FERTILIZER RESEARCH AND EDUCATION PROGRAM
FREP

Proceedings

October 28-30, 2019 • Fresno, California

California Department of Food and Agriculture
Fertilizer Research and Education Program
Twenty Seventh Annual Conference

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Twenty Seventh Annual Conference

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Note:
The summaries in this publication are the results of projects in progress and have not been subjected to independent scientific review.

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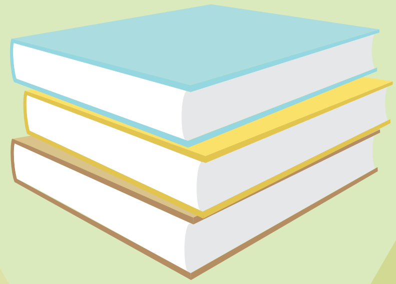
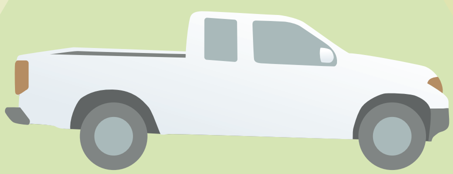




INTRODUCTION

Fertilizer Research and Education Program

Welcome to the California Department of Food and Agriculture's (CDFA) Fertilizer Research and Education Program (FREP) and Western Plant Health Association (WPHA) Annual Nutrient Management Conference. Over the last 27 years, this conference has provided a forum where grant recipients report findings from FREP-funded projects and for industry representatives to share valuable nutrient management information with an audience of crop advisors, growers, researchers, and other agricultural professionals.

Each year we strive to evolve our approach to the annual conference to best meet the changing needs of the agricultural community. This year we are introducing a new opportunity for attendees to engage in smaller breakouts with our Nitrogen and Irrigation Management Planning Workshops. Additionally, students have a new opportunity at our conference to participate in an academic poster competition. We encourage attendees and competitors to use this space to network and absorb information on current research projects regarding irrigation and nutrient management in California agriculture.

27th Annual FREP WPHA Conference

During the conference this year, we will hear from researchers and industry representatives from across the state on the latest developments and ideas in nutrient and irrigation management. Of the researchers speaking, four will be presenting their findings from FREP-funded projects.

Dr. Michael Cahn, University of California Cooperative Extension irrigation and water resources Farm Advisor, started CropManage, a web-based irrigation and nitrogen management application, with a FREP grant in 2011. Initially focused on coastal vegetable crops, CropManage is now available for a variety of other crops, including several grown in the Central Valley (See page 20). Dr. Cahn will provide an overview of the CropManage program and discuss how it is being adapted to Central Valley cropping systems.

Dr. Douglas Amaral, a Postdoctoral Scientist at the University of California, Davis, will speak about his project with Dr. Patrick Brown, developing nutrient demand curves and an early leaf sampling model for citrus. The research they are performing will create a phenology-based nutrient prediction model for mandarin and orange.

Dr. Suduan Gao will present her FREP-funded research, in which she looks at different kinds of biochar as potential amendments to improve nitrogen (N) and water management in California agriculture.

Trina Walley will speak about her work with growers on irrigation system maintenance and improving distribution uniformity. Irrigation management profoundly influences nutrient management, and this project helps growers maximize the performance of these systems to minimize nutrient losses.

Past Research

Since 1991, CDFA has committed over 19 million dollars in nutrient management research, outreach, and the development of decision support tools. These projects span various topics on many of the hundreds of commodities grown in California, across many regions (Figures 1-2).

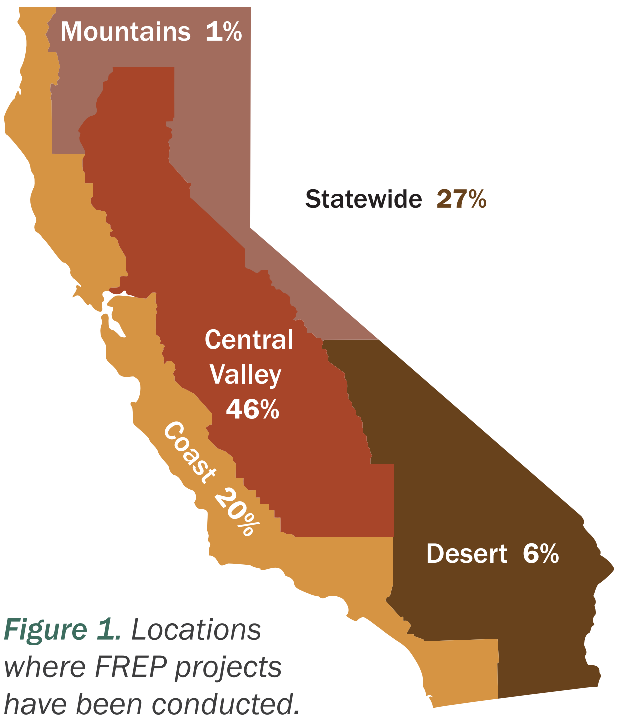


Figure 1. Locations where FREP projects have been conducted.

An important resource that FREP-funded projects have yielded is the Crop Fertilization Guidelines (cdfa.ca.gov/go/FREPguide). These guidelines provide insight to nutrient management for the most widespread irrigated crops in California, based on crop development stage. Many agricultural consultants and growers refer to the online guidelines when making recommendations and decisions about fertilizer applications. FREP has adapted the nitrogen management information from the Fertilization Guidelines into trifold pamphlets. If you would like to make these printed pamphlets available to your clients or at your meeting or conference, send a request to FREP at FREP@cdfa.ca.gov.

