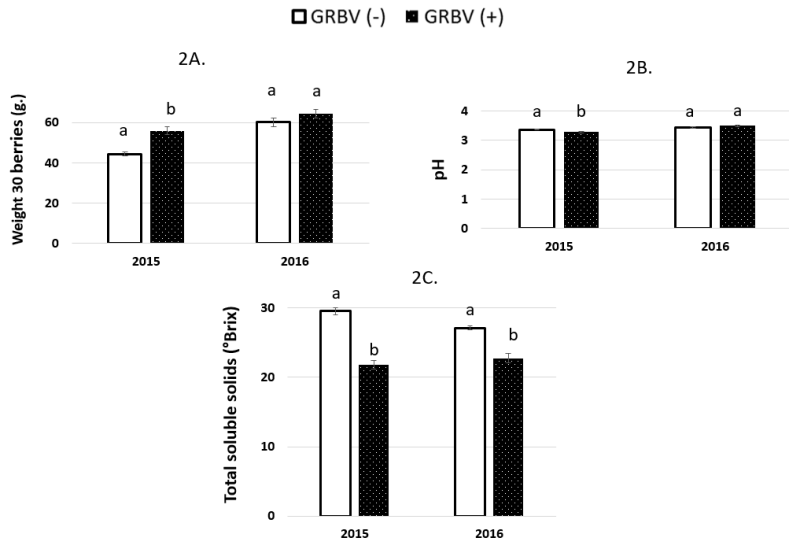


Figure 2. Measured mean berry and juice components in healthy, GRBV(-), and infected, GRBV(+), dry-farmed Zinfandel vines, 2015 and 2016. Berry weight (2A.) was greater for GRBV (+) fruit than for healthy fruit in 2015 ($F_{1, 18} = 23.075$, $P < 0.01$), but was not different in 2016. GRBV (+) juice pH (2B.) was less than healthy juice pH in 2015 ($F_{1, 18} = 14.217$, $P < 0.01$) but was not different in 2016. GRBV (+) juice total soluble solids, °Brix, (2C.) was less than °Brix from healthy in 2015 ($F_{1, 18} = 90.296$, $P < 0.01$) and in 2016 ($F_{1, 17} = 30.507$, $P < 0.01$).

*******Tables 1–17 and Figures 1–20*******

Table 1. Occurrence and MPN values of *Salmonella* spp. in irrigation well water.

	Sampling date	MPN/L	Upper limit*	Lower limit
Well A	3/23/2015	3.4	9.3	1.3
Well B				
Well C	6/1/2015	0.42	3.2	0.0055
Well D	9/21/2015	1.5	4.9	0.43
	9/28/2015	0.46	3.2	0.065
	12/21/2015	3.4	9.3	1.3

Table 2. Occurrence and MPN values of *Listeria monocytogenes* in irrigation well water.

	Sampling date	MPN/L	Upper limit*	Lower limit
Well D	4/20/2015	24	8	72
	10/5/2015	0.46	3.2	0.065

Table 3. Correlation coefficients between environmental factors and the population of *Salmonella enterica* spp. (Se) isolated from irrigation ponds.

Water parameters	Se MPN correlation coefficient	P value
Temperature	0.028619863	0.690586
Conductivity	-0.022679506	0.753205
Dissolved Oxygen percentage	-0.015714816	0.827112
Dissolved Oxygen charge	0.05324747	0.458622
pH	-0.030228895	0.674346
pHmV	0.001772284	0.980357
Oxidation Reduction Potential	-0.024194071	0.737406
Turbidity	0.178114753	**0.012504**
Temperature	0.057310855	0.424949
Rainfall	-0.037480388	0.602762
Temperature-1	0.058021483	0.419226
Rainfall-1	-0.07548581	0.29356
Coliform	0.035183962	0.624473
gE. coli	-0.023775576	0.741608

Table 4. Correlation coefficients between environmental factors and the prevalence and population of *Salmonella enterica* spp. isolated from irrigation wells.

Water parameters	Se MPN correlation coefficient	P value
Temperature	-0.016725192	0.816289
Conductivity	0.027387653	0.703248
Dissolved Oxygen percentage	-0.001896953	0.980024
Dissolved Oxygen charge	-0.02925719	0.684543
pH	-0.058643371	0.414584
pHmV	0.044567272	0.535154
Oxidation Reduction Potential	0.075559036	0.292598
Turbidity	-0.005999806	0.934589
Temperature	-0.06090302	0.396475
Rainfall	0.031963391	0.656543
Temperature-1	-0.036002162	0.616414
Rainfall-1	0.126490946	0.077289
Coliform	0.207758907	**0.00348**
gE. coli	0.081067518	0.258712

Table 5. List of sanitizers and active ingredients.

Trade Name	Active Ingredients	Concentration (mg/L)	Application Dose (μL/100 mL)
Ecolab XY-12 (XY)	8.4 % sodium hypochlorite	4*	4.8
CDG Solution 3000™ (CDG)	0.3% chlorine dioxide	5	167
Sanidate 5.0 (S 5.0)	23.0 % hydrogen peroxide/ 5.3 % peroxyacetic acid	10/2.4	4.5
Sanidate 5.0 High Dose (S 5.0-HD)	23.0 % hydrogen peroxide/ 5.3 % peroxyacetic acid	84/20	36.4
Sanidate 12.0 (S 12.0)	18.5 % hydrogen peroxide/ 12.0 % peroxyacetic acid	4.6/3	2.5
Sanidate 12.0 High Dose (S 12.0-HD)	18.5 % hydrogen peroxide/ 12.0 % peroxyacetic acid	14/9	7.7
Control (CK)	Sterilized tap water	/	/

*, the maximum residual disinfectant level under the Safe Drinking Water Act (http://www.epa.gov/laws-regulations/summary-safe-drinking-water-act).

Table 6. Water pH values and changes after sanitizer treatment in *Salmonella* deduction experiment.

Initial concentration	Sanitizer	Pond (mean ± sd)	Well (mean ± sd)
7 log	CK	**7.25 ± 0.036**	**7.323 ± 0.026**
	XY	0.01* ± 0.009	0.025 ± .013
	CDG	0.018 ± 0.024	0.018 ± 0.29
	S 5.0	-0.19 ± 0.028 Δ	-0.288 ± .041 Δ
	S 5.0-HD	-0.548 ± 0.030 Δ	-0.665 ± .041 Δ
	S 12.0	-0.233 ± 0.030 Δ	-0.335 ± .031 Δ
	S12.0-HD	-0.313 ± 0.020 Δ	-0.428 ± .027 Δ
5log	CK	**7.088 ± 0.030**	**7.155 ± 0.034**
	XY	0.118 ± 0.027	0.095 ± 0.018 Δ
	CDG	0.168 ± 0.036	0.103 ± 0.015 Δ
	S 5.0	-0.04 ± 0.009	-0.055 ± 0.010 Δ
	S 5.0-HD	-0.405 ± 0.039 Δ	-0.358 ± 0.044 Δ
	S 12.0	-0.228 ± 0.040 Δ	-0.198 ± 0.022 Δ
	S12.0-HD	-0.328 ± 0.048 Δ	-0.3 ± 0.046 Δ
3 log	CK	**7.1 ± 0.054**	**7.105 ± 0.044**
	XY	0.085 ± 0.021	0.03 ± 0.012
	CDG	0.06 ± 0.020	0.09 ± 0.017
	S 5.0	-0.048 ± 0.026	-0.078 ± 0.035
	S 5.0-HD	-0.443 ± 0.053 Δ	-0.415 ± 0.037 Δ
	S 12.0	-0.313 ± 0.050 Δ	-0.28 ± 0.032 Δ
	S12.0-HD	-0.358 ± 0.059 Δ	-0.333 ± 0.040 Δ

*, water pH changes compared to control (CK).

Δ, significant differences (p = 0.05) between treatment and control.

Table 7. Active ingredient residual percentages of sanitizers after treatment in *Salmonella* deduction experiment.

Initial concentration	Sanitizer	Pond (%)	Well (%)
7 log	XY	3.875 ± 3.217 a	7.063 ± 4.839 a
	CDG	8.15 ± 5.889 a	18.05 ± 6.779 a
	S 5.0	47.396 ± 18.559 c	69.896 ± 16.755 bc
	S 5.0-HD	59.101 ± 8.232 c	55.830 ± 10.141 c
	S 12.0	46.268 ± 16.044 bc	79.685 ± 19.399 c
	S12.0-HD	64.607 ± 14.749 c	65.933 ± 17.393 c
5log	XY	8.563 ± 6.691 a	17.5 ± 9.017 a
	CDG	12.95 ± 10.167 a	36.05 ± 10.011 ab
	S 5.0	68.75 ± 22.750 bc	82.917 ± 15.435 c
	S 5.0-HD	70.733 ± 15.139 bc	71.638 ± 7.430 c
	S 12.0	87.471 ± 7.446 c	78.870 ± 13.054 c
	S12.0-HD	86.651 ± 1.633 c	81.603 ± 13.939 c
3 log	XY	15.25 ± 7.887 a	32.333 ± 10.804 a
	CDG	15.8 ± 7.940 a	30.533 ± 10.110 a
	S 5.0	77.917 ± 18.430 b	92.083 ± 1.917 b
	S 5.0-HD	69.5 ± 15.313 b	67.433 ± 12.597 b
	S 12.0	77.889 ± 16.547 b	94 ± 0.490 b
	S12.0-HD	81.074 ± 5.897 b	85.704 ± 4.636 b

Different lowercase letters indicate significant differences ($p = 0.05$) between treatments within each of the experiments.

Table 8. Water parameters of sampled irrigation ponds and wells in *Salmonella* deduction test.

	Pond	Well
Temperature	25.069 ± 1.832 a	22.503 ± 2.031 b
Conductivity	0.212 ± 0.026 a	0.237 ± 0.066 a
Dissolved Oxygen percentage	107.225 ± 25.449 a	77.331 ± 20.049 b
Dissolved Oxygen charge	47.469 ± 15.627 a	44.2 ± 13.553 a
pH	7.309 ± 0.215 a	7.235 ± 0.111 a
pHmV	-70.796 ± 12.019 a	-66.076 ± 6.223 a
Oxidation Reduction Potential	81.638 ± 16.087 a	45.263 ± 29.337 b
Turbidity	8.248 ± 5.156 a	2.329 ± 1.581 b

Different lowercase letters indicate significant differences (p = 0.05) between Pond and Well water samples.

Table 9. Population of fecal indicators in sampled irrigation pond and well water in *Salmonella* deduction test.

MPN/100 ml	Pond	Well
Coliform	2259.65 ± 130.431 a	22.503 ± 2.031 b
Generic E. coli	218.356 ± 293.211 a	0.237 ± 0.066 b

Different lowercase letters indicate significant differences (p = 0.05) between Pond and Well water samples.

Table 10. Water pH values and changes after sanitizer treatment in *Listeria monocytogenes* deduction experiment.

Initial concentration	Sanitizer	Pond (mean ± sd)	Well (mean ± sd)
7 log	CK	**7.76** ± 0.053	**7.53** ± 0.036
	XY	0.005* ± 0.043	0.06 ± 0.031
	CDG	0.028 ± 0.028	0.04 ± 0.026
	S 5.0	-0.23 ± 0.073	-0.133 ± 0.069
	S 5.0-HD	-0.858 ± 0.036 Δ	-0.443 ± 0.104
	S 12.0	-0.653 ± 0.025 Δ	-0.368 ± 0.073 Δ
	S12.0-HD	-0.64 ± 0.041 Δ	-0.408 ± 0.076 Δ
5 log	CK	**7.223** ± 0.073	**7.165** ± 0.050
	XY	0.175 ± 0.042	0.225 ± 0.040 Δ
	CDG	0.183 ± 0.037 Δ	0.135 ± 0.012 Δ
	S 5.0	-0.028 ± 0.006 Δ	-0.013 ± 0.022
	S 5.0-HD	-0.433 ± 0.019 Δ	-0.313 ± 0.053 Δ
	S 12.0	-0.258 ± 0.038 Δ	-0.1 ± 0.021 Δ
	S12.0-HD	-0.233 ± 0.032 Δ	-0.13 ± 0.022 Δ
3 log	CK	**7.213** ± 0.075	**7.175** ± 0.074
	XY	0.178 ± 0.044	0.173 ± 0.040
	CDG	0.13 ± 0.026 Δ	0.205 ± 0.024 Δ
	S 5.0	-0.01 ± 0.007	-0.018 ± 0.004 Δ
	S 5.0-HD	-0.39 ± 0.046 Δ	-0.34 ± 0.055 Δ
	S 12.0	-0.238 ± 0.039 Δ	-0.178 ± 0.034 Δ
	S12.0-HD	-0.195 ± 0.034 Δ	-0.175 ± 0.028 Δ

*, water pH changes compared to control (CK).
Δ, significant differences (p = 0.05) between treatment and control.

Table 11. Active ingredient residual percentages of sanitizers after treatment in *Listeria monocytogenes* deduction experiment.

Initial concentration	Sanitizer	Pond (%)	Well (%)
7 log	XY	3.125 ± 1.277 a	14.438 ± 7.483 a
	CDG	1.6 ± 0.548 a	4.45 ± 1.576 a
	S 5.0	47.708 ± 14.212 b	61.979 ± 7.363 bc
	S 5.0-HD	59.413 ± 6.559 bc	48.713 ± 5.977 b
	S 12.0	65.667 ± 13.374 bc	74.083 ± 14.290 bc
	S12.0-HD	78.944 ± 4.872 c	65.944 ± 19.369 bc
5 log	XY	5.375 ± 2.982 b	24.625 ± 9.986 b
	CDG	2.2 ± 1.219 b	**20.7 ± 6.402 b**
	S 5.0	86.667 ± 29.001 c	88.125 ± 11.162 c
	S 5.0-HD	69.65 ± 2.164 c	66.325 ± 17.607 c
	S 12.0	75.583 ± 16.674 c	81.667 ± 9.205 c
	S12.0-HD	74.333 ± 5.062 c	75.389 ± 4.715 c
3 log	XY	6.938 ± 3.930 a	25.188 ± 5.968 a
	CDG	2.7 ± 0.614 a	8.05 ± 2.391 a
	S 5.0	64.688 ± 13.551 b	78.229 ± 7.530 bc
	S 5.0-HD	64.775 ± 3.156 b	70.6 ± 3.978 bc
	S 12.0	77.083 ± 17.018 bc	92.583 ± 14.428 c
	S12.0-HD	82.694 ± 7.329 bc	85.194 ± 9.391 bc

Different lowercase letters indicate significant differences (p = 0.05) between treatments within each of the experiments. Bold number indicates significant difference (p = 0.05) between Pond and Well water samples.

Table 12. Water parameters of sampled irrigation ponds and wells in *Listeria monocytogenes* deduction test.

	Pond	**Well**
Temperature	28.877 ± 1.029 a	24.983 ± 2.180 b
Conductivity	0.251 ± 0.233 a	0.182 ± 0.080 a
Dissolved Oxygen percentage	28.094 ± 99.529 a	13.244 ± 76.302 a
Dissolved Oxygen charge	55.813 ± 32.259 a	58.494 ± 30.348 a
pH	7.525 ± 0.191 a	7.354 ± 0.164 a
pHmV	-71.044 ± 34.160 a	-73.288 ± 9.189 a
Oxidation Reduction Potential	50.056 ± 19.636 a	39.994 ± 46.179 a
Turbidity	29.161 ± 22.139 a	4.519 ± 4.360 b

Different lowercase letters indicate significant differences (p = 0.05) between Pond and Well water samples.

Table 13. Population of fecal indicators in sampled irrigation pond and well water in *Listeria monocytogenes* deduction test.

MPN/100 ml	**Pond**	**Well**
Coliform	2241.294 ± 207.510 a	24.983 ± 2.180 b
Generic E. coli	190.581 ± 201.319 a	0.182 ± 0.080 b

Different lowercase letters indicate significant differences (p = 0.05) between Pond and Well water samples.

Table 14. Water pH values and changes after sanitizer treatment in *Escherichia coli* O157:H7 deduction experiment.

Initial concentration	Sanitizer	Pond (mean ± sd)	Well (mean ± sd)
7 log	CK	**7.643** ± 0.035	**7.64** ± 0.053
	XY	0.07 ± 0.018	0.098 ± 0.020 Δ
	CDG	0.085 ± 0.022	0.09 ± 0.030
	S 5.0	-0.04 ± 0.010	-0.09 ± 0.018 Δ
	S 5.0-HD	-0.645 ± 0.079 Δ	-0.513 ± 0.049 Δ
	S 12.0	-0.258 ± 0.045 Δ	-0.193 ± 0.040 Δ
	S12.0-HD	-0.34 ± 0.029 Δ	-0.32 ± 0.056 Δ
5log	CK	**7.568** ± 0.111	**7.455** ± 0.056
	XY	0.068 ± 0.014 Δ	0.08 ± 0.017 Δ
	CDG	0.03 ± 0.005 Δ	0.063 ± 0.016
	S 5.0	-0.185 ± 0.021 Δ	-0.21 ± 0.036 Δ
	S 5.0-HD	-0.96 ± 0.113 Δ	-0.643 ± 0.039 Δ
	S 12.0	-0.478 ± 0.035 Δ	-0.293 ± 0.039 Δ
	S12.0-HD	-0.538 ± 0.016 Δ	-0.395 ± 0.045 Δ
3 log	CK	**7.613** ± 0.023	**7.488** ± 0.053
	XY	0.028 ± 0.009	0.073 ± 0.013
	CDG	0.04 ± 0.016	0.06 ± 0.029
	S 5.0	-0.323 ± 0.056 Δ	-0.158 ± 0.032 Δ
	S 5.0-HD	-0.98 ± 0.117 Δ	-0.695 ± 0.116 Δ
	S 12.0	-0.31 ± 0.046 Δ	-0.198 ± 0.029 Δ
	S12.0-HD	-0.465 ± 0.026 Δ	-0.318 ± 0.046 Δ

*, water pH changes compared to control (CK).
Δ, significant differences (p = 0.05) between treatment and control.

Table 15. Active ingredient residual percentages of sanitizers after treatment in *Escherichia coli* O157:H7 deduction experiment.

Initial concentration	Sanitizer	Pond (%)	Well (%)
7 log	XY	11.625 ± 3.618 a	9.375 ± 4.140 a
	CDG	3.65 ± 1.063 a	5.8 ± 1.747 a
	S 5.0	55.625 ± 9.589 bcd	44.479 ± 11.331 bc
	S 5.0-HD	39 ± 4.417 b	47.738 ± 6.734 bc
	S 12.0	70.167 ± 9.567 d	58.833 ± 9.723 cd
	S12.0-HD	68.583 ± 3.234 d	69.222 ± 2.762 d
5log	XY	8.5 ± 3.501 a	16.813 ± 8.286 ab
	CDG	6.15 ± 2.707 a	7.65 ± 3.902 a
	S 5.0	75.104 ± 24.106 cd	97.396 ± 31.448 d
	S 5.0-HD	53.563 ± 2.743 bc	**66.025 ± 1.087 cd**
	S 12.0	72.583 ± 19.746 cd	67.917 ± 9.263 cd
	S12.0-HD	74.639 ± 5.412 cd	72.417 ± 4.321 cd
3 log	XY	8 ± 3.866 a	17.688 ± 5.179 a
	CDG	5.7 ± 1.310 a	8.05 ± 3.540 a
	S 5.0	55.833 ± 15.778 b	57.083 ± 10.789 b
	S 5.0-HD	68.15 ± 3.114 b	62.45 ± 4.175 b
	S 12.0	55.417 ± 10.058 b	62.083 ± 7.132 b
	S12.0-HD	71.556 ± 7.057 b	64.278 ± 7.576 b

Different lowercase letters indicate significant differences (p = 0.05) between treatments within each of the experiments. Bold number indicates significant difference (p = 0.05) between Pond and Well water samples.

Table 16. Water parameters of sampled irrigation ponds and wells in *Escherichia coli* O157:H7 deduction test.