Present Projects

FREP is currently funding over twenty-five innovative projects to progress the agronomically safe and environmentally sound use of fertilizing materials. These projects help us better understand grower decision making, provide important technical trainings, and glean more information about fertilizer and irrigation management in California crops.

In the Central Valley, Dr. Mark Lubell and Dr. Patrick Brown are conducting research to better understand key influences and barri-

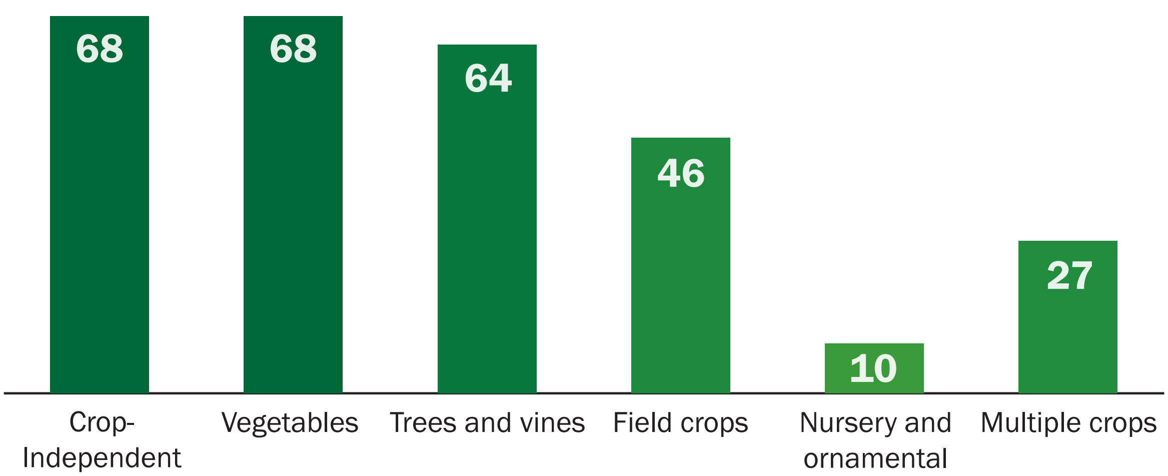


Figure 2. Distribution of FREP-funded projects by commodity.

ers to adoption of improved N management practices through extensive surveys and interviews with growers and crop consultants. Preliminary results show that growers' uncertainty about the success of new practices is the most common challenge to adoption, especially on smaller farms.

On the Central Coast, Dr. William Horwath is researching nutrient release dynamics from organic fertilizers. He is characterizing the temperature response of N mineralization of organic fertilizers in a variety of California soils and using these data to model long-term N availability.

Across California, Dr. Loren Oki and his team have been conducting nutrient management workshops in Spanish and English for nursery and greenhouse growers. Fertilizer management can be very different due to the substrate and containers plants are grown in. These trainings show growers how to achieve optimal plant nutrition in container plants.

Future of FREP

In the California low desert, Dr. Jairo Diaz and his team started researching onion development under drip irrigation. This will be a three-year project, focusing on different fertilizer application rates and irrigation management practices.

To better understand Pima cotton N requirements, Robert Hutmacher and his team are studying nitrogen requirements and harvest removal rates for this cotton type. This research will address a high-priority knowledge gap for FREP and will make the FREP nitrogen fertilization guidelines more relevant and accurate.

Starting in 2013, FREP funded and collaborated with several individuals and organizations to create a nitrogen management training program for Certified Crop Advisors (CCAs). Under the leadership of University of California researchers and extension advisors, this group produced 14 two-day workshops covering a wide range of nitrogen management topics. Over 1,000 CCA's have participated in this program. In 2020, we will offer the last in-person training as the program transitions to a new online format to ensure that California CCAs have the right tools and recognition to help growers with crop nutrient management. In future years, this program will focus on online resources and using testing to ensure that new CCAs are ready to provide advice on nitrogen management planning in California.

Acknowledgements

We are grateful to members of the fertilizer industry for their support in providing funds for the Fertilizer Research and Education Program. Their foresight in creating FREP and their long-term commitment and dedication have been instrumental in the program's success.

We recognize the members of the Fertilizer Inspection Advisory Board's Technical Advisory Subcommittee who review and recommend projects for funding. The professionalism, expertise, and experience of Rex Dufour, Dr. Eric Ellison, Dr. Suduan Gao, Charles Hornung, Dr. Marja Koivunen, DD Levine, David McEuen, Dr. Jerome Pier, Dr. Steve Petrie, Dr. Tom Bottoms, and Jenny Rempel have provided FREP with direction to ensure the program achieves its goals.

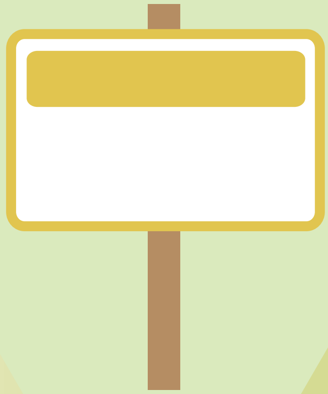
In addition, we thank the members of the Fertilizer Inspection Advisory Board for their continued support of the FREP program: Greg Cunningham, Jake Evans, Doug Graham, Jay Irvine, David McEuen, Melissa McQueen, Edward Needham, Gary Silveria, and Steve Spangler.