	Pond	Well
Temperature	20.043 ± 2.883 a	19.489 ± 1.982 a
Conductivity	8.088 ± 15.366 a	0.239 ± 0.069 a
Dissolved Oxygen percentage	101.988 ± 23.261 a	87.194 ± 23.019 a
Dissolved Oxygen charge	56.338 ± 6.233 a	49.819 ± 7.676 a
pH	7.853 ± 0.863 a	7.634 ± 0.902 a
pHmV	-38.65 ± 48.280 a	-39.838 ± 31.817 a
Oxidation Reduction Potential	108.838 ± 29.243 a	47.269 ± 68.274 b
Turbidity	22.544 ± 20.741 a	6.792 ± 6.989 b

Different lowercase letters indicate significant differences (p = 0.05) between Pond and Well water samples.

Table 17. Population of fecal indicators in sampled irrigation pond and well water in *Escherichia coli* O157:H7 deduction test.

MPN/100 ml	Pond	Well
Coliform	2288.719 ± 261.763 a	19.489 ± 1.982 b
Generic E. coli	75.867 ± 104.522 a	0.239 ± 0.069 b

Different lowercase letters indicate significant differences (p = 0.05) between Pond and Well water samples.

Figure 1. *Salmonella* MPN values in pond irrigation water.

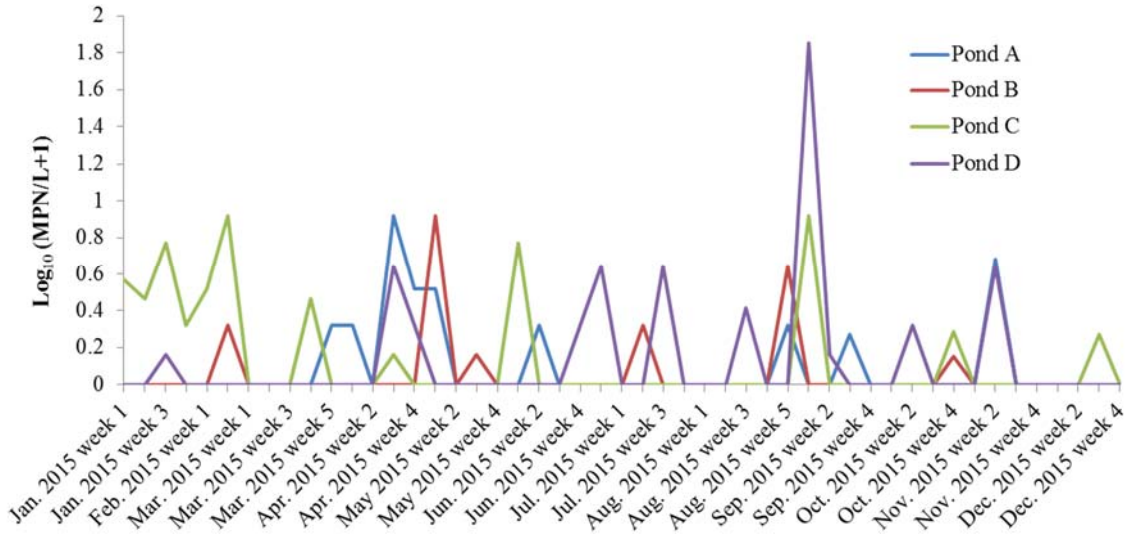


Figure 2. *Listeria monocytogenes* MPN values in pond irrigation water.

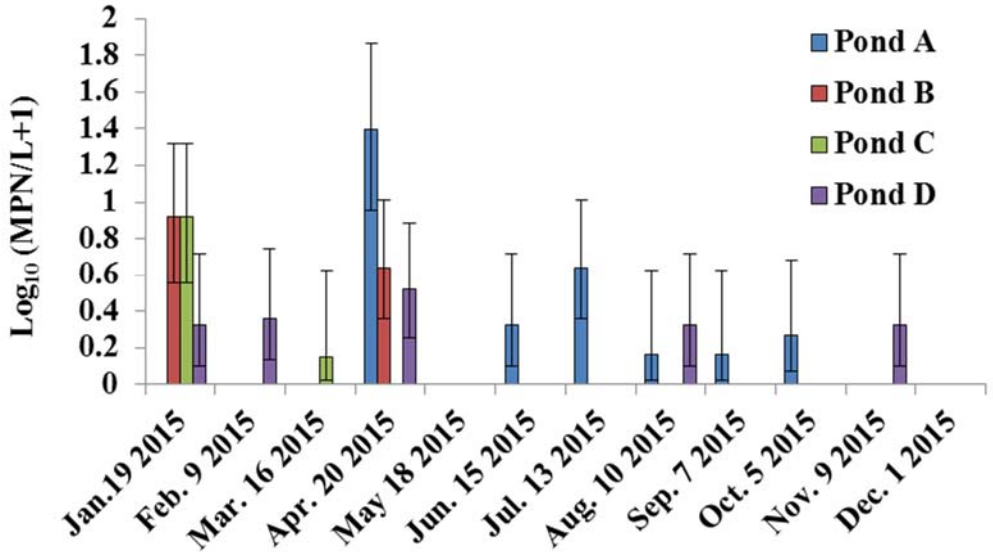


Figure 3. MPN values of coliform and generic *E. coli* in pond water.

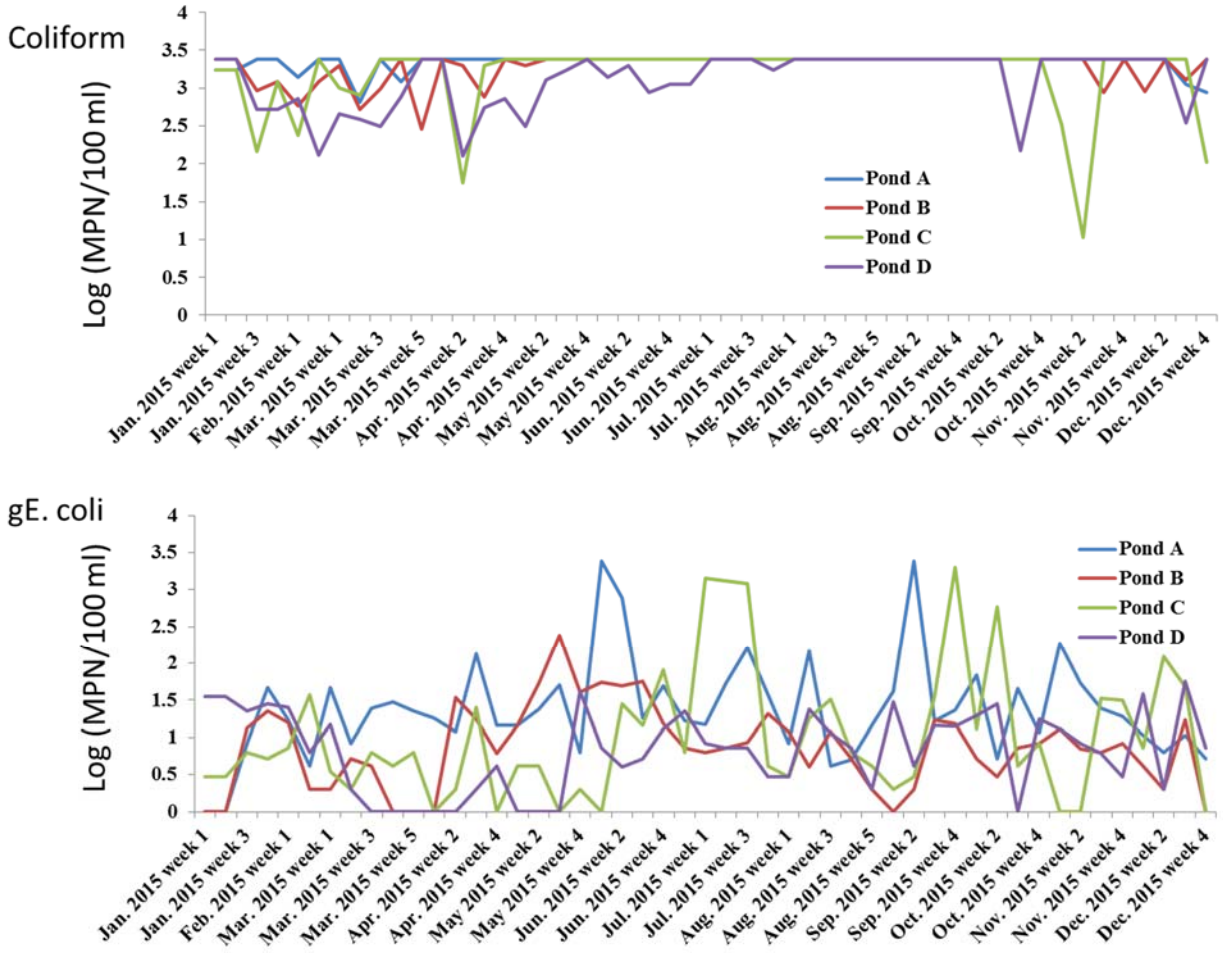


Figure 4. MPN values of coliform and generic *E. coli* in well water.

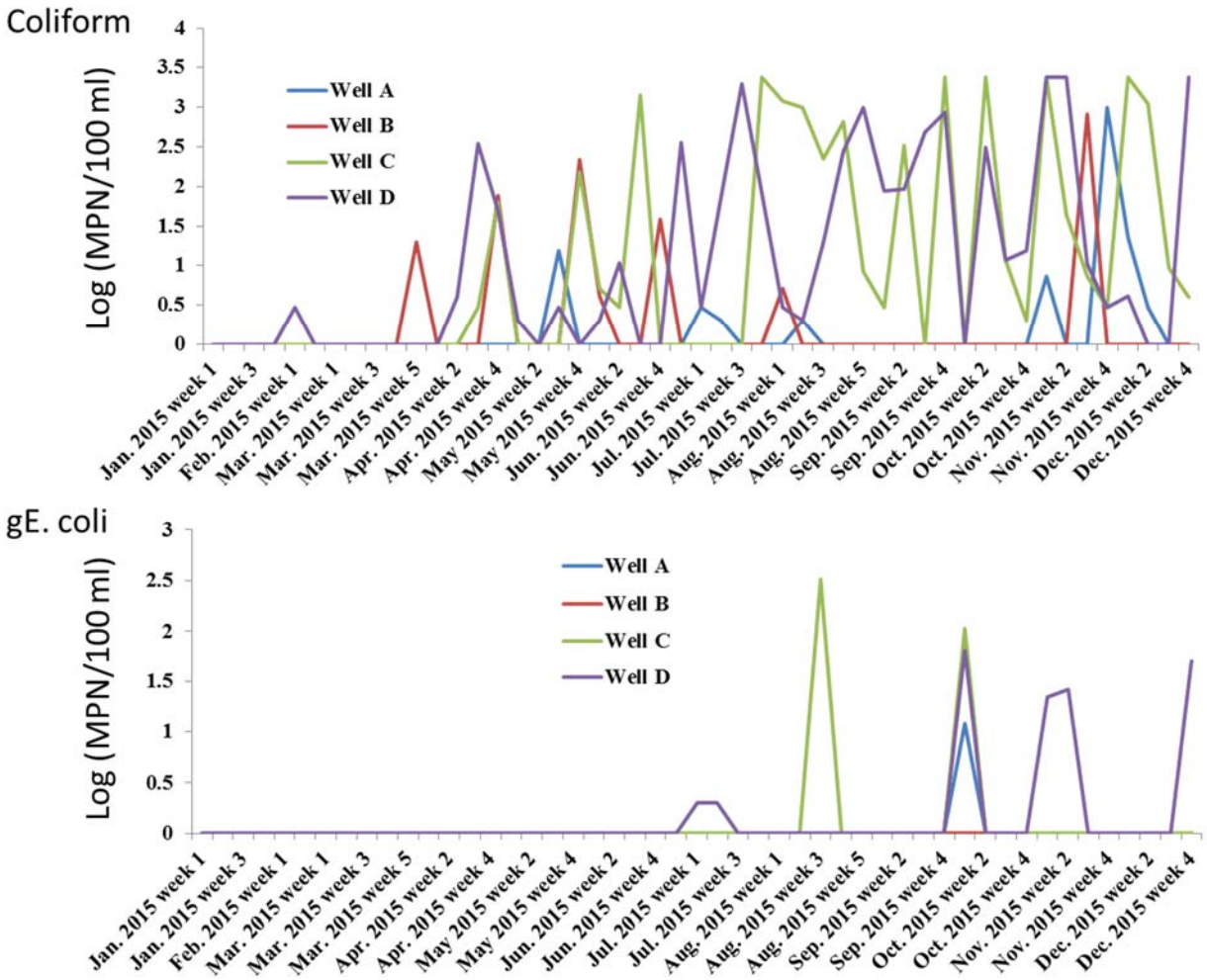


Figure 5. Dynamics of temperature and total rainfall of tested farms.

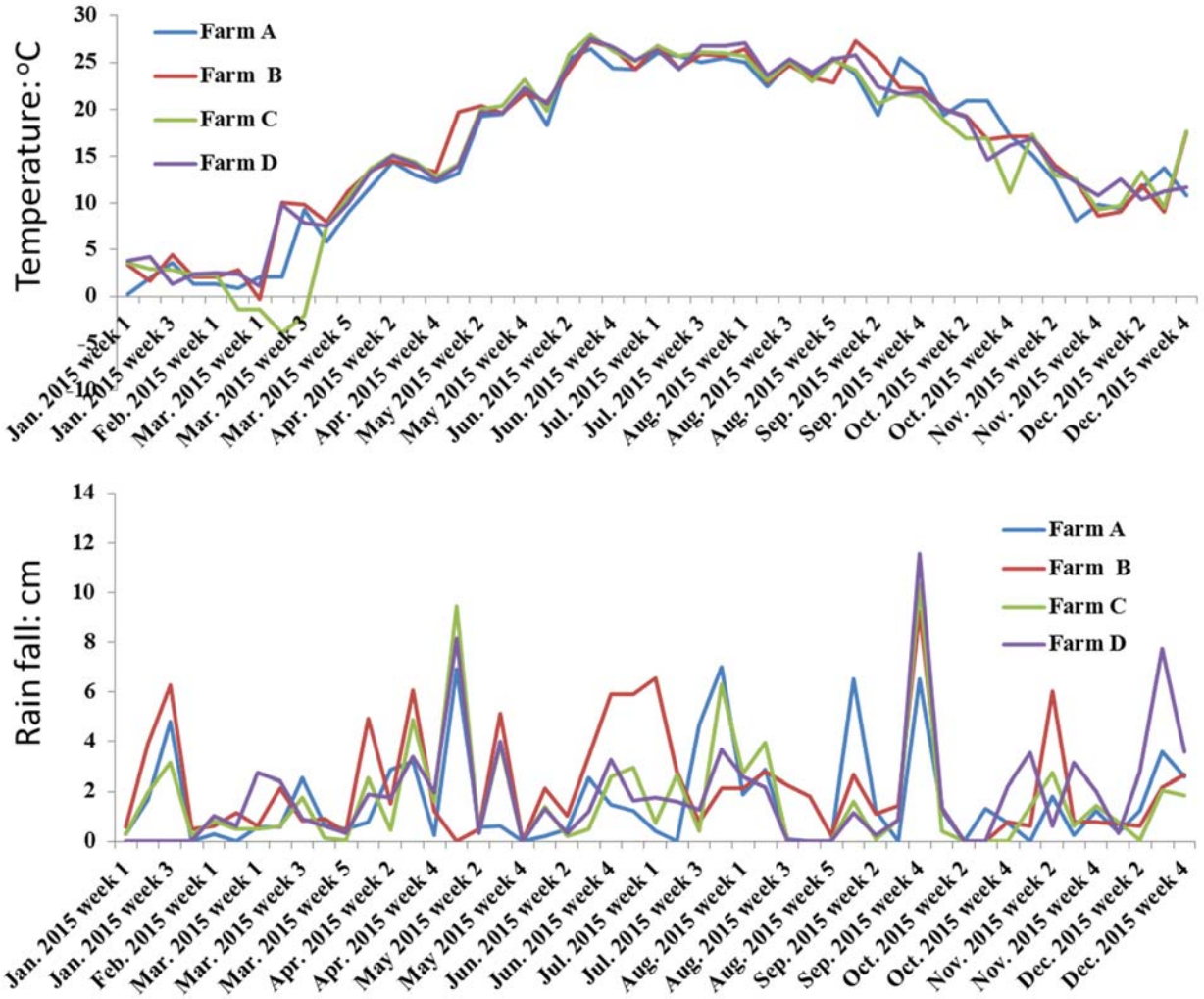


Figure 6. Serovar diversity of *Salmonella* spp. in the four tested ponds.

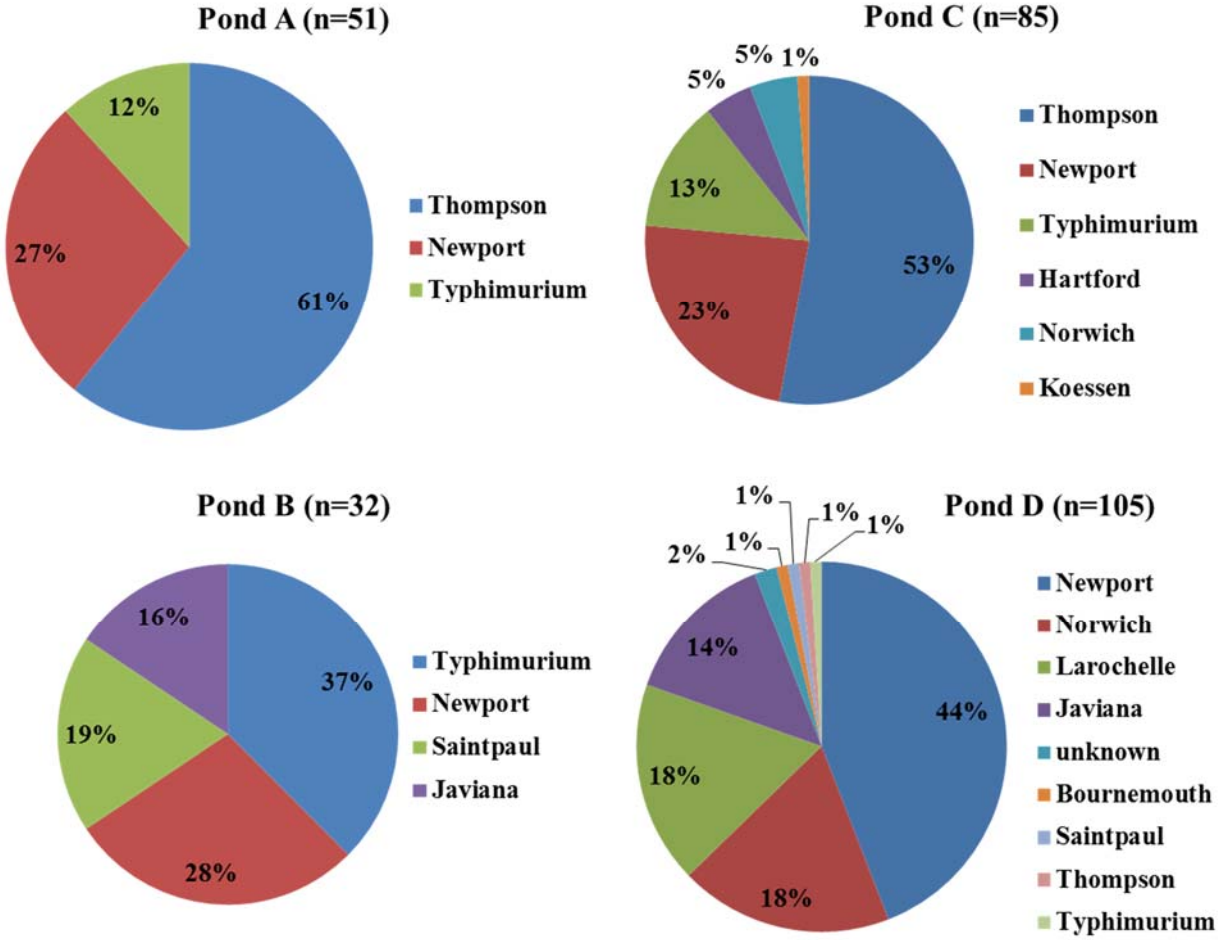


Figure 7. Serovar diversity of *Salmonella* spp. in irrigation pond water on ESV.