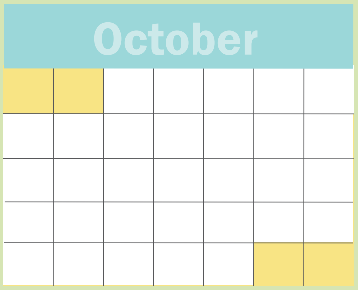
We thank the Western Plant Health Association as a continued valued partner in the conference. Since 2005, FREP has teamed

up with WPHA to strengthen our impact on industry and deliver the most essential nutrient management information. The input and support of Renee Pinel, President and CEO have led to greater outreach and dissemination of FREP research findings.

Vital contributors are the project leaders and cooperators themselves and the numerous professionals who peer-review project proposals, significantly enhancing the quality of FREP's work.

Special recognition also goes to the leadership at the California Department of Food and Agriculture, including Secretary Karen Ross; Science Advisor Dr. Amrith Gunasekara; Inspection Services Division Director Natalie Krout-Greenberg; and Dr. Amadou Ba, Environmental Program Manager II. Thanks also to Dr. Martin Burger, Senior Environmental Scientist (Supervisory) of the Fertilizing Materials Inspection Program for his help reviewing proposals and advising this program. FREP staff are Brooke Elliott, Research Data Analyst I; Mark Cady, Senior Environmental Scientist (Supervisory); Nicole Crouch, Environmental Scientist; Dr. Emad Jahanzad, Senior Environmental Scientist (Specialist); and Natalie Jacuzzi, Senior Environmental Scientist (Specialist).





CONFERENCE PROGRAM

Tuesday, October 29, 2019

Facilitator: *Keith Backman, Consultant Manager, Dellavalle Laboratory, Inc.*

9:00 **Welcome**
Renee Pinel, President/CEO, WPHA
Karen Ross, Secretary, CDFA

9:30 **Overview of CropManage: Inputs, Outputs, and Users**
Dr. Michael Cahn, Irrigation and Water Resources Advisor, University of California (UC) Cooperative Extension, Monterey County

10:00 **Citrus: Nitrogen Management Practices and Recommendations**
Dr. Douglas Amaral, Postdoc Scientist, Department of Plant Sciences, UC Davis

10:30 **Break**

10:50 **Effects of Soil Biochar Amendment on Soil Nitrogen Dynamics**
Dr. Suduan Gao, Research Scientist, United States Department of Agriculture (USDA) Agricultural Research Service

11:20 **A Normal California Farm, Farmed Abnormally**
Scott Park, Owner/Operator, Park Farming

11:50 **Lunch: Nitrogen Management Plans: Where Is This All Leading?**
Parry Klassen, Executive Director, Coalition for Urban Rural Environmental Stewardship

1:10 **Panel: Nitrogen Budgeting with Organic Amendments**
Facilitator: Dr. Karen Lowell, Agronomist, USDA Natural Resources Conservation Service. Panelists: Gina Colfer, Ward Burroughs, and Gerald Davis.

2:25 **Break**

2:45 **Nitrogen and Irrigation Management Planning Workshop**

Annuals
Do-It-Yourself Tensiometer – *Dr. Michael Cahn*
Soil Nitrate Quick Test – *Dr. Mark Lundy*
Nitrogen Budget Exercise – *Dr. Daniel Geisseler*

Perennials
Irrigation Scheduling Pressure Chamber – *Dr. Ken Schakel*
Soil Amendments – *Dr. Sat Darshan S. Khalsa*
Nutrient Management Considerations – *Dr. Sebastian Saa*
CropManage Demonstration – *Dr. Michael Cahn*

4:15 **Poster Session and Competition**

6:30 **End**

Wednesday, October 30, 2019

Facilitator: *Dr. Steve Petrie, Director of Agronomic Services, Yara North America*

8:15 **Welcome and Recap**

8:30 **Potassium Fertilization in Crops**
Dr. Saiful Muhammad, Research Agronomist, QualiTech

9:00 **Irrigation Maintenance and Distribution Uniformity**
Trina Walley, District Manager, East Stanislaus Resource Conservation District

9:30 **Characterizing Soil Texture for Water and Nutrient Management**
Dr. Toby O'Geen, Soil Resource Specialist in Cooperative Extension, Department of Land, Air and Water Resources, UC Davis

10:00 **Break**

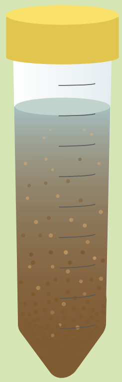
10:20 **Deficit Irrigation and Nutrient Management in High Density Olive Orchards**
Dr. Richard Rosecrance, Professor, California State University Chico

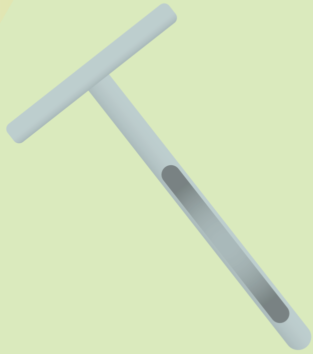
10:50 **Best Practices for Fertigation Design and Equipment**
Dr. Franklin Gaudi, Project Manager, Cal Poly Irrigation Training and Research Center

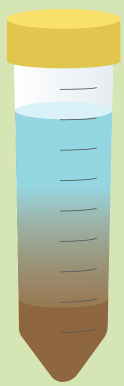
11:20 **Salinity Effects and Management**
Mark Battany, Water Management and Biometeorology Advisor, UC Cooperative Extension, San Luis Obispo/Santa Barbara Counties

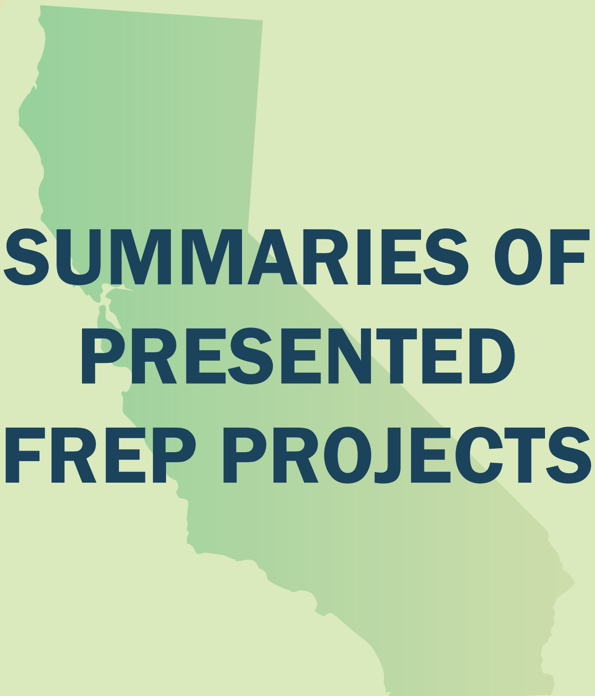
11:50 **Closing Remarks**

12:00 **End**









SUMMARIES OF PRESENTED FREP PROJECTS

Soil Biochar Amendment to Improve Nitrogen and Water Management

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INTRODUCTION

Nitrogen (N) is an essential element for crop production. Unused N from fertilizer application is also the source of contamination that impacts environmental quality. Ammonia (NH_3) volatilization from soil has detrimental effects on human health and accounts for the largest mass loss in gaseous form for N. Use of N fertilizer is the major source of atmospheric emissions of nitrous oxide (N_2O, a potent greenhouse gas). Nitrogen leaching from agricultural fields has been identified as the major cause for the statewide groundwater pollution in California (CA). Regulatory decisions have been in place or are in the process of being made that require monitoring and reporting of N use in production fields.

Biochar, which is produced from heating organic materials at high temperature under limited oxygen, has shown the benefits of organic carbon storage (sequestration), improving soil properties, and mitigating environmental contamination problems. Many studies illustrated potential benefits of biochar in increased N retention, reduced N leaching, and decreased gas emissions. However, variabilities in observed biochar effects are large with many showing no or negative effects. There are large gaps in our understanding of what effects biochar products could have on N dynamics especially under field conditions.

OBJECTIVES

The goal of this study is to determine the overall benefits and best practices of using biochar as a soil amendment in N and water management in vegetable crop production systems. Specific objectives are:

1. To determine effects of soil amended with biochars (produced from different feedstocks found in the San Joaquin Valley of California) on adsorption capacity for NH_4^+ and NO_3^- and N transformation (urea hydrolysis and nitrification) rates as well as soil-water retention.
2. To determine effective amendment rate of biochar products and irrigation rates

on crop response and N fate under field conditions.

DESCRIPTION

For objective 1, laboratory studies have been carried out to characterize biochar products (e.g., surface area, chemical composition), and then tested for their adsorption capacity of N species (ammonium NH_4^+ and nitrate NO_3^-) and pH effects. Seven biochar products from different feedstocks were collected including two freshly made from almond shells from California orchards, two from softwood, and one each from wood/tree trimming, bamboo, or coconut shells. They vary in pyrolysis temperature, particle size, composition, etc. All products were tested for their adsorption capacity of N and selected products were tested for pH effects.

For objective 2, a three-year field experiment was conducted to evaluate soil incorporation of biochar and irrigation rates on crop response and N losses to the environment. The field experiment was established at the USDA-ARS, San Joaquin Valley Agricultural Sciences Center, Parlier, CA. Processing bulb onions were grown for three years (2016-2018). The soil is Hanford sandy loam (coarse-loamy, mixed, super active, nonacid, thermic Typic Xerorthents). Treatments included three irrigation levels with or without biochar amendments first year and a high char treatment was added in the second year. Field design was a split-plot with three irrigation levels as main treatments (50, 75, and 100% of a reference that provides sufficient water for plant growth), and three biochar amendment rates as sub-treatments [0, low char (29 t/ha), and high char (58 t/ha)] in three replications. The biochar was produced from softwood by Charborn LLC (Oakland, CA). Fertilizers were applied four times during first growing season but weekly during the second growing season. Soil at the end of the growing season was sampled and analyzed for N. Ammonia and N_2O emissions were measured using chamber methods described in Gao et al. (2017) and Jantalia et al. (2012), respectively. Nitrate leaching was collected during the third year using resin method (Penn State, 2017).