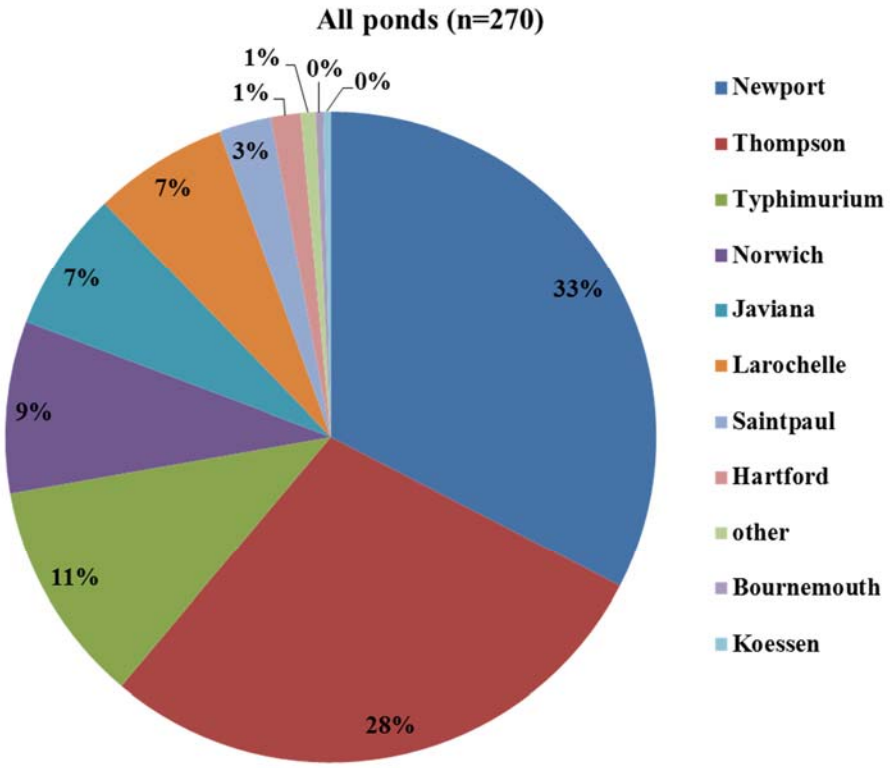


Figure 8. Serovar diversity of *Salmonella* spp. in irrigation well water on ESV.

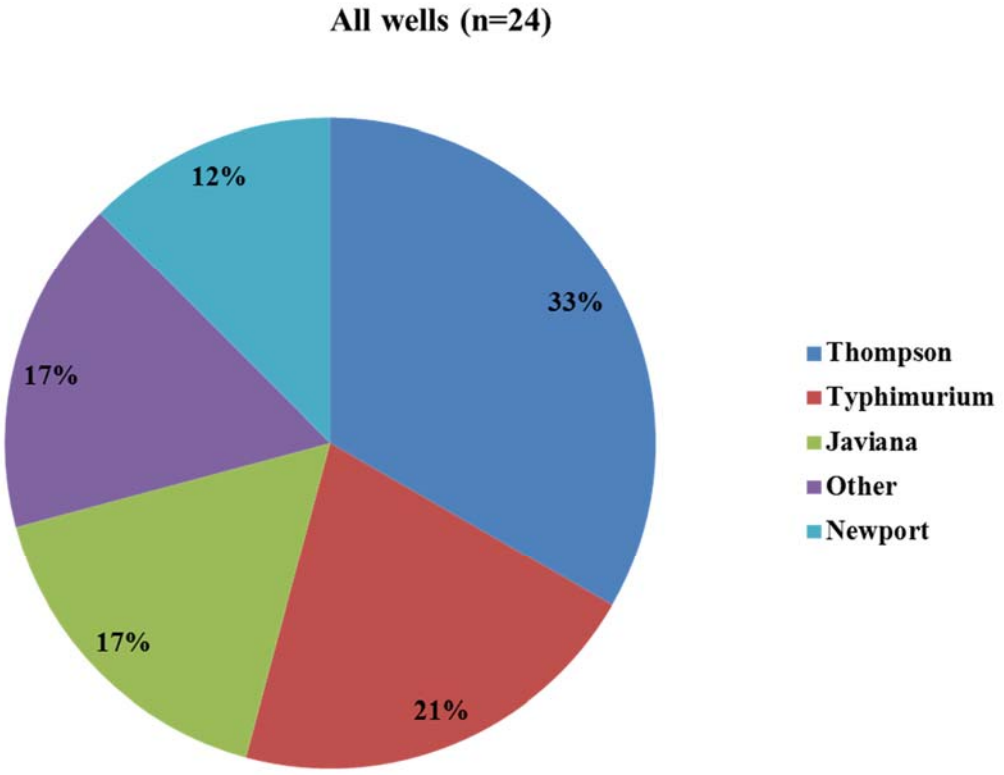


Figure 9. Hierarchical clustering of samples based on the 50 most dominant class level taxa revealing a strong clustering associated with water source.

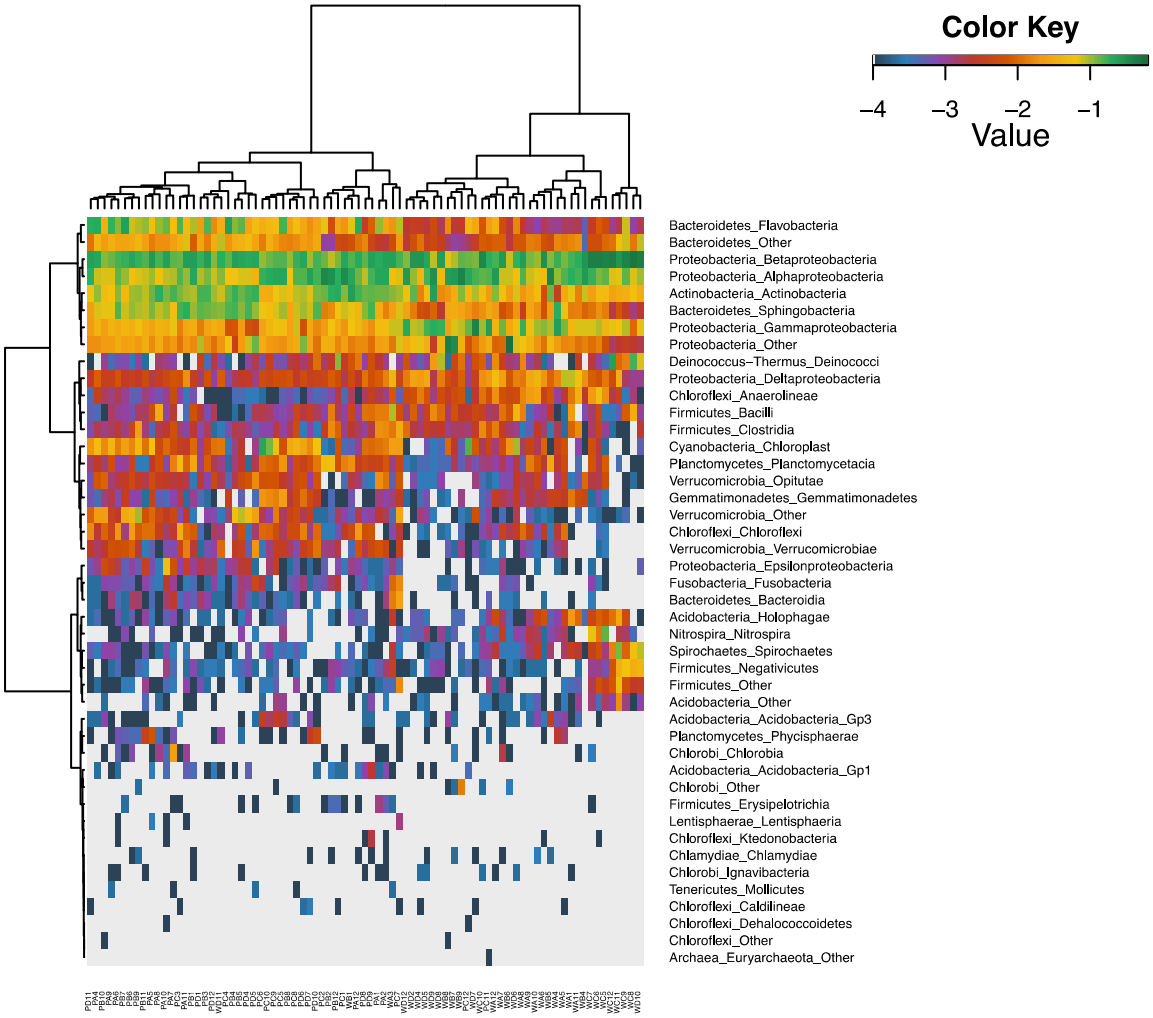


Figure 10. Hierarchical clustering of samples based on the 50 most dominant genus level taxa revealing a strong clustering associated with water source.

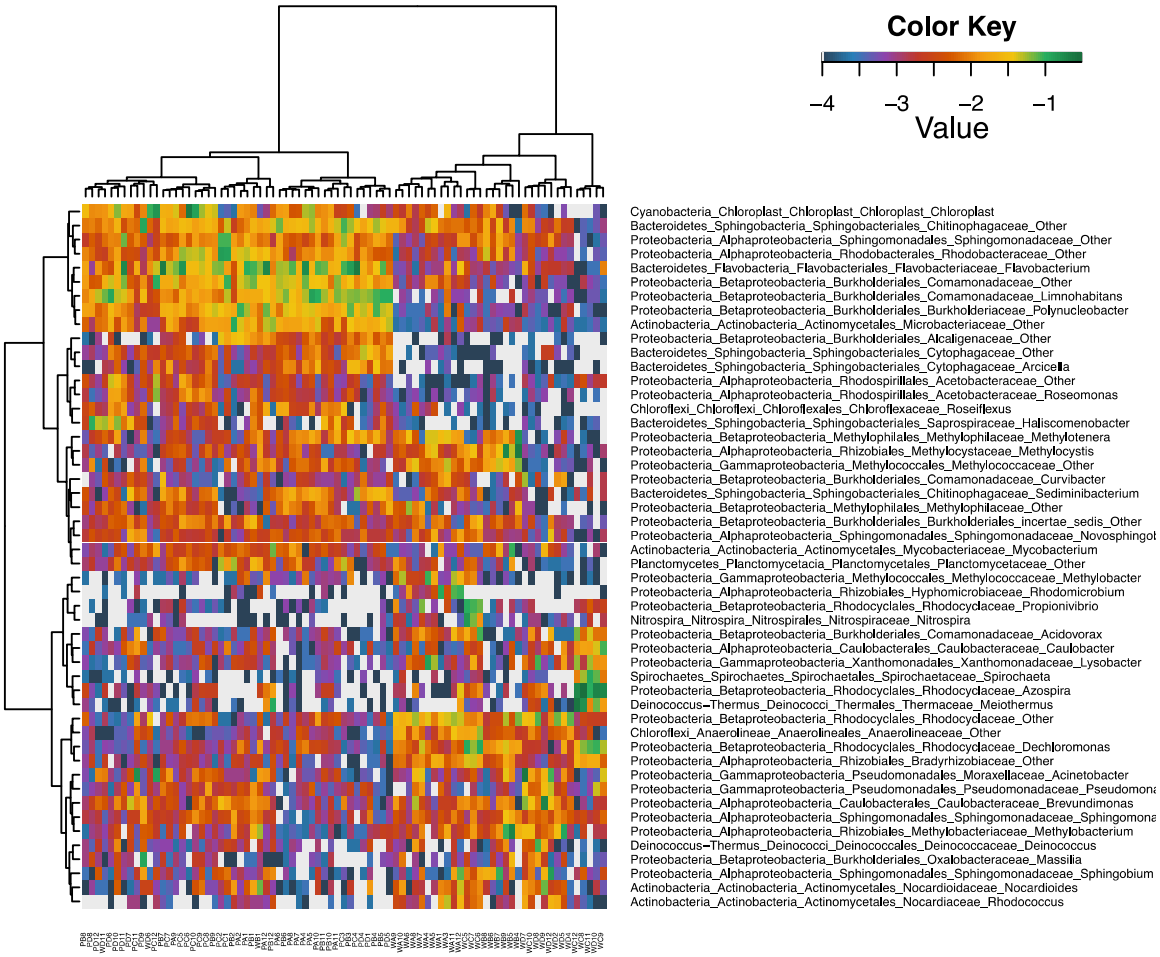


Figure 11. Beta-diversity (Principal coordinates analysis) based on Bray-Curtis distances and points are colored by (i) water source status and (ii) location and source combination.

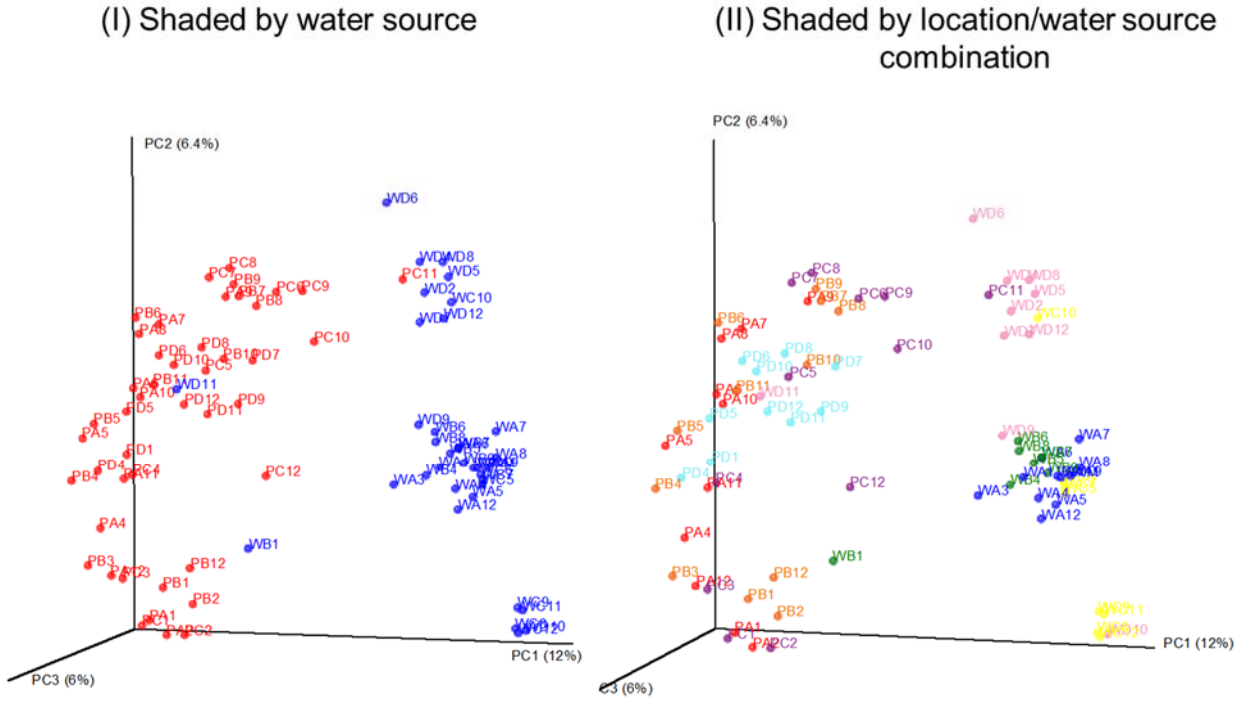


Figure 12. Relative abundance of dominant taxa of sampled irrigation ponds and wells.

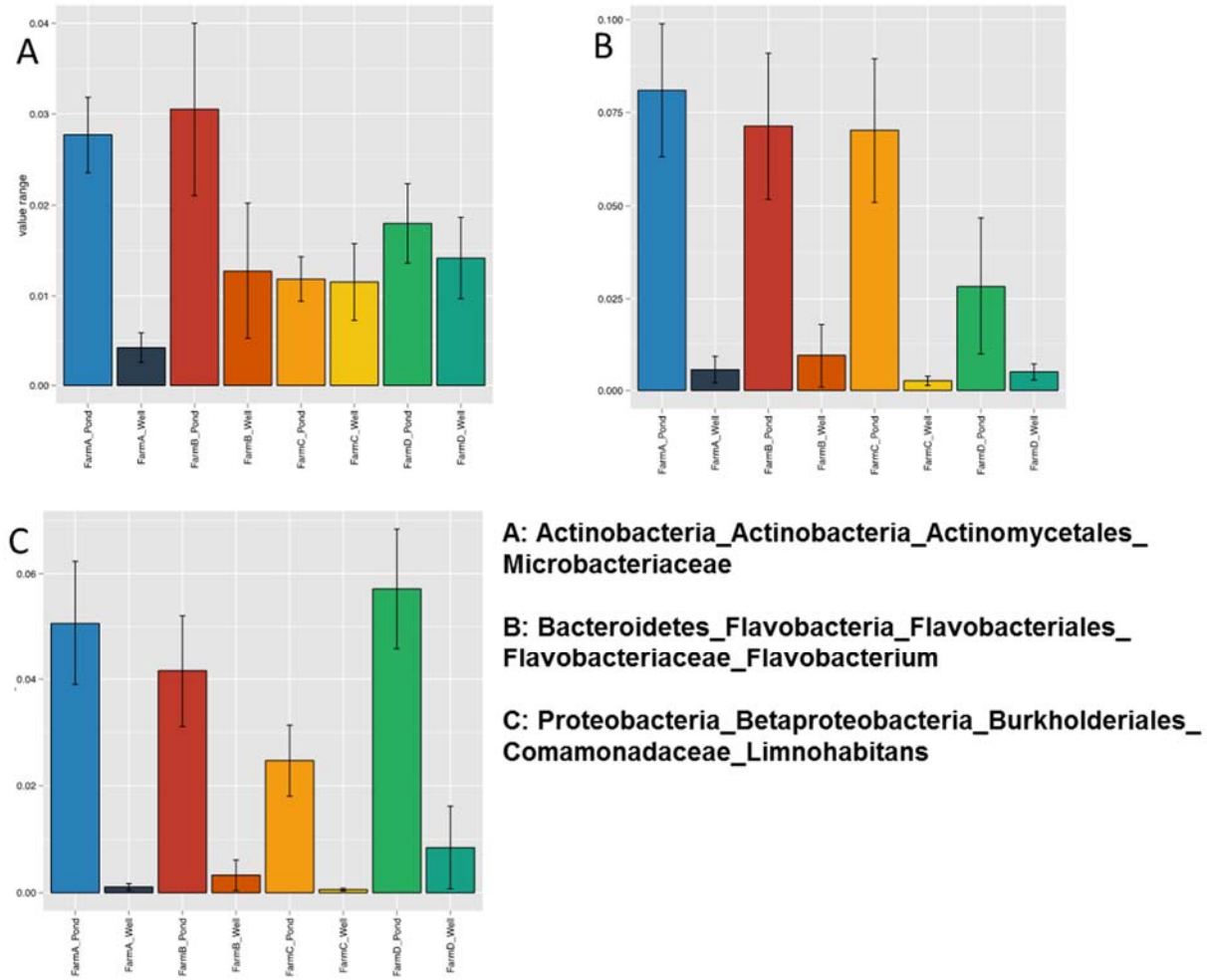


Figure 13. Abundance of taxa correlated with *Listeria monocytogenes* negative and positive samples.

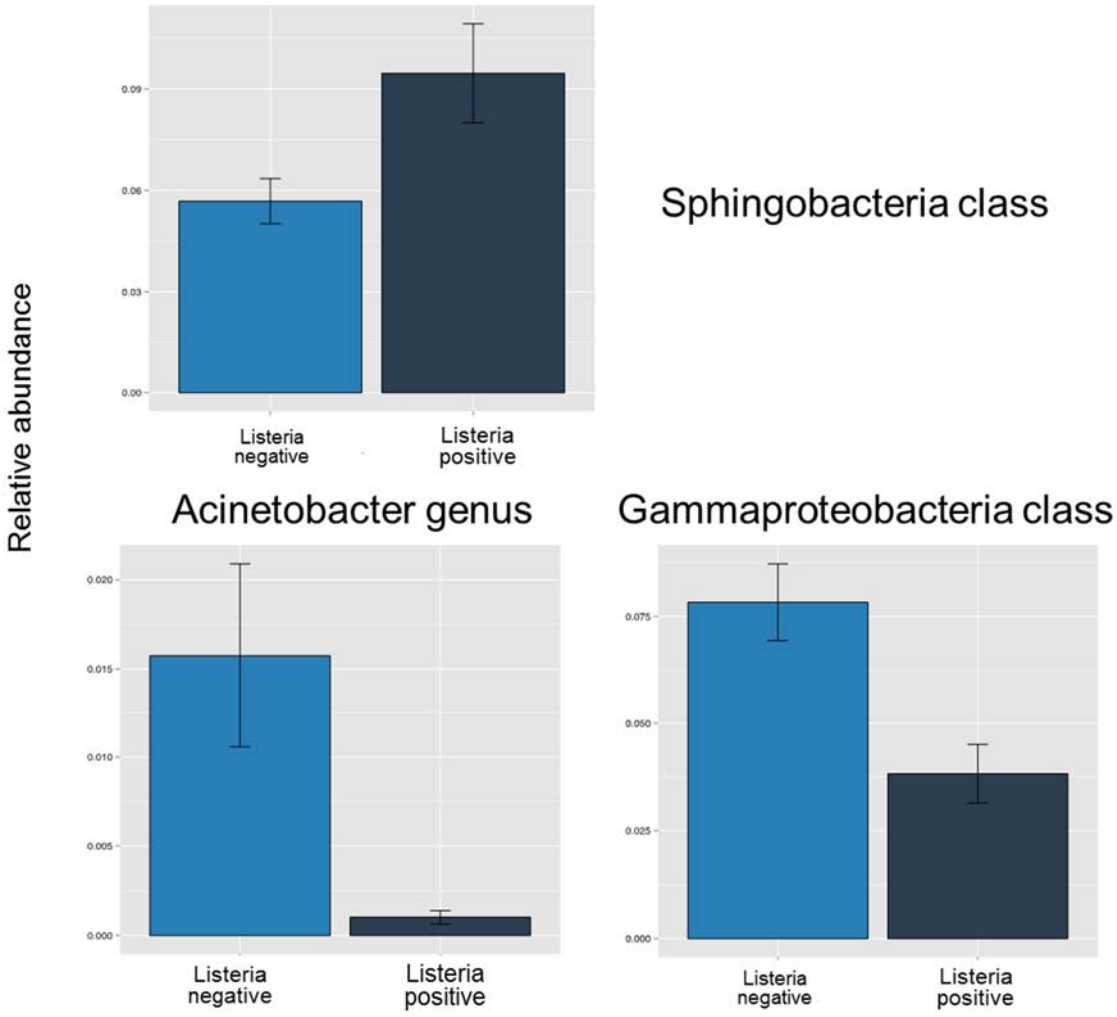


Figure 14. Abundance of taxa correlated with *Salmonella* negative and positive samples.

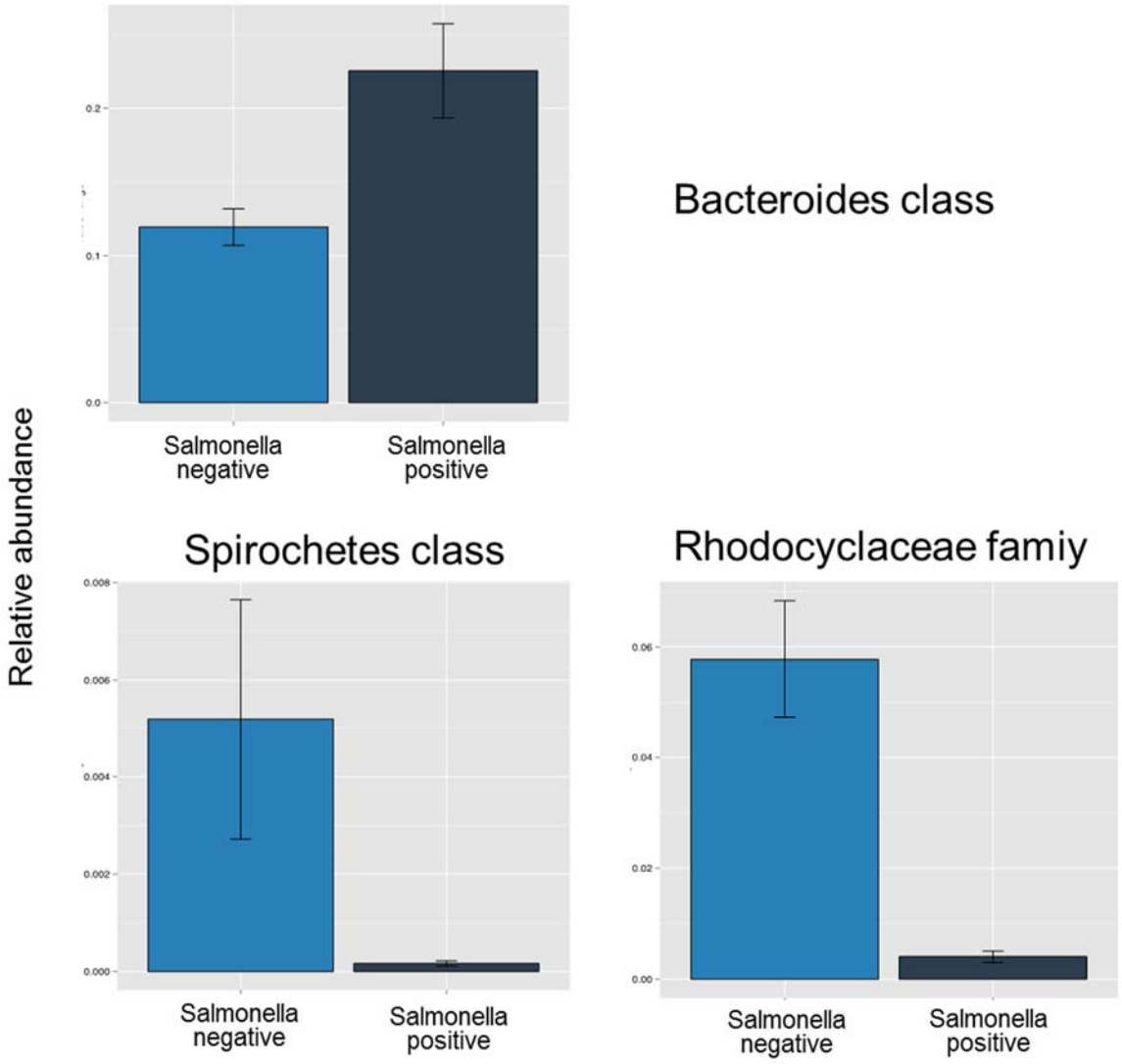


Figure 15. *Salmonella* levels after sanitization with 1 min contact time.

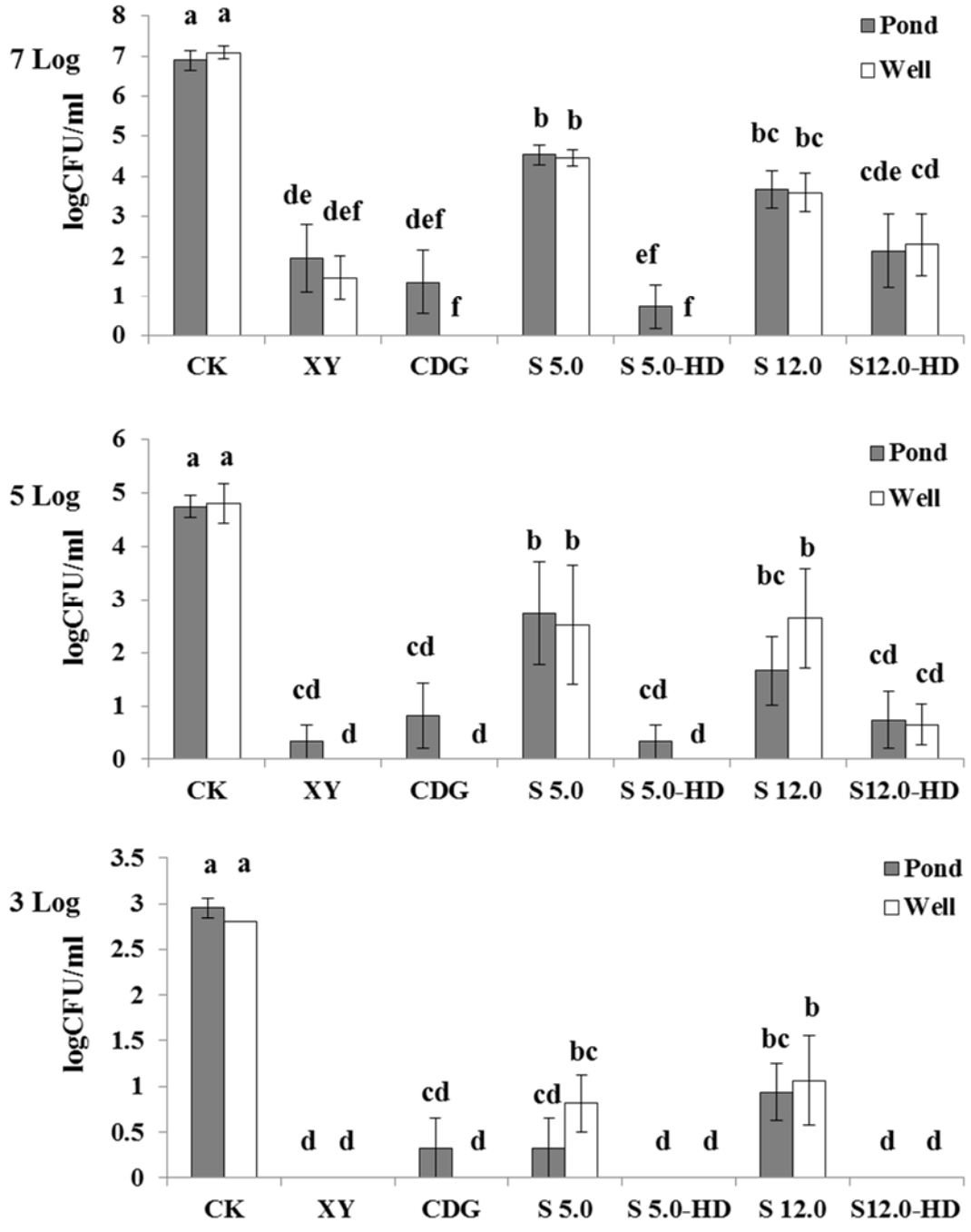


Figure 16. *Salmonella* levels after sanitization with 30 min contact time.

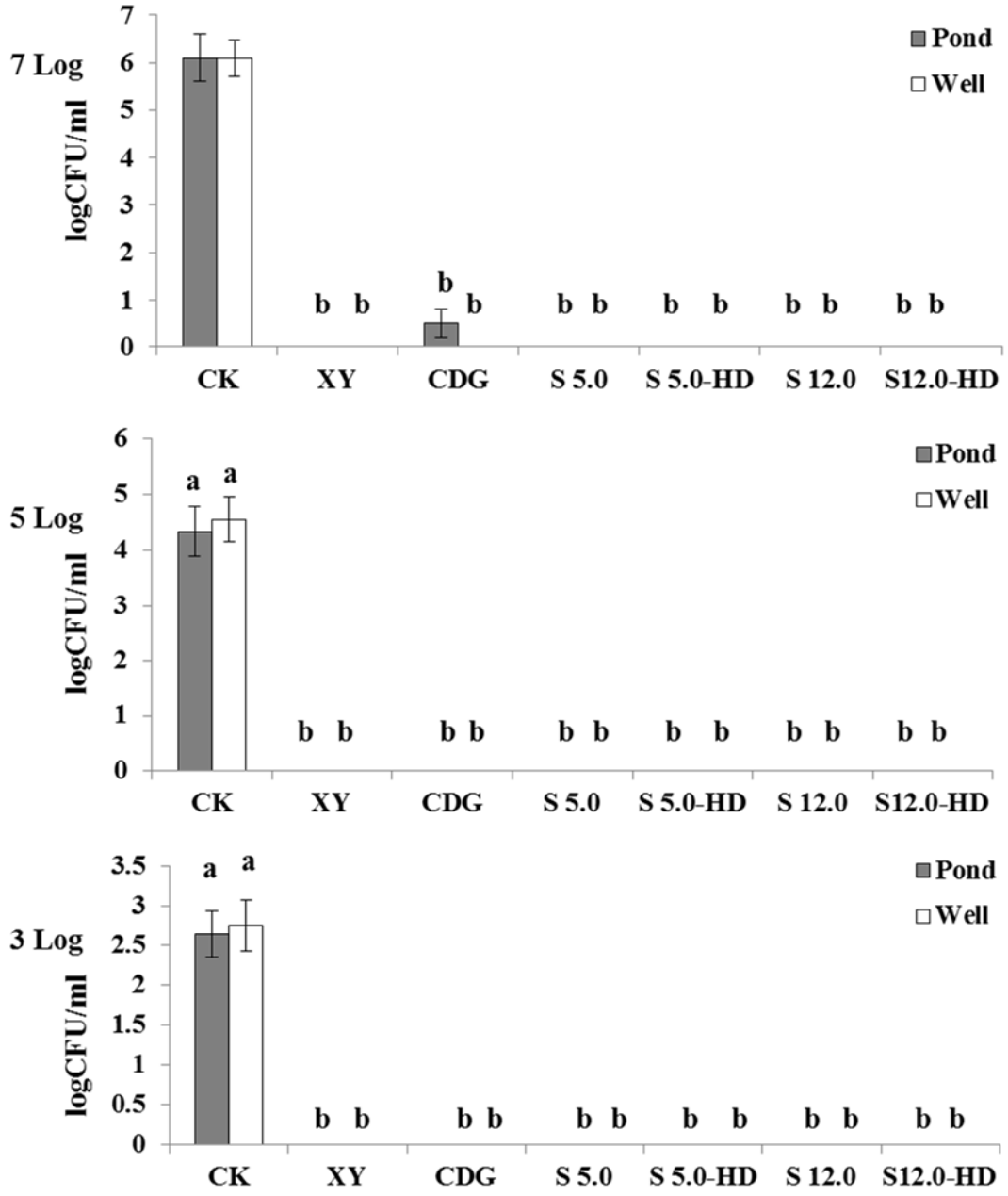


Figure 17. *Listeria monocytogenes* levels after sanitization with 1 min contact time.

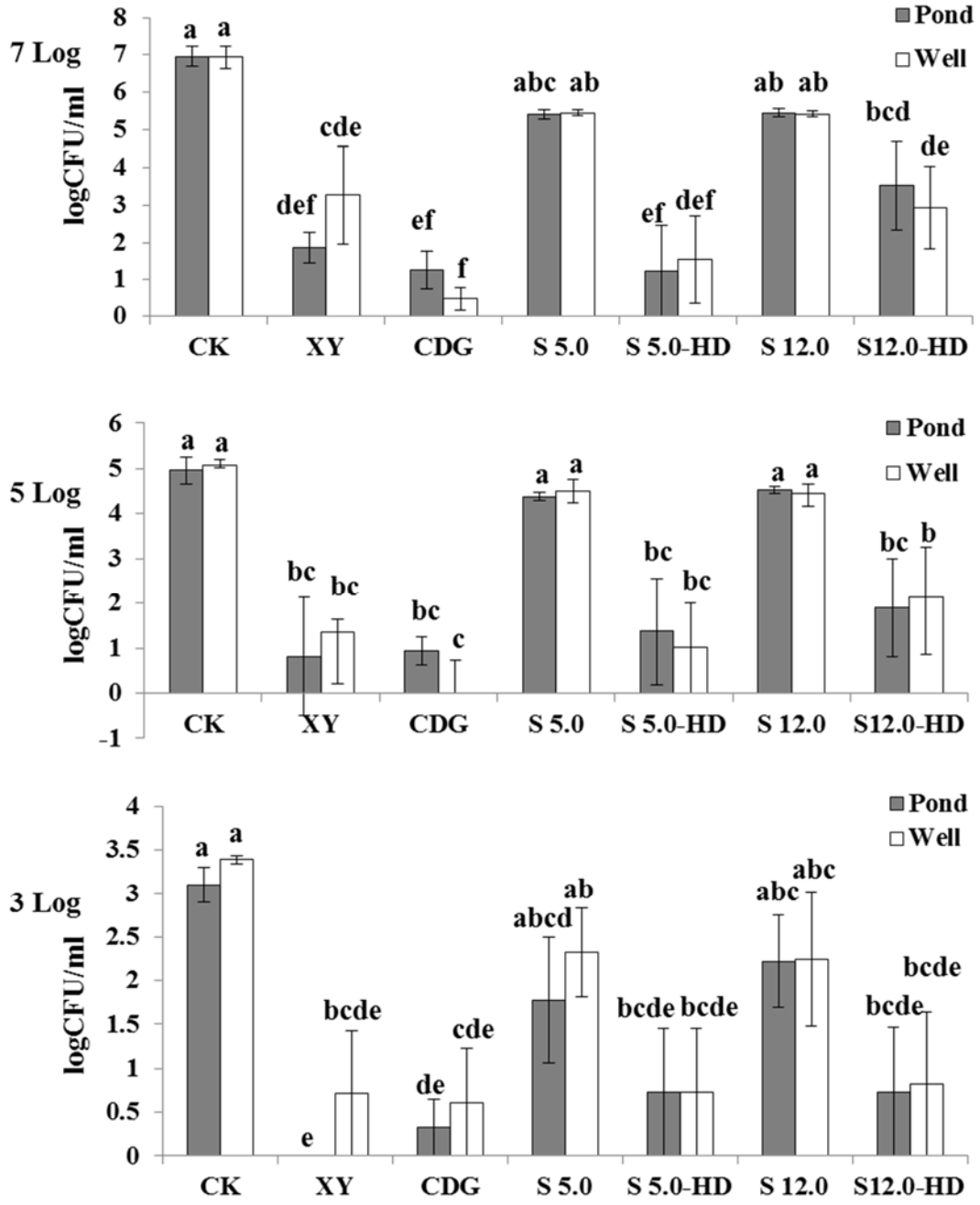


Figure 18. *Listeria monocytogenes* levels after sanitization with 30 min contact time.

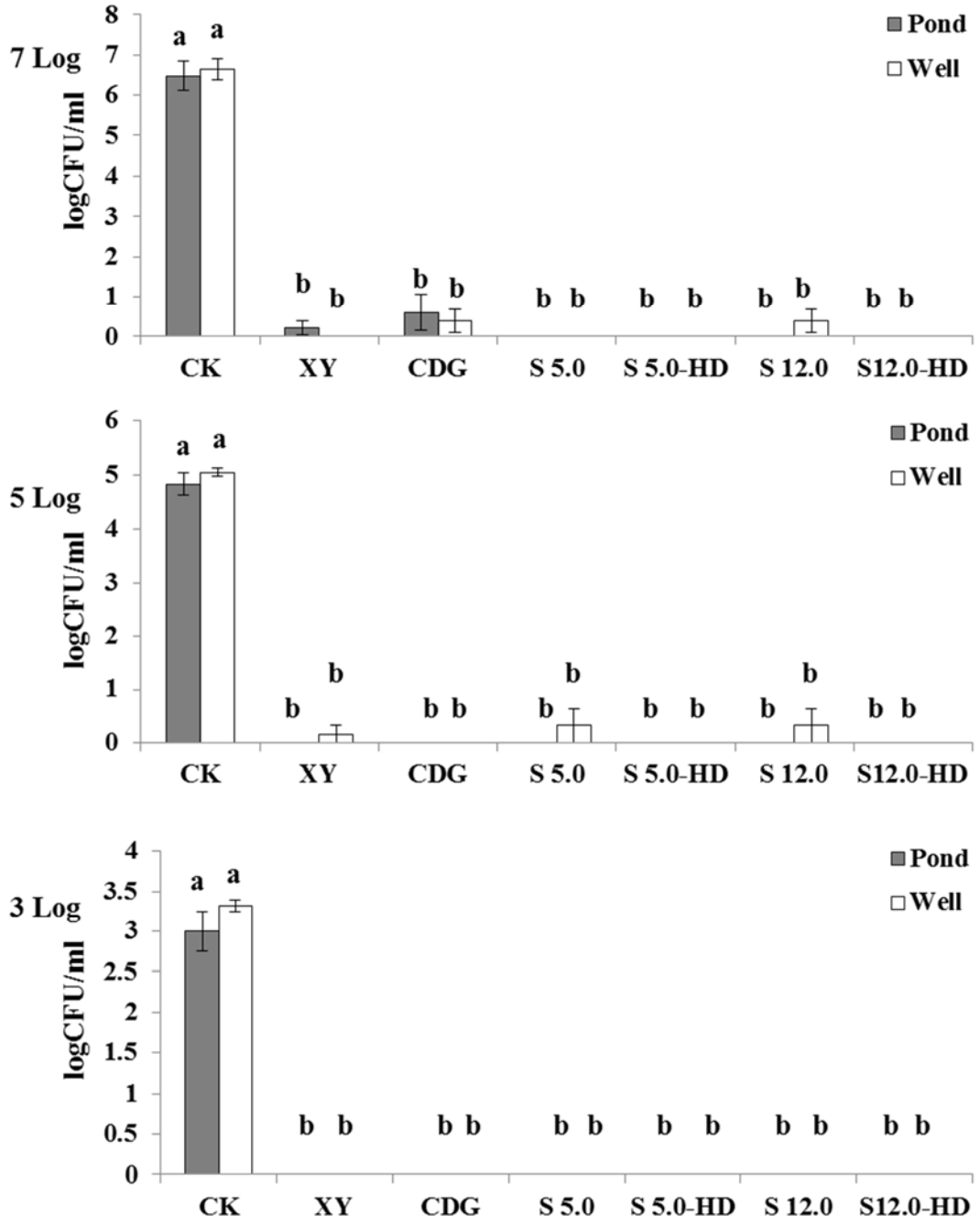


Figure 19. *Escherichia coli* O157:H7 levels after sanitization with 1 min contact time.