RESULTS AND DISCUSSION

Adsorption of N species on biochar. Preliminary data on adsorption isotherm have shown that all biochar products exhibit some ability to adsorb NH_4^+, but not NO_3^-. The pH effects on NH_4^+ adsorption are shown in Figure 1. The adsorption was minimal at low pH, increased with pH increase, reached the maximum between pH 8-9, and then decreased as pH was raised further. Almond shell char and two softwood chars showed NH_4^+-N adsorption capacity up 1 g kg^{-1}, which translates to 30 kg N adsorption per hectare at biochar application rate of 30 ton ha^{-1}. However, at pH 7 the amount of adsorption can be reduced to half and it is unknown how long before the adsorbed NH_4^+ can be oxidized to NO_3^-, which is most mobile among N species. Overall, the ability of biochar to retain N is expected to be small.

Onion field experiment. Ammonia volatilization rates increased significantly following each N fertilizer application with much higher peaks when fertilizer was applied fewer times during 2016 growing season with a larger amount each time. Total NH_3 loss during the growing season ranged from 11.4-18.2 kg N ha^{-1} in 2016, higher than those in 2017 (7.2-8.1 kg N ha). Nitrous oxide emission followed a similar pattern, but total N_2O emissions were similar between the years ranging from 0.13-0.22 in 2016 and 0.18-0.23 kg N ha^{-1} in 2017. The total NH_3 volatilization loss accounted for 5.1-8.1% in 2016 and 3.0-3.5% in 2017 of the total amount of fertilizer applied, but the total N_2O emissions were much smaller

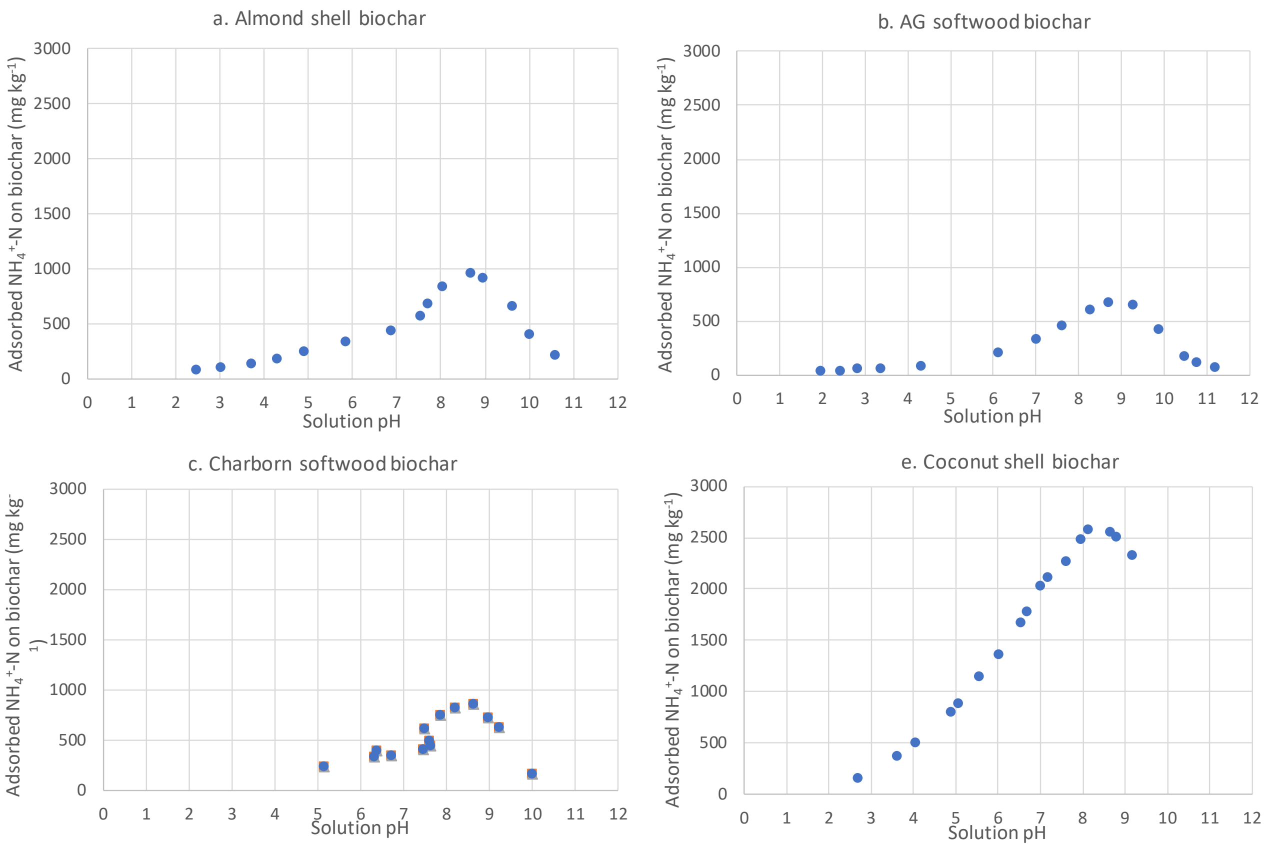

***Figure 1**. Adsorption envelope of NH_4^+ on biochar products from different biochars when initial solution concentration was 100 mg NH_4^+-N L^{-1} at a 50:1 (v/w) solution:biochar ratio.*

(0.06-0.1% for 2016 and 0.08-0.1% for 2017).