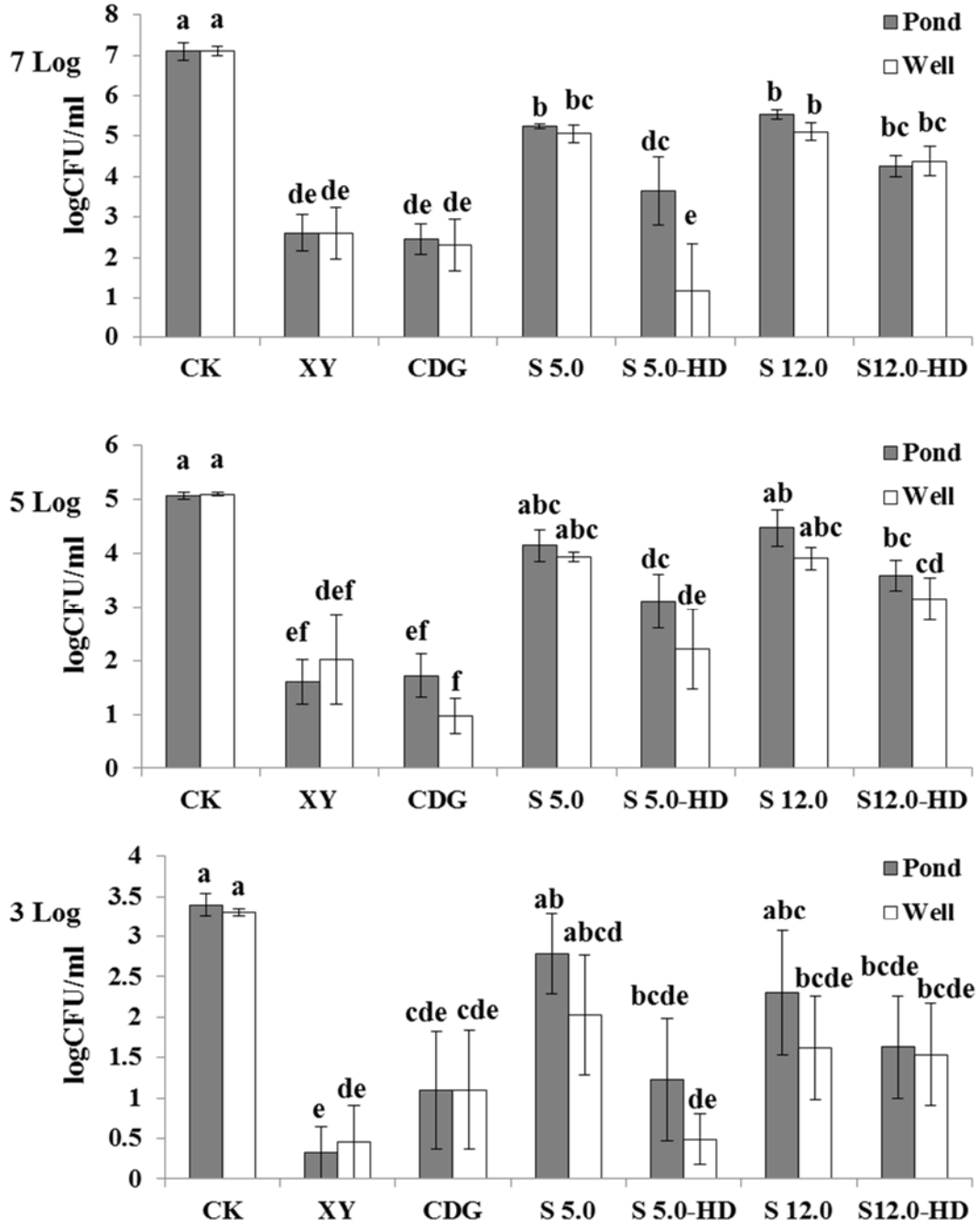
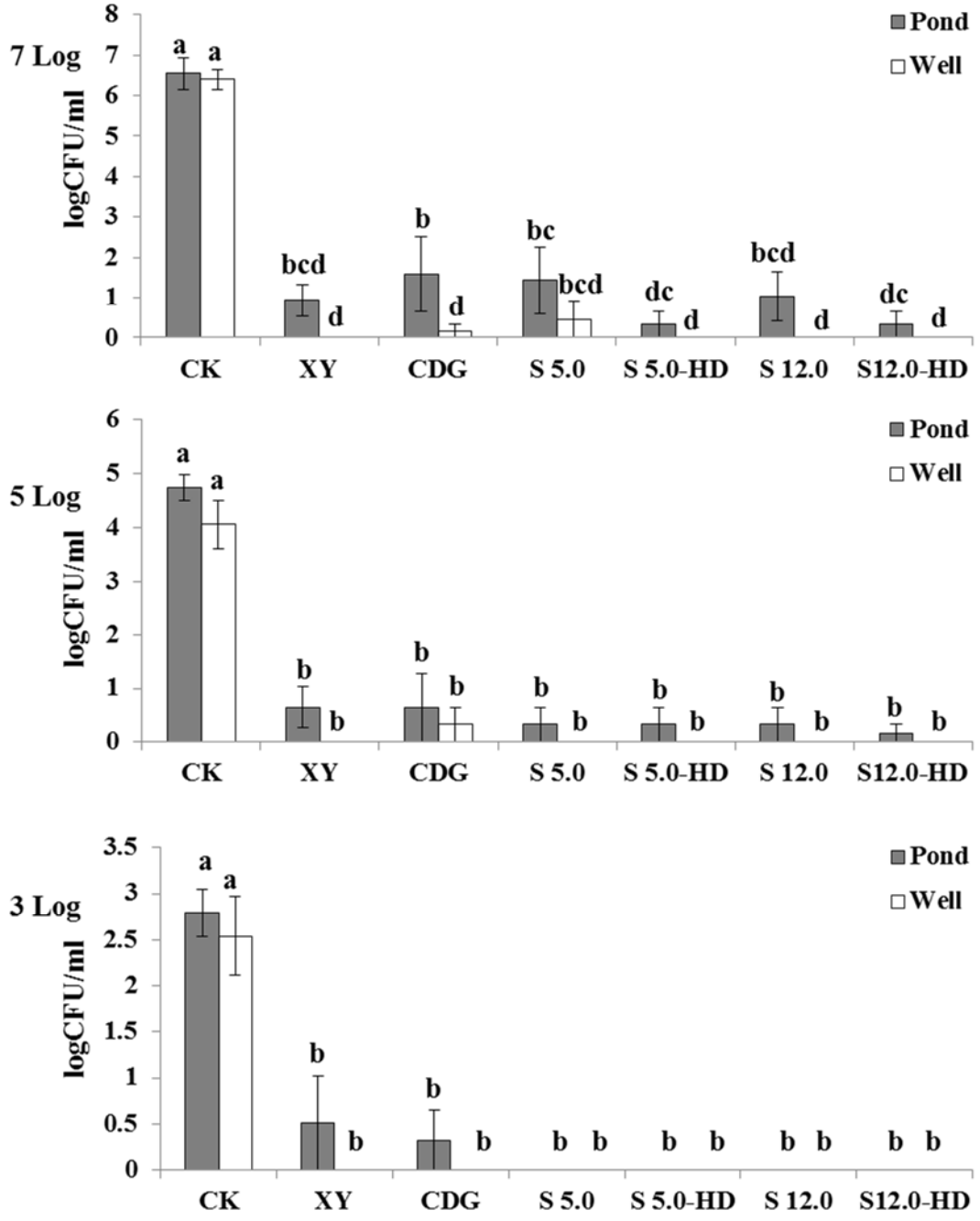
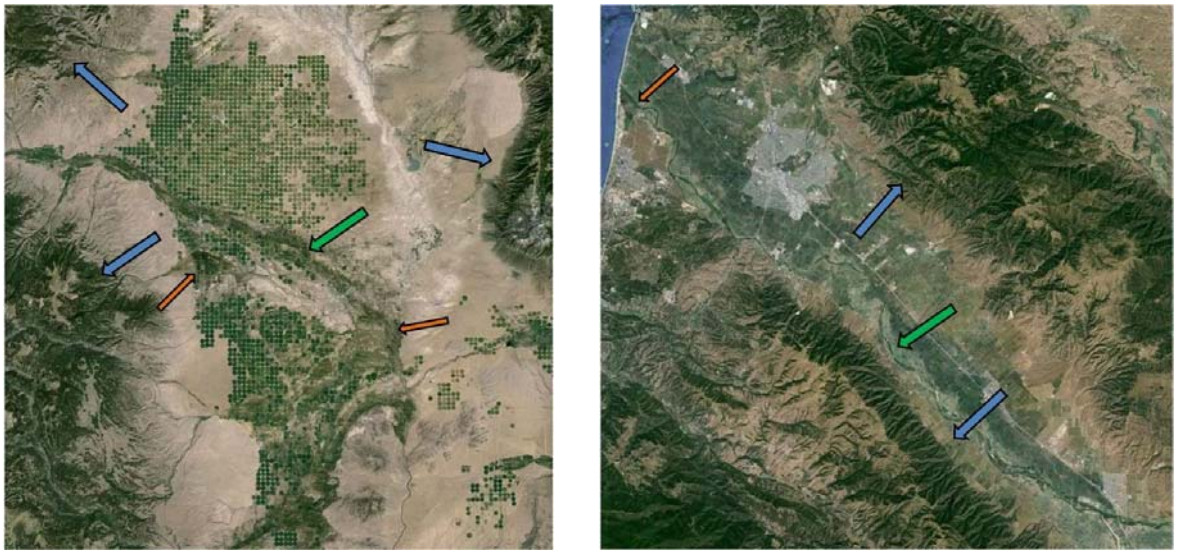


Figure 20. *Escherichia coli* O157:H7 levels after sanitization with 30 min contact time.



SCB14055 Attachment 1

Figures 1–8 and Tables 1–4



A. San Luis Valley, Colorado B. Salinas Valley, California

Figure 1. Similar landscape characteristics between two U.S. leafy-green producing areas: (A) San Luis Valley, CO, and (B) Salinas Valley, CA. Blue arrows indicate public lands, green arrows indicate riparian systems, and brown arrows indicate wildlife refuges.

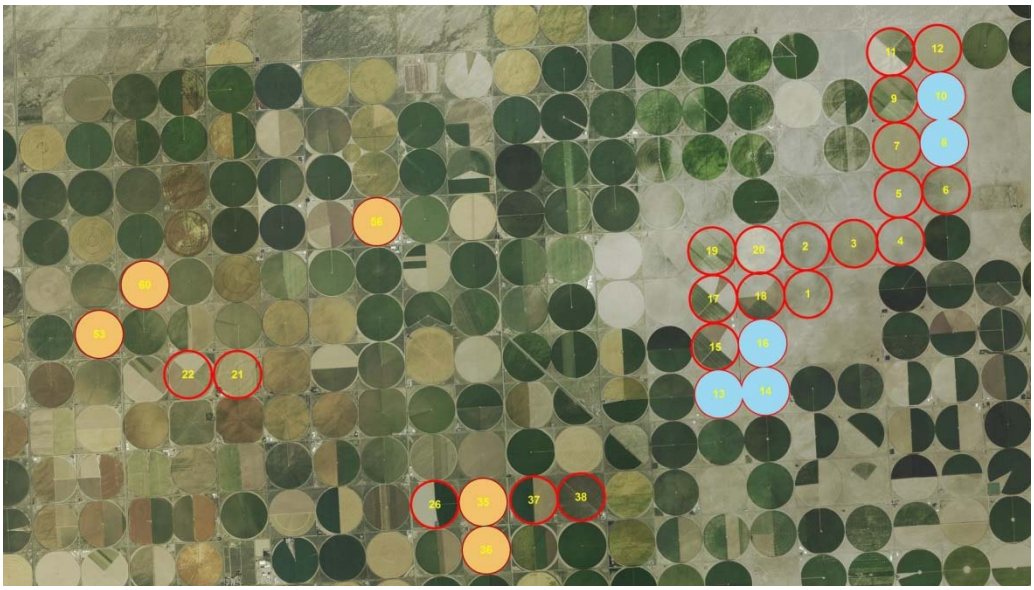


Figure 2. Crop fields sampled from June through September in two strata in the San Luis Valley, Colorado: fields in proximity to wildlife habitat (blue circles) and fields not in proximity to wildlife habitat (orange circles). Red circles indicate crop fields operated by Southern Colorado Farms.

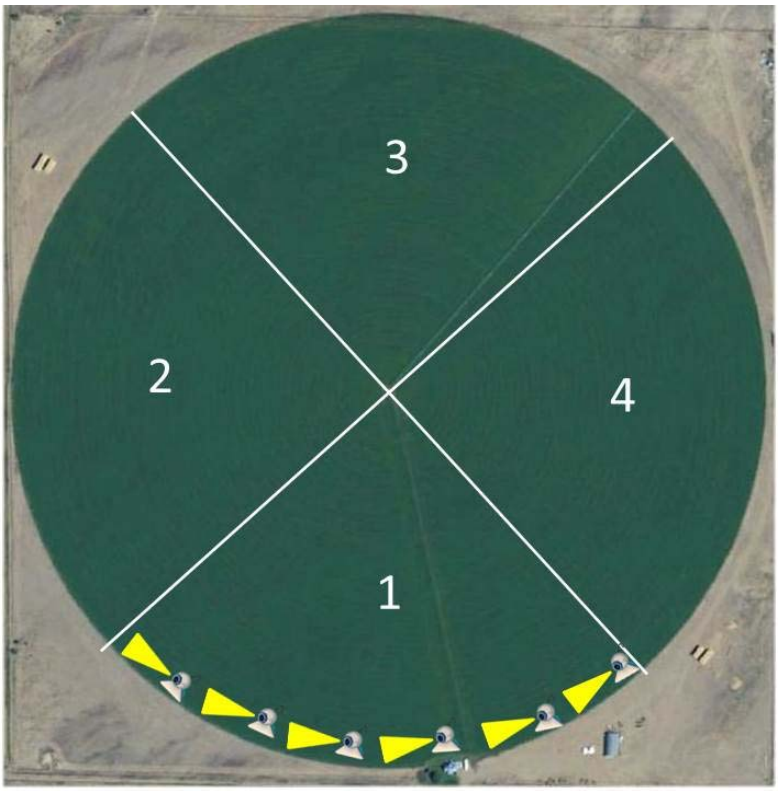


Figure 3. Sampled crop field separated into 4 subsampling quadrants, which corresponds to the planting scheme used by Southern Colorado Farms. Yellow cones in quadrant 1 represent coverage of field edge by 6 camera traps, based on camera characteristics.

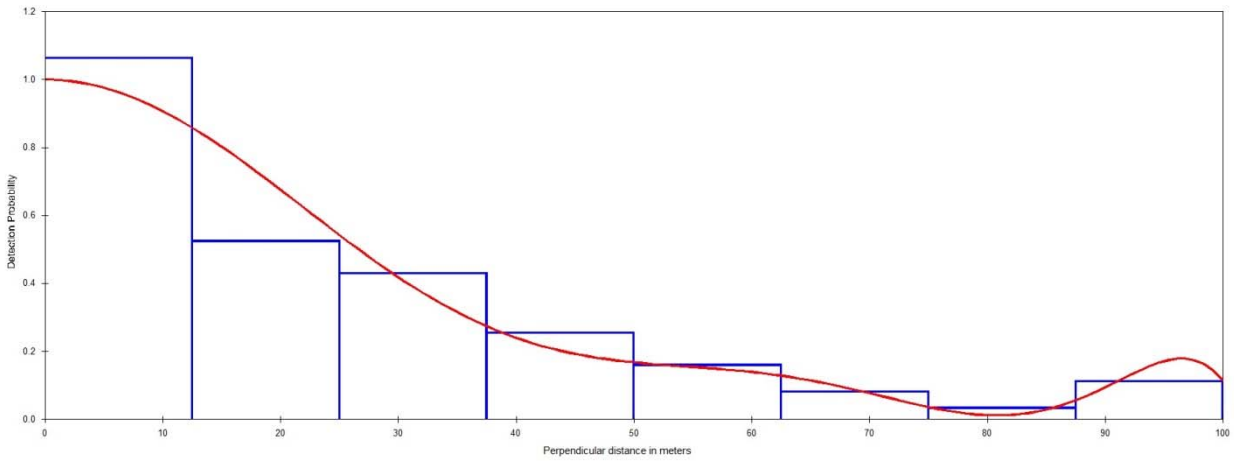


Figure 4. Example of uniform detection function with polynomial expansion fit to observed detections for Horned Larks using distance analysis of line transects.

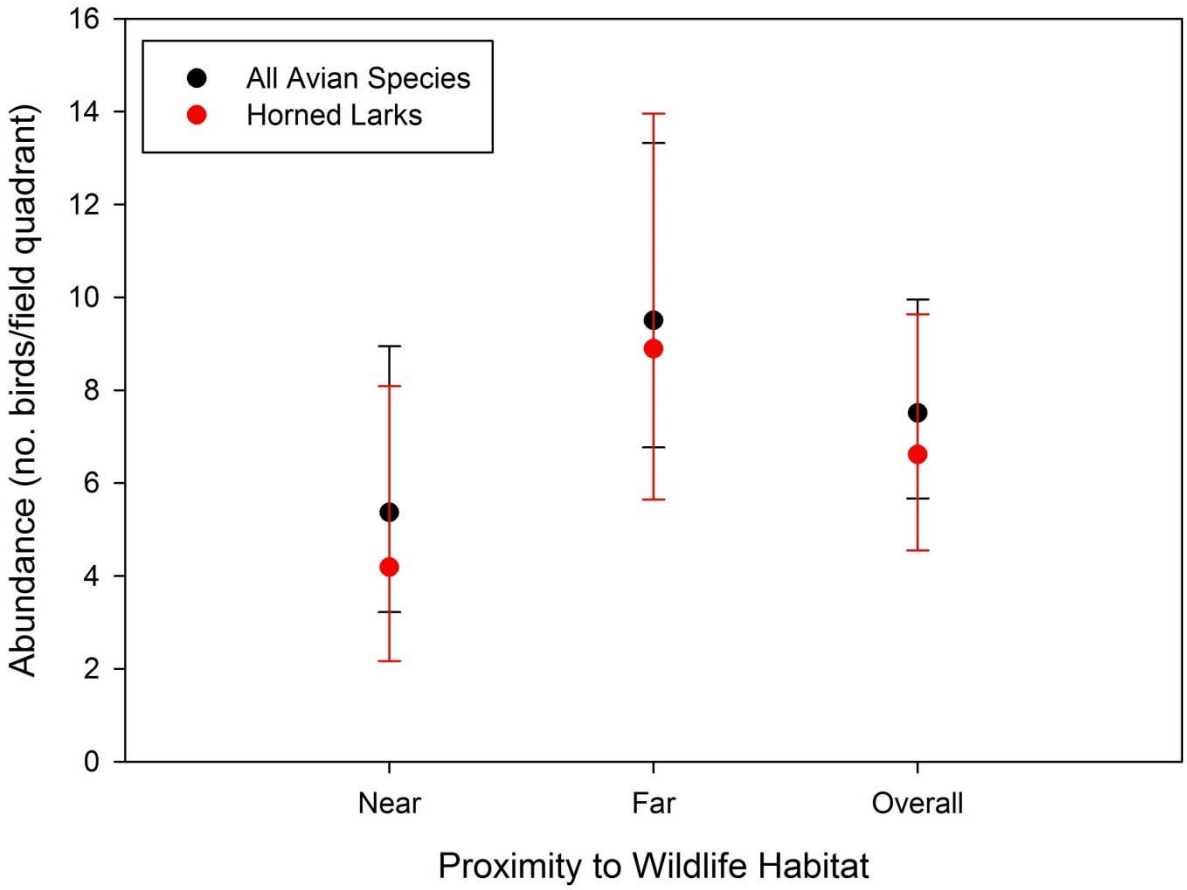


Figure 5. Abundance, with 95% confidence intervals, of all avian species and Horned Larks based on distance sampling transects in fields near wildlife habitat and further from wildlife habitat (see Figure 2).

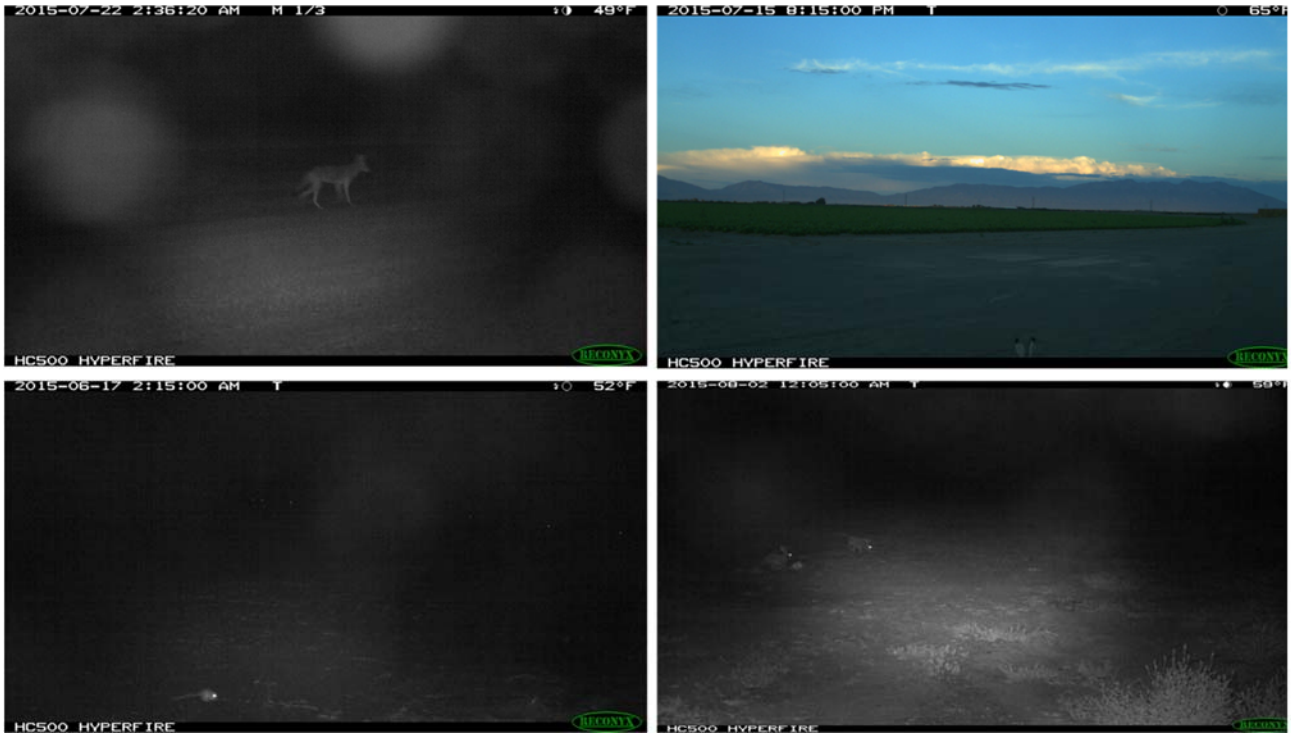


Figure 6. Select images from motion-detection/time-lapse cameras placed along field margins. Clockwise from upper left are, a coyote, jackrabbit, multiple jackrabbits in a single frame, and a kangaroo rat.



Figure 7. Coyote tracks showing movement through a lettuce field.

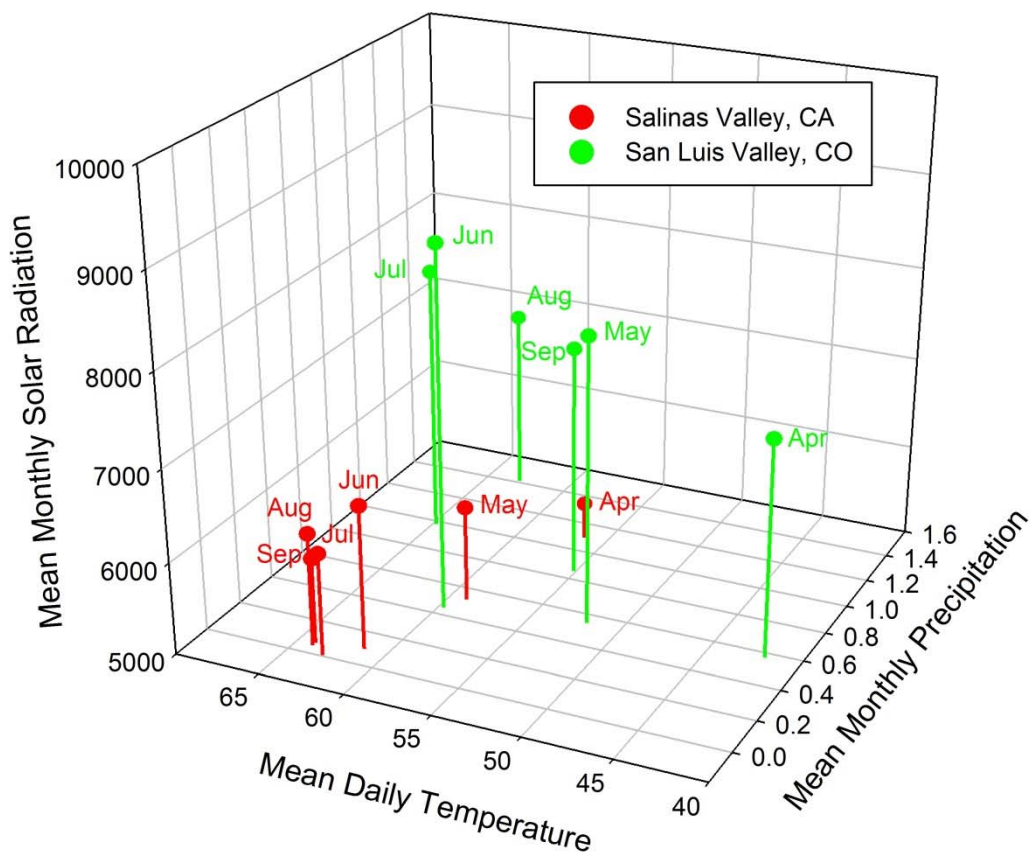


Figure 8. Comparison of climatic environment during the growing season (April–September) between the Salinas Valley, CA (red dots) and the San Luis Valley, CO (green dots) from 1991–2010. Temperature and precipitation data are from the Western Regional Climate Center (www.wrcc.dri.edu) while solar radiation data are from the National Solar Radiation Database (rredc.nrel.gov/solar/).

Attachment 1

Table 1. Bird species detected during 37 distance sampling transects in lettuce and spinach fields in the San Luis Valley, Colorado.

Species	No. Transects (*n* = 37)	% Detections (*n* = 246)
Horned Lark (*Eremophila alpestris*)	28	73.6
Barn Swallow (*Hirundo rustica*)	6	8.5
Unidentified Passerine spp.	5	4.1
Rock Dove (*Columba livia*)	2	3.7
Brewer's Blackbird (*Euphagus cyanocephalus*)	1	1.6
Common Grackle (*Quiscalus quiscula*)	2	1.6
Mourning Dove (*Zenaida macroura*)	3	1.6
Red-winged Blackbird (*Agelaius phoeniceus*)	2	1.6
Killdeer (*Charadrius vociferous*)	1	0.8
Mallard (*Anas platyrhynchos*)	1	0.8
Western Kingbird (*Tyrannus verticalis*)	2	0.8
American Crow (*Corvus brachyrhynchos*)	1	0.4
Black-billed Magpie (*Pica hudsonia*)	1	0.4
Common Raven (*Corvus corax*)	1	0.4

Table 2. Species detected in partial analysis of camera trap data from 60 cameras deployed over a 16-week period.

Group	Species	Number of Images
Carnivores		
	Coyote (*Canis latrans*)	24
	Domestic dog (*Canis domesticus*)	4
	Badger (*Taxidea taxus*)	1
	Gray fox (*Urocyon cinereoargenteus*)	2
Lagomorphs		
	Jackrabbit (*Lepus* sp.)	188
	Cottontail rabbit (*Sylvilagus* sp.)	129
	Unidentified	24
Rodents		
	Northern grasshopper mouse (*Onychomys leucogaster*)	6
	Ord's kangaroo rat (*Dipodomys ordii)*	182
	Unidentified	2775
Raptors		
	Red-tailed hawk (*Buteo jamaicensis*)	2
	Unidentified	106
Doves		
	Mourning dove (*Zenaida macroura*)	1
Passerines		
	Horned lark (*Eremophila alpestris*)	67
	Barn swallow (*Hirundo rustica*)	1
	Black-billed Magpie (*Pica hudsonia*)	9
	Unidentified	454
Plovers		
	Killdeer (*Charadrius vociferus*)	2
Corvids		
	American crow (*Corvus brachyrhynchos*)	1
	Unidentified	26
Unidentified		211
Total		4215

Attachment 1

Table 3. Laboratory results for wildlife fecal samples collected in and around crop fields in the 2015 in the San Luis Valley, Colorado.

	Samples		STEC Positive	
Species	**No.**	**%**	**Presumptive**	**Confirmed**
MAMMALS (n = 174)				
Canids	**5**	**1.4**		
Coyote (*Canis latrans*)	1			
Red Fox (*Vulpes vulpes*)	2		1	0
Unidentified Spp.	2			
Lagomporphs	**92**	**25.5**		
Black-tailed Jackrabbit (*Lepus californicus*)	13		1	0
Desert Cottontail (*Sylvilagus audubonii*)	3			
Unidentified Spp.	76		2	0
Rodents	**77**	**21.3**		
Deer Mouse (*Peromyscus maniculatus*)	9			
N. Grasshopper Mouse (*Onychomys leucogaster*)	9			
House Mouse (*Mus musculus*)	9			
Ord's Kangaroo Rat (*Dipodomys ordii*)	26			
Unidentified Spp.	24		2	0
BIRDS (n = 184)				
Raptors	**4**	**1.1**		
Burrowing Owl (*Athene cunicularia*)	2		2	0
Swainsons Hawk (*Buteo swainsoni*)	1			
Unidentified Falcon	1			
Doves	**5**	**1.4**		
Mourning Dove (*Zenaida macroura*)	2			
Rock Dove (*Columba livia*)	3		2	0
Passerines	**162**	**44.9**		
Black-billed Magpie (*Pica hudsonia*)	1		1	0
American Pipit (*Anthus rubescens*)	12			
Horned Lark (*Eremophila alpestris*)	41		1	0
European Starling (*Sturnus vulgaris*)	3			
Sage Thrasher (*Oreoscoptes montanus*)	1			
Red-winged Blackbird (*Agelaius phoeniceus*)	10			
Mountain Bluebird (*Sialia currucoides*)	1			
Western Kingbird (*Tyrannus verticalis*)	1			
Brewer's Sparrow (*Spizella breweri*)	2			
Savannah Sparrow (*Passerculus sandwichensis*)	2			
Vesper Sparrow (*Pooecetes gramineus*)	1			
White-crowned Sparrow (*Zonotrichia leucophrys*)	1			
House Sparrow (*Passer domesticus*)	1			
Unidentified Spp.	85		3	0
Unidentified	**13**	**3.6**		
UNIDENTIFIED (n = 3)		**0.8**		

Table 4. Comparison of agricultural risk factors between the Salinas Valley, California and the San Luis Valley, Colorado.

Location	Size (km^2)[a]	Cattle Density[b] ($No./km^2$)	Feral Pig Density[c] ($No./km^2$)
Salinas Valley	8,500	6.90	1.5
San Luis Valley	12,440	3.81	0.0

[a] Size of Salinas Valley represented by size of Monterey County and size of San Luis Valley by size of Alamosa, Rio Grande and Saguache Counties.
[b] Data from USDA 2012 Agricultural Census (agcensus.usda.gov).
[c] Based on estimates for the Rancho San Carlos, Monterey County, California in Sweitzer et al. (2000).

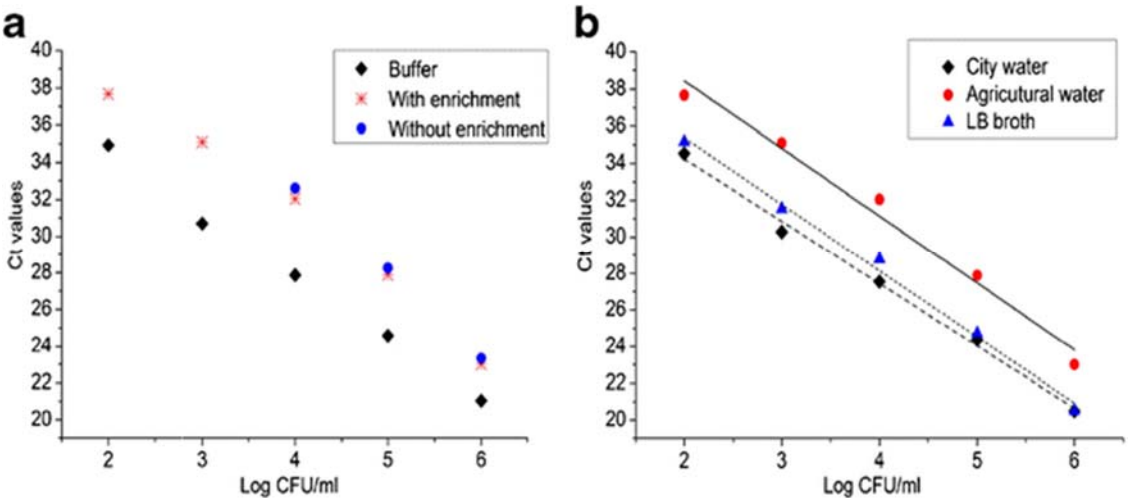


Figure 1: a) qPCR detection of artificially contaminated agricultural water samples with/without phage-based magnetic concentration. The threshold cycle value (Ct) versus the logarithmic cell number of E. coli O157:H7 in spiked agricultural water sample was higher compared to reference sample (cells spiked in PBS buffer). Direct PCR without phage-based isolation resulted in failure of amplification at lower concentrations, and paramagnetic bead (pMB) pre-concentration contributed to improve the PCR efficiency. b) Standard curves of different samples including LB broth, agricultural water, and city water with pMB magnetic separation coupled qPCR.

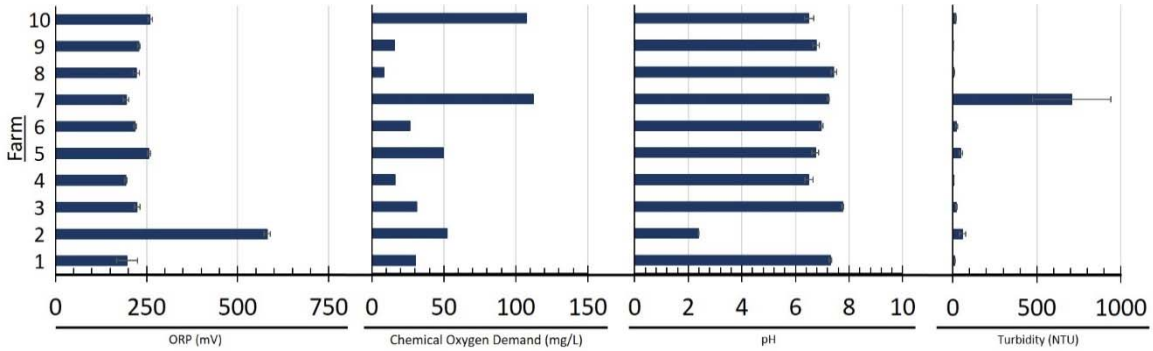


Figure 2: Agricultural water samples were analyzed from 10 farms in Western Massachusetts. The data show that while there is some degree of uniformity, outliers are evident.

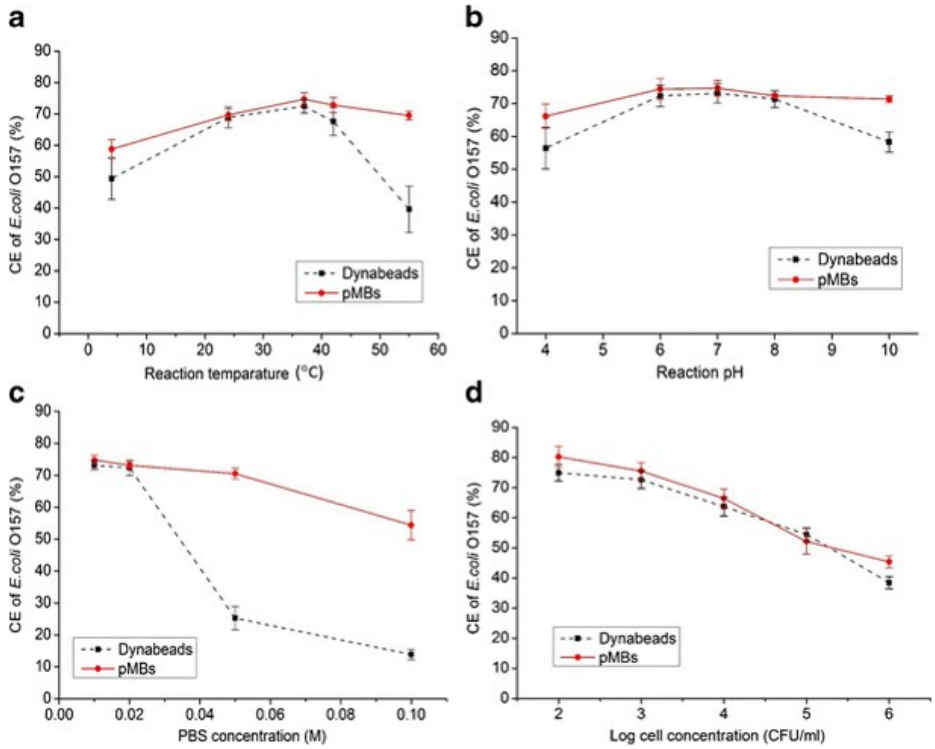


Figure 3: Phages were compared to antibodies for the magnet separation of bacteria. The influence of a) temperature, b) pH, c) salinity, and d) bacterial concentration were evaluated. The data suggests phage binding at non-biological conditions were significantly better than commercially available antibody-based kits.