Statistical analyses showed that for the first two years, biochar effect was not significant, but irrigation and interaction with biochar significantly affected the yield. The 50% irrigation level regardless with or without biochar had significantly lower yield than those at 75% and 100% irrigation, with no significant difference between the 75% and 100% irrigation levels. In 2017, irrigation with biochar treatment showed a similar trend, but the control at 50% irrigation showed a high yield similar to the higher irrigation levels and significantly higher than biochar treatments at the same irrigation level. For both years, the high-char treatment at 100% irrigation level gave consistently high yield that are significantly higher than some of the treatments at 75% irrigation level. N uptake was positively correlated with yield.

By the end of each growing season, NO_3^- in the profile showed significant differences among irrigation treatments: highest in the 50% irrigation and lowest from the 100% irrigation. The concentration was the highest in surface soil for 100% and 75% irrigation levels, but below 20 cm the concentration increased as soil depth increased for all irrigation levels with the greatest increase for the 50% irrigation treatment. All the accumulated N, however, was leached out by early spring after the winter rain season. Statistical analyses showed irrigation, soil depth, and irrigation × soil depth interaction had significant impact on the soil N data, but no significant effect of biochar and its interaction with other treatments was observed.

Nitrogen leaching data collected in the third year showed large variations among treatments. Statistical analysis did not show any significant effects of irrigation, biochar, or their interactions. However, when biochar main effects were compared with the control only, the low biochar treatment versus the control had a p value of 0.081. Most of high N leaching was observed from biochar treatments and all controls showed low leaching indicating biochar at least did not reduce leaching.

TAKE-HOME MESSAGE

Based on three-year data from an onion field experiment, there was no clear benefit of biochar on N management in terms of reducing N losses, and irrigation levels showed greater impact on N dynamics and crop production. There were no significant effects of biochar on ammonia or nitrous oxide emissions. Biochar showed a tendency to increase N leaching, which may be due to its ability to increase infiltration. Biochar showed some ability to retain NH_4^+, but likely also increased water infiltration rate by decreasing soil bulk density. Irrigation showed a profound impact on yield, N accumulation, N mobility, and N leaching. Lower irrigation levels led to higher accumulation of soil nitrate, but all was subject to leaching from winter rain. The high costs of biochar production are the major hurdles for adoption as a common agronomic practice at this time. Efforts should focus on low-cost methods in biochar production when suitable and incorporation in agricultural fields may provide long-term benefits in organic carbon storage. In addition, low-cost biochar versus direct biomass return should be evaluated.

LITERATURE CITED

Gao, S., Hendratna, A., Pflaum, T., 2017. An inexpensive automatic sampler with static chambers for nitrous oxide emission measurement. Int. J. Environ. Sci. Dev. 8(1), 55–61, DOI: 10.18178/ijesd.2017.8.1.920.

Jantalia, C.P., Halvorson, A.D., Follett, R.F., Alves, B.J.R., Polidoro, J.C., Urquiaga, S. 2012. Nitrogen source effects on ammonia volatilization as measured with semi-static chambers. Agronomy Journal. 104(6):1595-1603, DOI: 10.2134/agronj2012.0210.

Penn State, 2017. How to make resin bags, https://plantscience.psu.edu/research/labs/roots/methods/field/measuring-nitrate-leaching-with-resin-bags/how-to-make-resin-bags

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Adapting CropManage Irrigation and Nitrogen Management Decision Support Tool for Central Valley Crops

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INTRODUCTION

Central Valley farmers are under regulatory pressure to use fertilizer nitrogen efficiently and demonstrate that they are following best management practices. Because soil nitrate can readily leach a combination of practices that help growers follow the 4Rs (right source, right amount, right time, right place) and optimize water management is required to achieve improved N use efficiency. UC research has greatly increased the understanding of crop N needs and resulted in several spreadsheet and online tools that growers can use to determine appropriate amounts of fertilizer to apply to their crops.

In addition to nutrient management, water scarcity during the latest drought has increased the urgency for easy-to-use tools that can assist growers in using limited supplies of water as efficiently as possible to maximize production. The California Irrigation Management and Information System (CIMIS) operates approximately 150 weather stations that collect reference evapotranspiration (ET_o) data in most agricultural production regions of California. To determine how long to irrigate using ET_o data, growers need to complete a series of calculations that can be quite time consuming.

CropManage (CM) is an online tool for assisting growers with efficiently managing water and nitrogen fertilizer to match the specific needs of their crops. With financial support of CDFA-FREP, CM was originally developed to help farmers estimate irrigation schedules in lettuce using CIMIS ET_o data and determine fertilizer N needs using the soil nitrate quick test and models of lettuce N uptake. Since the first version was released in 2011, CM was expanded to include other coastal crops, including baby salad greens, spinach, celery, broccoli, cabbage, cauliflower, and strawberries. CM also allows growers to track fertilizer and water applications on each of their fields. This record keeping capability of the software allows multiple users to share and review water and N applications on each field of their ranch, and for growers to maintain data required to comply with water quality regulations. Since CropManage was first released, use of the on-line tool has steadily increased on the Central Coast. CM currently has more than 1600 registered users and provides more than 1200 recommendations per month to users for water and fertilizer during the production season.

There was much interest to expand CM to include Central Valley crops including alfalfa, processing tomatoes, and tree crops (almonds, walnuts, pistachio, prunes, pears). However, these commodities require algorithms and user interfaces that are significantly different than the current version of CM. The funding requested for this project is primarily needed for programming resources to add Central Valley crops to CM and improve the user-interface and user experience.

OBJECTIVES

The general objective is to adapt the CropManage (CM) online decision support tool for Central Valley crops, including trees, forage, and warm season vegetables. Specific objectives include:

1. Adding algorithms and user interface modules that accommodate warm season vegetables, forage, and tree crop commodities.
2. Supporting the addition of almonds, processing tomatoes, and alfalfa to CM.
3. Improve the user-interface so that users can intuitively and quickly navigate within the software tool on a personal computer or mobile device, and data is presented in an easily understandable format.
4. Conduct outreach to the agricultural industry through workshops, presentations at grower meetings, and newsletter, blog, and trade journal articles.

ACCOMPLISHMENTS

User interface

The user interface for CropManage (Objective 3) was redesigned and implemented during the first year of the project to provide a more intuitive experience navigating the software. Based on feedback from users the interface was further streamlined to speed performance during 2019. The current version of CM simplifies the user interface to maximize the ease of navigating to different plantings and ranches (Figures 1 and 2). The user can filter through a list of ranches by entering the name or first letter of the ranch. Similarly, the user can select a specific planting by entering the name, or search by field, or commodity.

The planting summary tile (Figure 3) was designed to display efficiently on a smart phone screen and facilitate reviewing upcoming and past events and tasks. Users can add an irrigation, fertilizer, and soil sample, and tissue sample events from the menu on the planting tile. The most urgent events are shown first, and the user can scroll to view events that are further in the future or in the past. An “attention needed” icon is displayed next to a past event that was not confirmed to have been completed (Figure 3). The “leaf symbol” indicates that the value displayed is a CropManage recommendation rather than a manager recommendation. The name of the user that entered an event, and date and time of the entry can be read when the event dialogue is opened. Summary tables and lists of all events entered for a planting can be viewed by selecting the icons in the lower right corner of the planting tile.

Addition of Central Valley Crops

Processing tomato, alfalfa, and almonds have been added to CM. The user interface and algorithms for each commodity group required major changes to the software (objectives 1 and 2). For example, modifica-

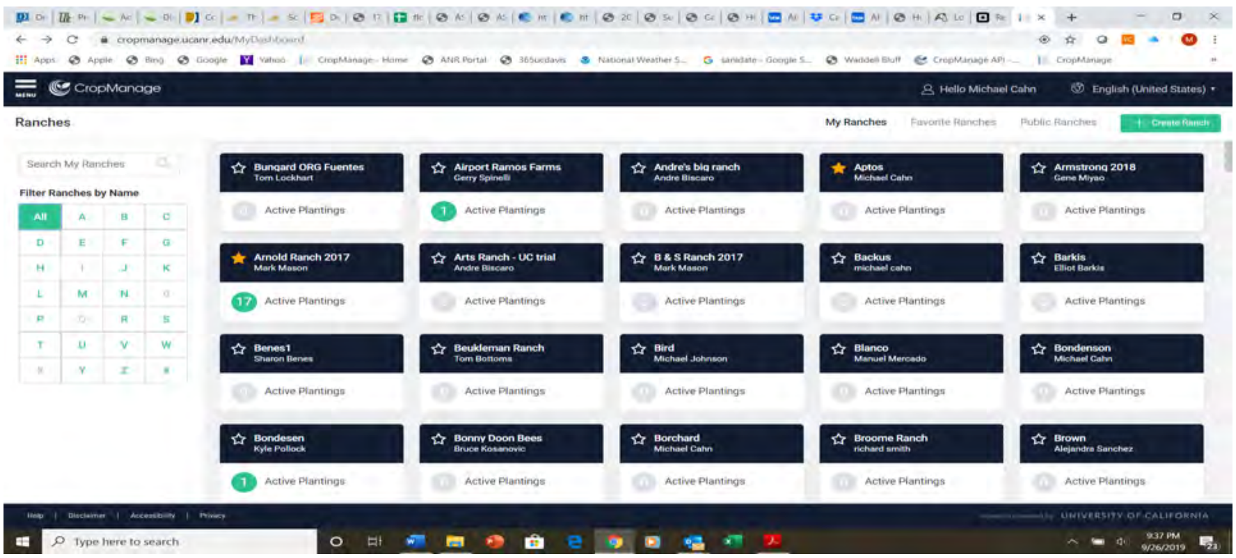

Figure 1*. Updated user interface in CropManage displays ranches available for the user to view. The user can filter by the first letter or complete name of the ranch.*