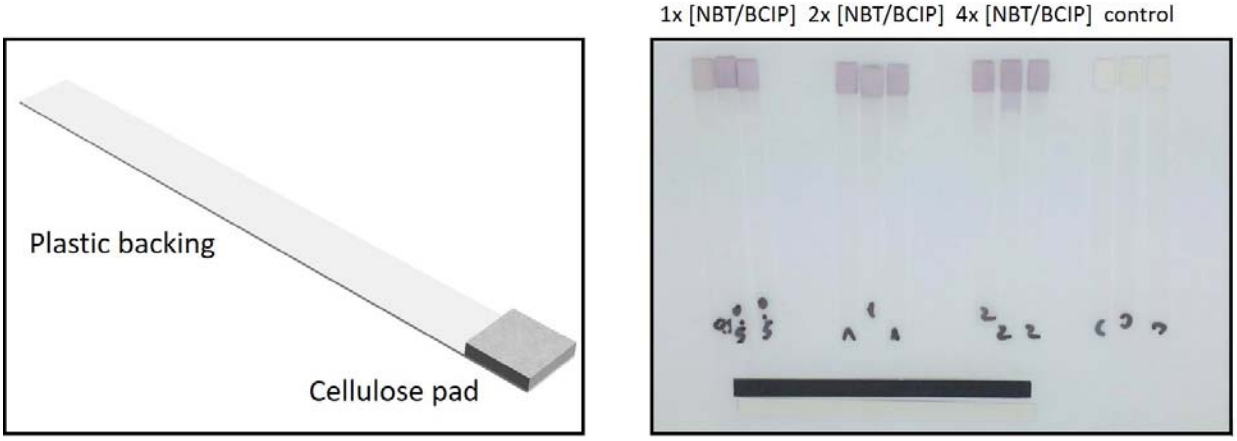


Figure 4: Dipsticks for bacterial testing. a) The dipsticks were constructed from a plastic backing and a cellulose pad. The cellulose served as the enzyme immobilization site for the assay. b) The concentration of the substrate NBT/BCIP was determined for optimal signal:noise.

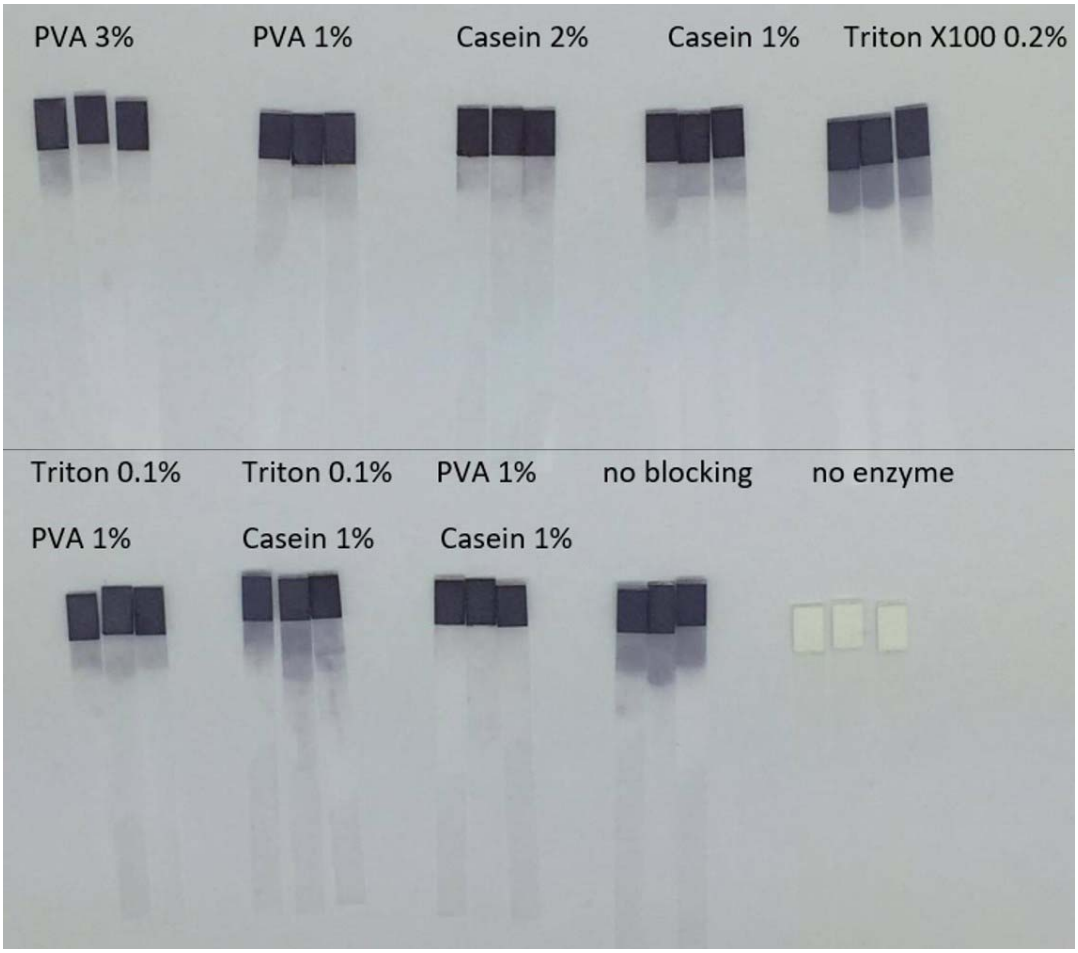


Figure 5: Blocking of the dipsticks. Various blocking solutions were evaluated for the reduction of substrate deposition on the plastic backing. This maximized the substrate deposition on the cellulose pad.

Figures 1–6 and Tables 1–2

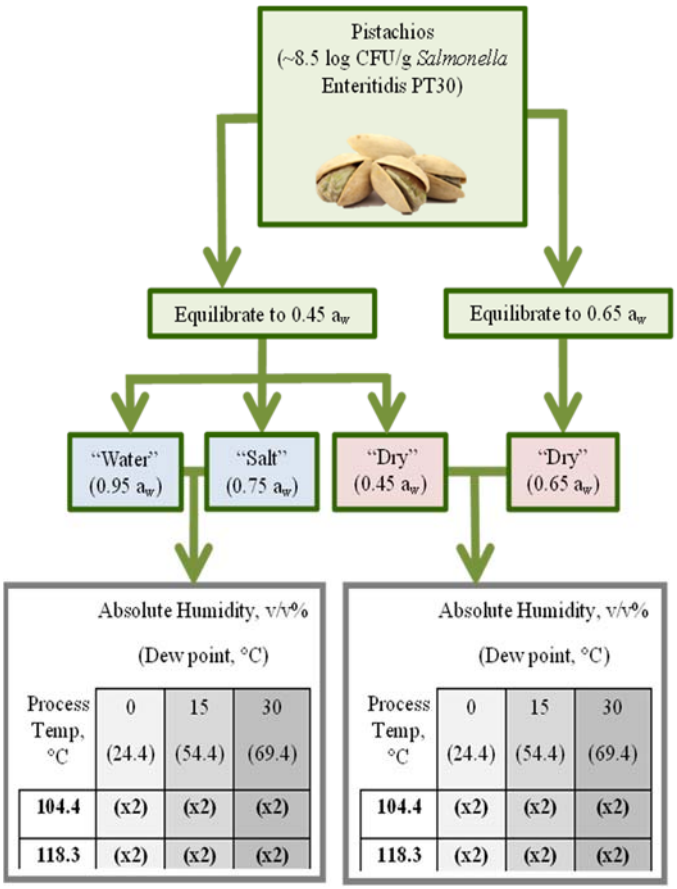


Figure 1. Overall design of lab-scale experiments, showing sample flow through inoculation, equilibration, pretreatment (i.e., "brining"), and oven conditions.



Figure 2. Inoculated pistachios in lab-scale convection oven.



Figure 3. Pilot-scale roasting/pasteurization trials.

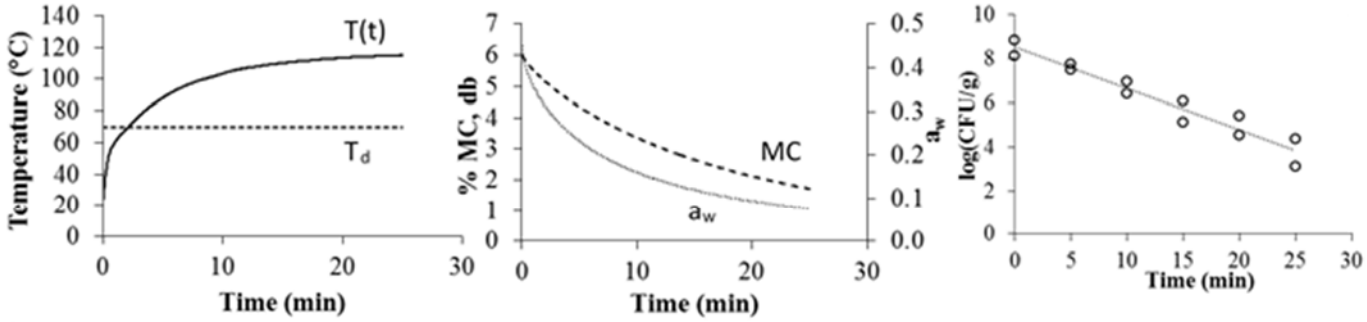


Figure 4. Example temperature (dry bulb and dew point), moisture, and *Salmonella* population changes during a lab-scale heating trial (118ºC dry bulb, 69ºC dew point).

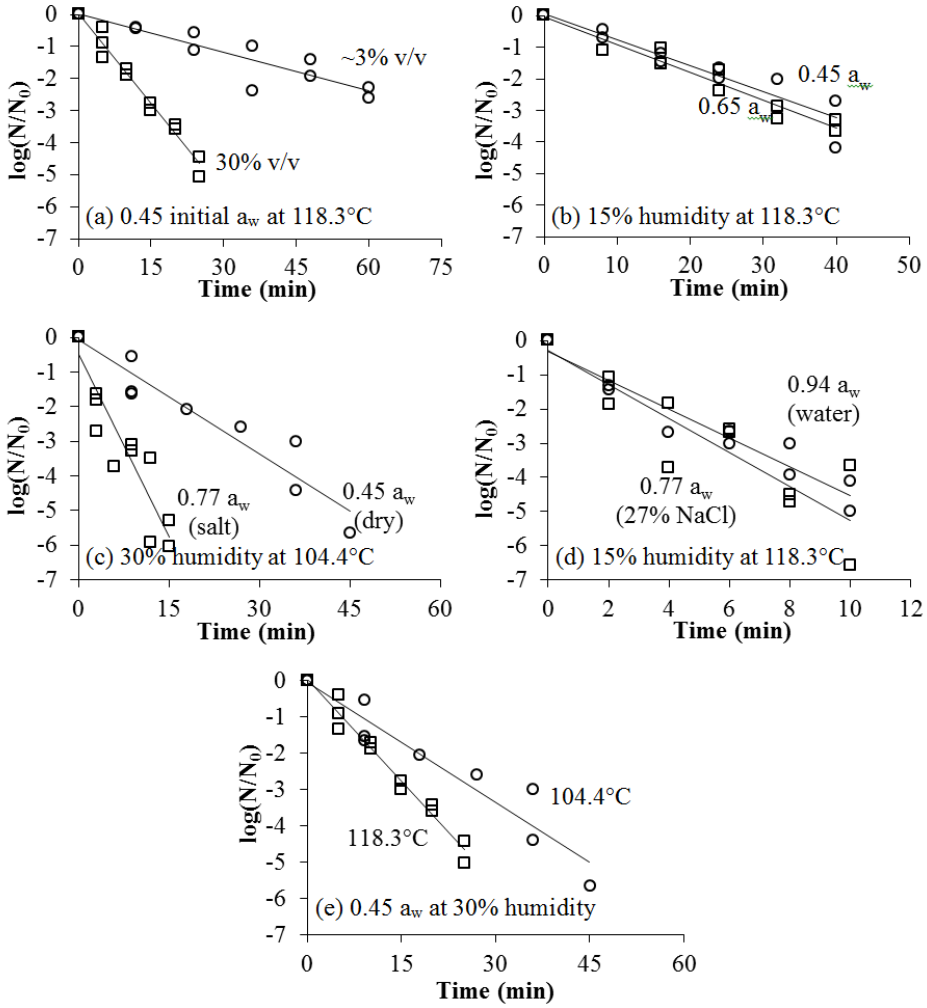


Figure 5. *Salmonella* inactivation curves comparing: (a) process humidity, (b) initial a_w for dry pistachios, (c) presoak treatment, (d) addition of NaCl to the presoaking treatment, and (e) temperature.

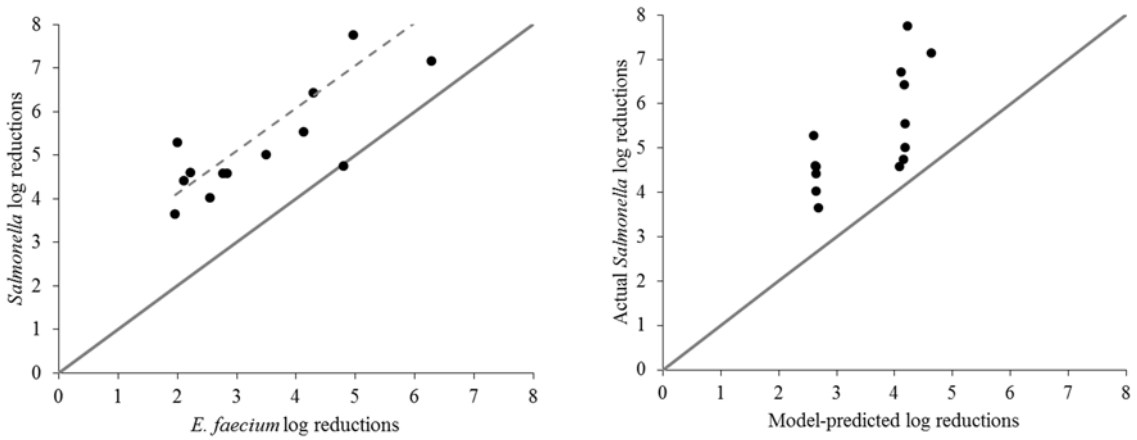


Figure 6. Comparison of actual *Salmonella* log reductions in pilot-scale roasting/heating trials to surrogate (*E. faecium*) and model-predicted lethality outcomes.

Table 1. Parameter estimates for *Salmonella* inactivation data from dry pistachios using secondary models integrated into the log-linear primary model.

Eqn	Reference Conditions	Parameter	Estimate	Percent Rel. Error	RMSE Log (CFU/g)	Mean of Residuals log(CFU/g)	AIC_c
(2)	T_{ref}=105°C $T_{d,ref}$=65°C	D_{ref} (min)	8.32	4.10	0.86	-0.36	-14.2
		z_T (°C)	19.6	8.73			
		z_M (°C)	38.2	7.99			
(3)	T_{ref}=105°C $a_{w,ref}$=0.3	D_{ref} (min)	4.12	8.64	0.95	-0.17	-8.0
		z_T (°C)	37.1	14.0			
		z_{aw}	0.26	6.59			
(4)	T_{ref}=105°C MC_{ref}=5% MC	D_{ref} (min)	5.60	6.19	0.97	-0.17	-3.7
		z_T (°C)	31.7	11.9			
		z_{MC} (%MC)	4.64	6.77			
(5)	T_{ref}=105°C $T_{d,ref}$=65°C $a_{w,ref}$=0.3	D_{ref} (min)	4.35	8.13	0.82	-0.22	-45.9
		z_T (°C)	22.1	8.37			
		z_M (°C)	70.2	13.9			
		z_{aw}	0.41	13.1			
(6)	T_{ref}=105°C $T_{d,ref}$=65°C MC_{ref}=5% MC	D_{ref} (min)	5.78	5.94	0.83	-0.23	-41.9
		z_T (°C)	22.0	8.13			
		z_M (°C)	67.6	14.0			
		z_{MC} (%MC)	8.54	16.1			

Table 2. Parameter estimates for *Salmonella* inactivation data from presoaked (brined) pistachios using secondary models integrated into the log-linear primary model.

Eqn	Reference Conditions	Parameter	Estimate	Percent Rel. Error	RMSE Log (CFU/g)	Mean of Residuals	AIC_c
(3)	T_{ref}=80°C $T_{d,ref}$=65°C	D_{ref} (min)	3.42	4.31	1.02	-0.22	11.6
		z_T (°C)	92.2	26.3			
		z_M (°C)	55.8	6.22			
(4)	T_{ref}=80°C $a_{w,ref}$=0.7	D_{ref} (min)	4.31	3.99	1.06	-0.13	23.0
		z_T (°C)	181	42.4			
		z_{aw}	0.50	7.22			
(5)	T_{ref}=80°C MC_{ref}=10	D_{ref} (min)	No results (failure to converge)				
		z_T (°C)					
		z_{MC} (%MC)					
(6)	T_{ref}=80°C $T_{d,ref}$=65°C $a_{w,ref}$=0.7	D_{ref} (min)	3.43	3.97	0.93	-0.13	-14.9
		z_T (°C)	98.0	23.1			
		z_M (°C)	99.8	15.4			
		z_{aw}	0.96	18.4			
(7)	T_{ref}=80°C $T_{d,ref}$=65°C MC_{ref}=10	D_{ref} (min)	4.42	5.39	0.89	-0.11	-25.6
		z_T (°C)	77.9	17.9			
		z_M (°C)	74.3	7.02			
		z_{MC} (%MC)	24.0	13.2			

CALIFORNIA SPECIALTY CROPS
Final Report Retail Promotion

Executive Summary

Imalinx coordinated the 2017 Retail Promotion for California Specialty Crops in Mexico City. The promotion consisted in sampling days in Walmart, for the store formats of Supercenter Walmart and Superama. These activities included PoS material and tastings of five main specialty crops: peaches, pears, nectarines, almonds and pistachios.

A total of 32 stores were activated during the promotion, accounting for a total of 393 sampling days. The length of the promotion lasted 31 days and activities were executed mainly during weekends due to the increased flow of customers attending supermarkets those days.

Preliminary Activities

Imalinx and CDFA defined the Retail Promotion since the first half of 2017, defining Mexico City as target market due to the high concentration of the total population. First, Imalinx provided a presentation for the buyers of Walmart to agree on the execution of the promotion. Imalinx then coordinated the logistics of the promotion, through direct contact with the buyers of Walmart for all the categories of the products being sampled. With bilateral agreement, the 32 stores were selected, which provide the best stores according to locations, sales and customer flow.

Imalinx developed PoS material with a focus on California Specialty Crops and CA Grown. Additionally, the company provided two training sessions for demo girls to provide information about California Specialty Crops, the benefits of the products, availability and about California in general to increase consumer awareness and product visibility.

Additionally, Imalinx was part of store checks to monitor sampling days in Mexico City to coordinate any potential issues regarding absences. During tastings, surveys were implemented to increase knowledge on the market of Californian products in Mexico.

Execution

As mentioned before, the Retail Promotion covered 32 stores. The itinerary for the promotion was executed as following:

CALIFORNIA SPECIALTY CROPS

Retail Promotion 2017 - Tastings of peaches, pears, nectarines, plums, almonds and pistachios.

				AUGUST						SEPTEMBER																												
				WEEK 1						WEEK 2							WEEK 3							WEEK 4							WEEK 5						
				M	M	J	V	S	D	L	M	M	J	V	S	D	L	M	M	J	V	S	D	L	M	M	J	V	S	D	L	M	M	J	V	S	
				28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
	CHAIN	STORE	NUMBER		4			4	16	14	10				7	13	13	6			18		31	33	15							33	40	45	46	45	393
1	WALMART	TOREO			2				2	2	2												2	2	2						1	2	2	2	2	
2	WALMART	MIRAMONTES	2464						2														1	1	1											
3	WALMART	TAXQUEÑA	3848						2	2	2												2	2	2						2	2	2	2	2	
4	WALMART	VILLA COAPA	3857						2	1	2												2	2	2											
5	WALMART	TORRES LINDAVISTA	3877						2	2	2					2	2	2														2	2	2	2	
6	WALMART	LAS AGUILAS	3876						2	2	2					1	1	1													2	2	2	2	2	
7	WALMART	CUAJIMALPA	3858																												2	2	2	2	2	
8	WALMART	UNIVERSIDAD	3845													2	2	2					2	2	2						2	1	2	2	2	
9	WALMART	FELIX CUEVAS	2689													1	1	1					1	1	1						2	2	2	2	2	
10	WALMART	PATIO SANTA FE	1770																				2	2	2											
11	WALMART	PERIFERICO SUR	3863																				1	1	1											
12	WALMART	TEPEYAC	2345																				2	2	2						2	2	2	2	2	
13	WALMART	BUENAVISTA	3846																												2	2	2	2	2	
14	WALMART	TLALPAN	2670																												1	1	2	2	2	
15	WALMART	PLATEROS	3852																													2	2			
16	WALMART	PLAZA ORIENTE	2033																												2	2	1	2	2	
17	WALMART	AZCAPOTZALCO	3862																													2	2	2	2	
18	SUPERAMA	SUPERAMA GRAN POLANCO	3481		2			1	2	2											2		2	2							2	2	2	2	2	
19	SUPERAMA	FUENTES DEL PEDREGAL	3896					1	1	1											2		2	2							1	2	2	2	2	
20	SUPERAMA	ORADORES	3824																		2			2												
21	SUPERAMA	ESMERALDA	3849					2	1	2					1	1	1				2		2	2							2	2	2	2	2	
22	SUPERAMA	SANTA FE	3881												1	1	1																			
23	SUPERAMA	SUPERAMA GEORGIA	3817												2	2	2																			
24	SUPERAMA	DEL VALLE NORTE	3223												1	1	1				2		2	2												
25	SUPERAMA	SUPERAMA PARQUES POLANCO	3025												2	2	2				2		2	2							2	2	2	2	2	
26	SUPERAMA	SUPERAMA HOMERO	3832																		2		2	2							2	2	2	2	2	
27	SUPERAMA	SUPERAMA LOS MORALES	3828																		2		2	2							2	2	2	2	2	
28	SUPERAMA	SUPERAMA HORACIO	3811																		2		2	2							2	2	2	2	2	
29	SUPERAMA	SUPERAMA DAKOTA	3480																												2	2	2	2	2	
30	SUPERAMA	COPILCO	2430																														2	2	1	
31	WALMART	CUITLAHUAC																																2	2	
32	SUPERAMA	CALZADA DE LOS LEONES																															2	2	2	

PoS Material

The following materials were developed or introduced within stores to promote California Specialty Crops.

PRINTED MATERIAL – Brochures highlighting the different specialty crops from California, recipes for cling peaches, properties of pears and magazines of California.







STICKERS – Stickers were implemented within the tasted products and in the products located in baskets and racks. The objective of this was to increase visibility of California products within stores to allow consumers to easily trace California products.





STOPPERS – Stoppers increased decorations of the baskets and racks where California products were sampled. This in order to increase visibility and to incentivize consumers to approach to the tastings and products.







Communications and Advertising

NEWSLETTERS – To invite customers to the Retail Promotion and communicate the activated stores, newsletters were sent to a large base of consumers. The open rate of the newsletters was 13%, 3% more than the average in the industry.



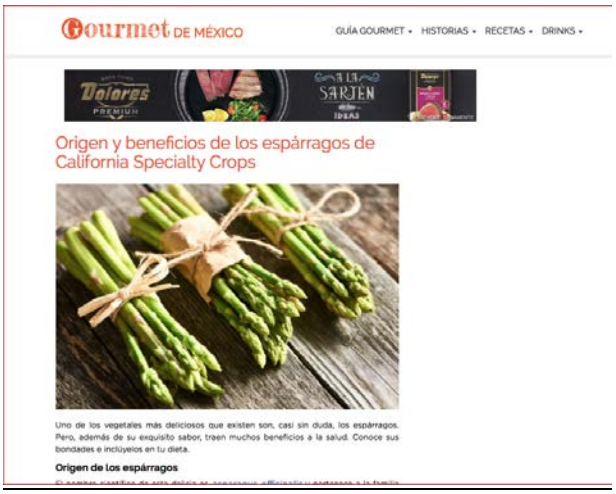
ADVERTISING – To increase visibility and awareness of consumers of California products.

- **Forward Travel:** post on social media and publication at webpage.
    - **Links:**
        - http://revistaforward.com.mx/experiencias/ecoturismo/visitar-granjas-en-california-una-experiencia-para-viajeros
    - **Total Reach:**
        - Twitter: 5,821
        - Facebook: 20,533
        - Publications: 87,000





- **El Gourmet:** post on social media and publication at webpage.
    - **Links:**
        - http://gourmetdemexico.com.mx/recetas/primer-tiempo/mousse-de-salmon-y-peras-por-california-grown
        - http://gourmetdemexico.com.mx/historias/gourmetips/origen-y-beneficios-de-los-esparragos-de-california-specialty-crops
        - http://gourmetdemexico.com.mx/historias/gourmetips/origen-y-beneficios-de-los-esparragos-de-california-specialty-crops
    - **Total Reach:**
        - Twitter: 41,500
        - Facebook: 52,120
        - Publications: 172,000


Gourmet DE MÉXICO
GUÍA GOURMET
HISTORIAS
RECETAS
DRINKS
Origen y beneficios de los espárragos de California Specialty Crops
Origen de los espárragos

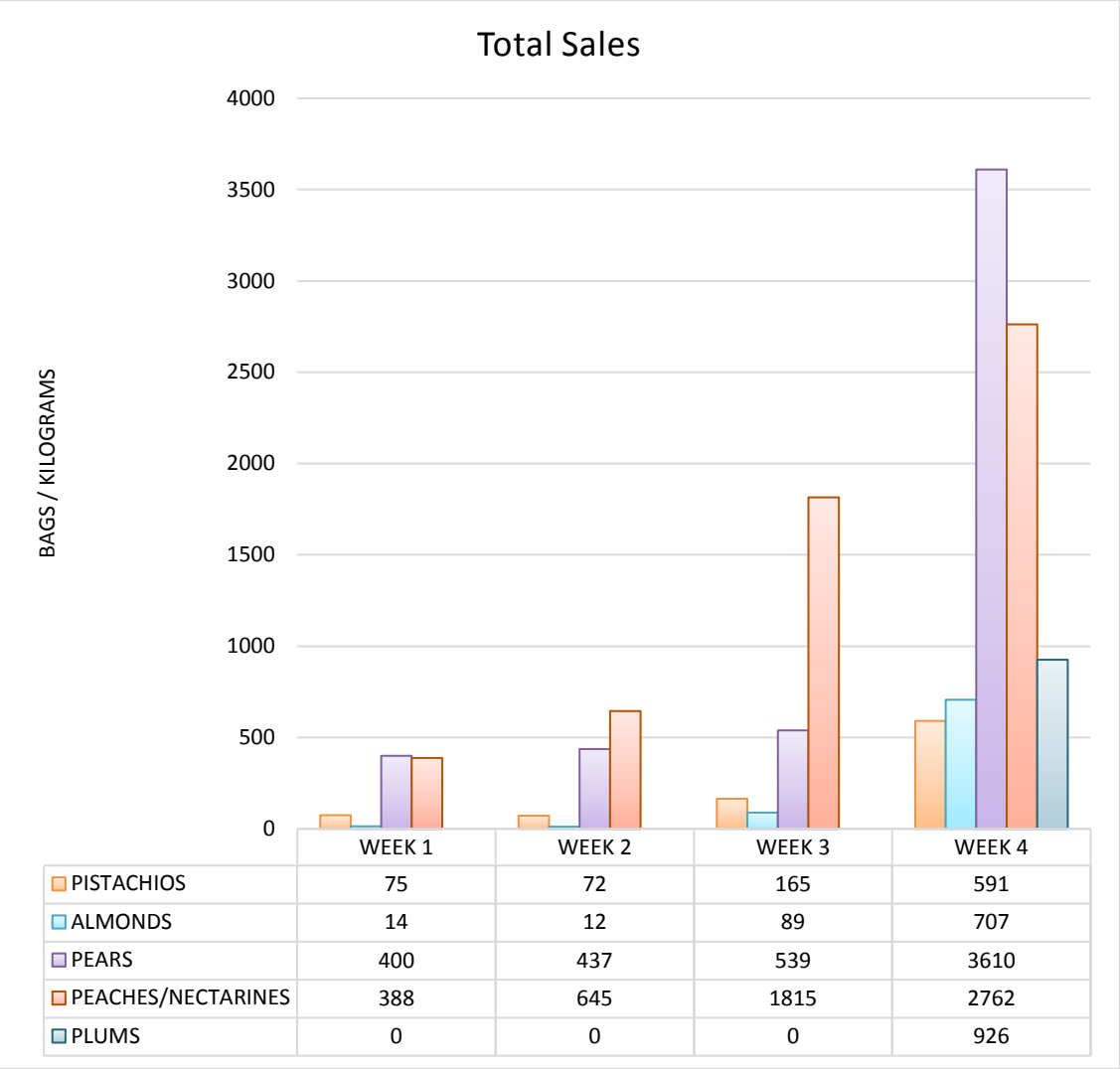

Origen y beneficios
ESPÁRRAGOS*
Los espárragos de California son ricos en vitaminas C, K y ácido fólico.
Previenen el cáncer y fortalecen los vasos sanguíneos.
¡Da clic al enlace y conoce más!
*Por California Specialty Crop


TELCEL
16:24
55%
Gourmet de México
11,568 Tweets
Tweets
Tweets y respuestas
Multimedia
Gourmet de México @gourme... · 1h
Hoy es un buen día para cocinar este rico mousse de salmón con pera. @CAGrownPin nos comparte la receta. bit.ly/mousse-
Mousse
DE SALMÓN Y PERAS POR CALIFORNIA SPECIALTY CROPS*
4 porciones
INGREDIENTES
PARA EL MOUSSE
1/2 tza de agua
25 g de grenetina
200 g de salmón ahumado
250 g de yogurt natural
2 tza de crema para batir


Gourmet de México Promocionar
Gourmet de México con California Grown.
Publicado por Alina Hernández Navarro
1 h · Patrocinado ·
Una delicia pequeña para alegrar el día. Intenta este mousse de salmón y peras para consentirte. 👉 http://bit.ly/mousse-
Mousse
DE SALMÓN Y PERAS POR CALIFORNIA SPECIALTY CROPS*
4 porciones
INGREDIENTES
PARA EL MOUSSE
1/2 tza de agua
25 g de grenetina
200 g de salmón ahumado
250 g de yogurt natural
2 tza de crema para batir
Da click en el enlace y descubre todos los ingredientes y su preparación.

Total Sampling and Sales

During the Retail Promotion, 19,600 tastings of dried fruit were offered. For fresh fruit, 38,000 were provided. The following table provides total sales for each product for every week of the promotion. For dried fruit, bags is the unit of measure whereas for fresh fruit is kilograms.



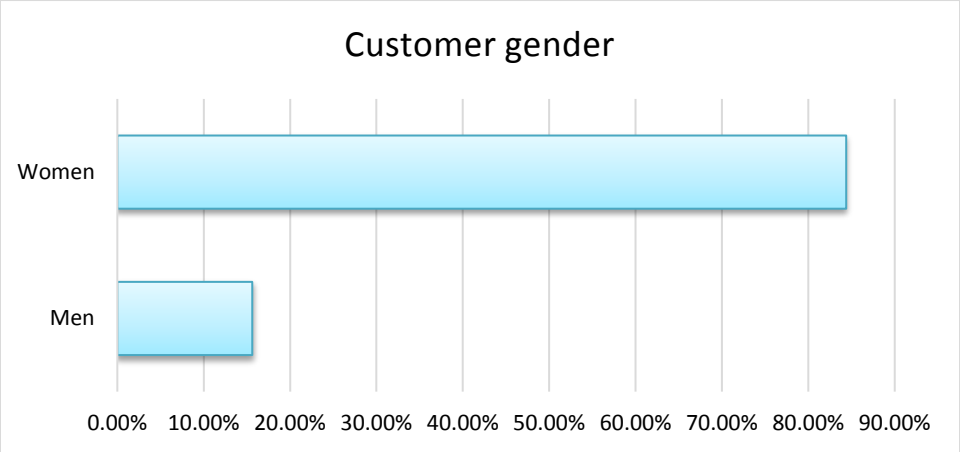
	WEEK 1	WEEK 2	WEEK 3	WEEK 4
PISTACHIOS	75	72	165	591
ALMONDS	14	12	89	707
PEARS	400	437	539	3610
PEACHES/NECTARINES	388	645	1815	2762
PLUMS	0	0	0	926

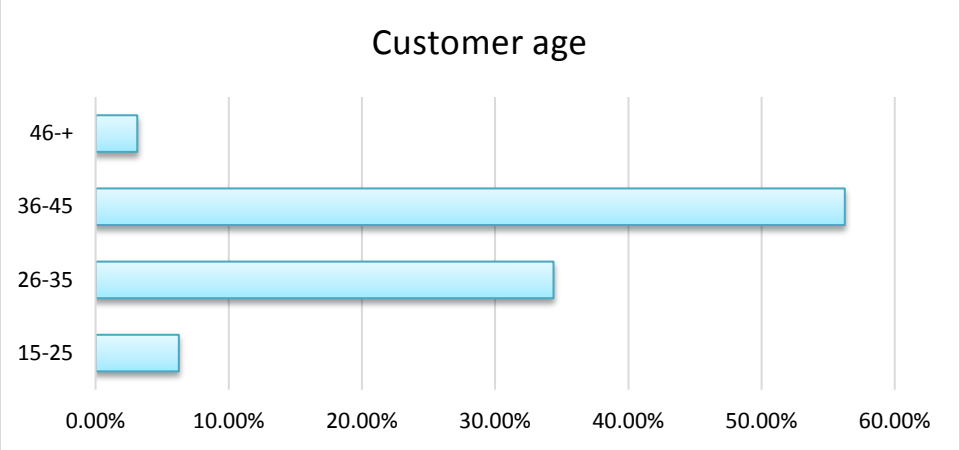
For further information on total sales, please refer to Appendix 1.

Surveys for California Products

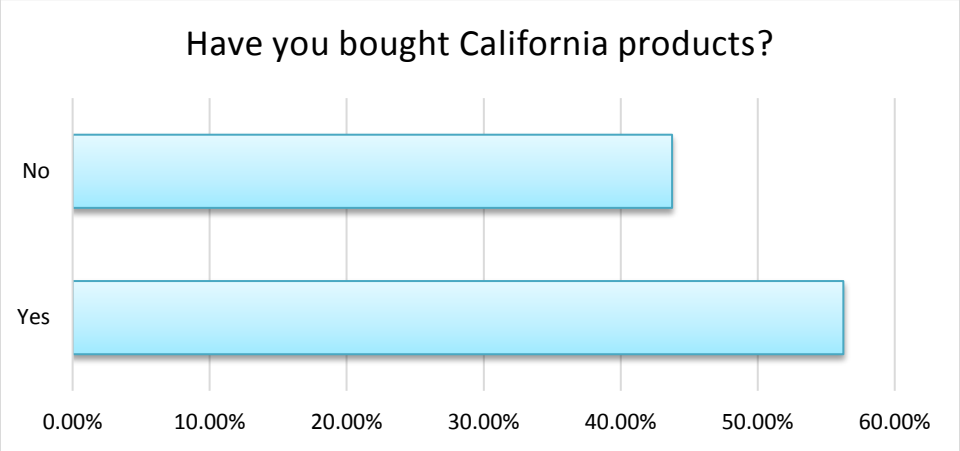
During the promotion, several surveys were implemented to generate information regarding the market and consumers' awareness on California products. The following section provides further information on the results.

From the total surveys, 84% of consumers surveyed were women between the age of 36-45 years old.

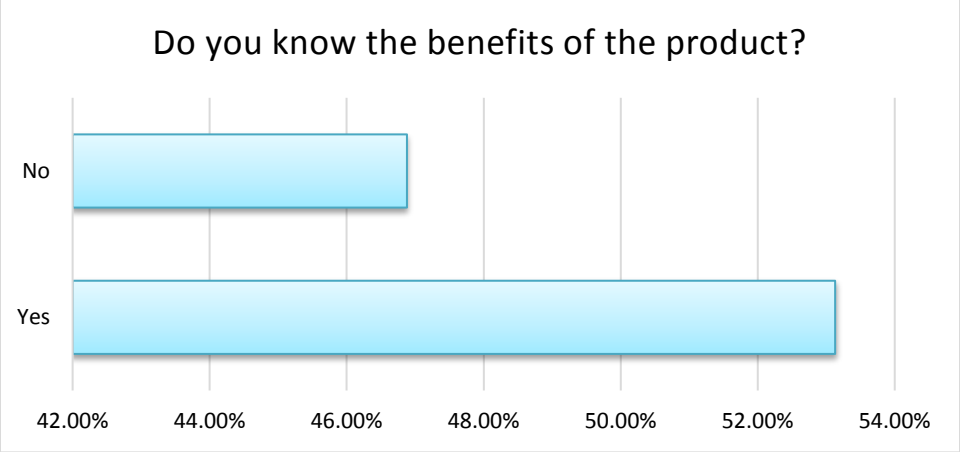




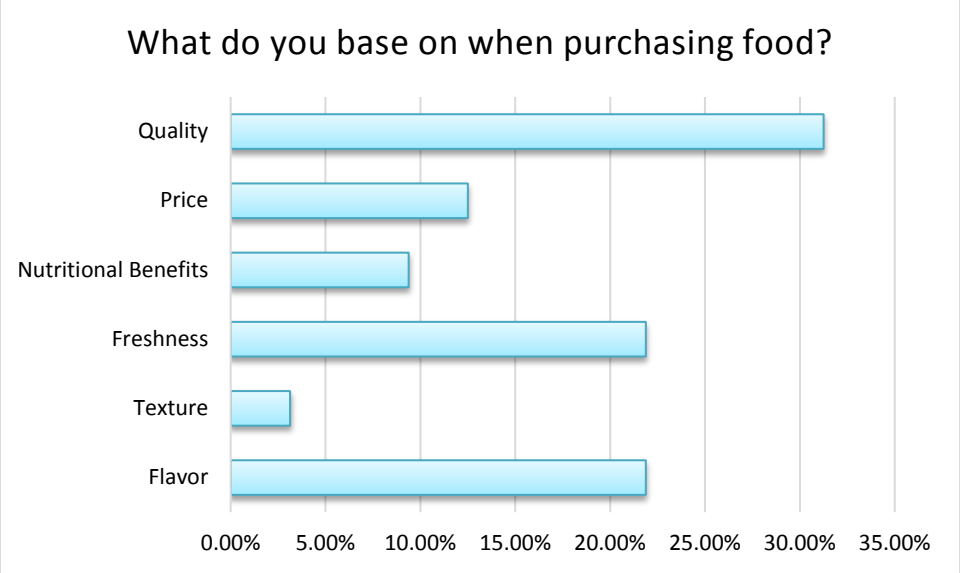
56% of customers mention they have already bought California products including pistachios, pears and wines.



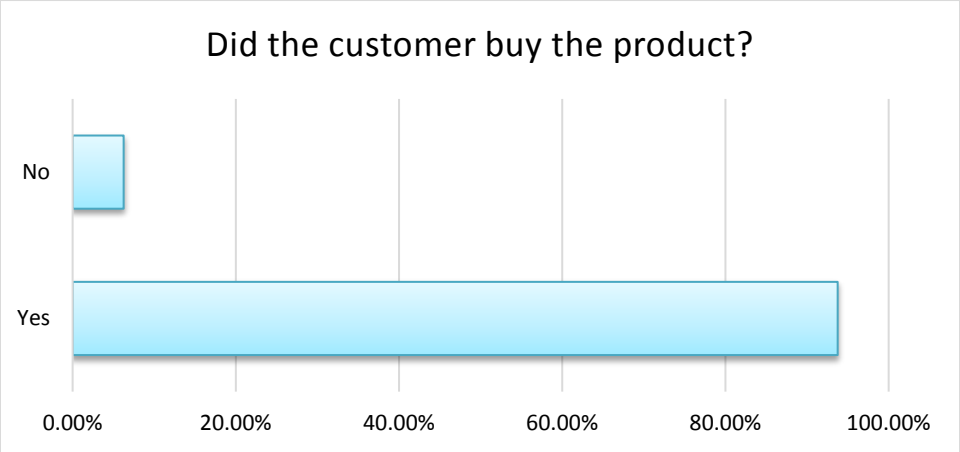
From the total customers surveyed, 53% of the clients argue that they already know the benefits of the product. Some characteristics for fresh fruits included high in vitamins, whereas in dried fruits included low calories, rich in fiber and minerals.



Clients put quality as the most important factor when purchasing food, followed by flavor and then freshness.



Thanks to the tastings, 94% of customers bought California products after trying the product.



Conclusions and Recommendations

- We recommend repeating Mexico City in any other Retail Promotion due to its importance in the Mexican market and its high levels of population.
- Focusing the Retail Promotion to one product or one category could ensure wider penetration to the market and smoother operations.
- Overall, total sales accounted for the following: pistachios 903 bags, almonds 822 bags, pears 4986 kilograms, peaches/nectarines 5610 kilograms and plums 926 kilograms.