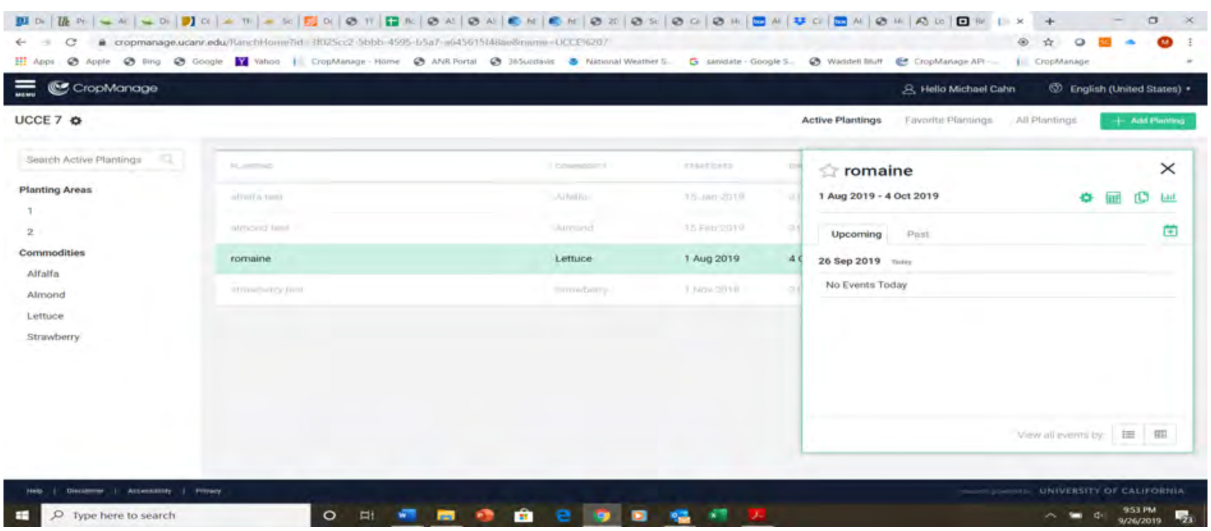

Figure 2*. Updated user interface in CropManage 3.0 displays plantings for alfalfa, almond, lettuce, and strawberry crops. The user can filter through plantings (crops) by planting area (field name), planting name, or commodity.*

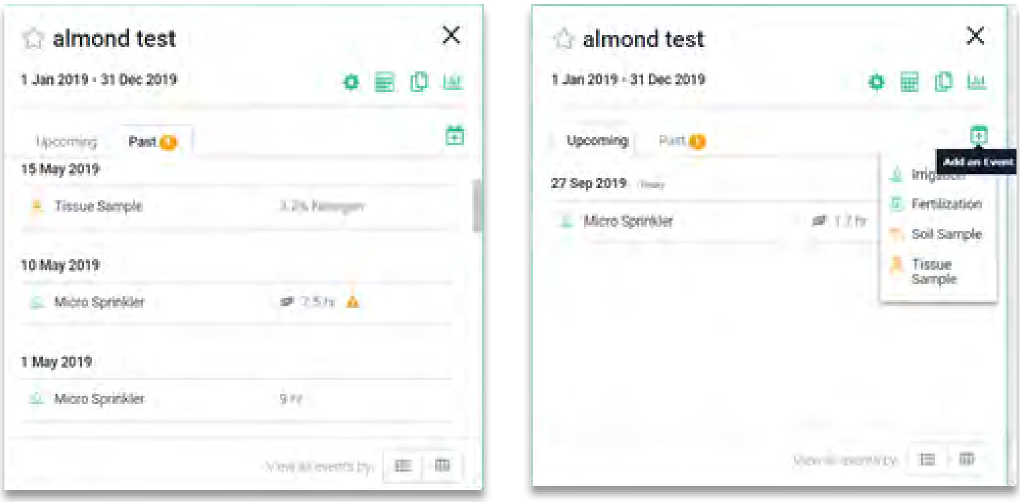

Figure 3. Updated user interface in CropManage 3.0 displaying events for an almond orchard. The interface is designed to display on smartphones and divides upcoming and past events onto different tabs.

tions were made so that the user can enter “cut dates” for alfalfa, which determines the shape of the crop coefficient curve. The user interface was modified so that *tissue sample* values can be entered for determination of fertilizer N requirements of tree crops. A new algorithm for N fertilization for trees was implemented based on the model developed by Brown et al. and includes estimated N contributions of cover crop, manure, and compost amendments. For almonds and processing tomato, algorithms and the user interface were modified to account for canopy senescence and to allow the user to adjust for a water stress period during fruit maturation. Major changes to the code and user interface were also needed to accommodate perennial crops which are grown over multiple years and develop deep root systems.

Outreach

CropManage was presented at nutrient and water management seminars (4) and tested by participants at hands-on workshops (4), as well as through individual demonstrations (3) during 2019. The demonstrations and workshops identified errors in the software which were later corrected by the programming team. Presentations at seminars informed growers and industry representatives about progress on improving the CropManage decision support application.

In summary, we expect that all software development tasks will be completed by the end of the project. Current efforts will be devoted to trainings on using CropManage for almond, alfalfa, and processing tomato and making modifications to improve the accuracy of the fertilizer and irrigation recommendations. We will also be expanding the user support sections of CropManage, which will include updated tutorials on using the newest features of the software.

Developing Nutrient Budget and Early Spring Nutrient Prediction Model for Nutrient Management in Citrus

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INTRODUCTION

Increasing awareness of the environmental impact of excess nitrogen (N) and new N management regulations demand user-friendly tools to help growers make fertilization decisions. Currently, nutrient management decisions in citrus are based on leaf analysis and critical value interpretation, which only indicates a deficiency or sufficiency and is performed too late to respond to deficiencies or plan N applications. In other high value crops such as Almond, Pistachio, and Walnut, nutrient management is increasingly based on early season leaf sampling, stage of plant growth and estimated crop demand. This approach has not been developed for citrus species in California, hence citrus growers do not have improved fertilizer management decision tools to apply the right rate of fertilizer at the right time to optimize productivity and avoid environmental losses. Current approaches to nutrient management in citrus rely heavily on leaf sampling collected during late summer, which is too late to respond to deficiencies or adjust fertilizer schedules. The utility of leaf sampling can be improved if samples are collected early in the season so that farmers have enough time to respond to current tree nutrient status. Protocols for early season leaf analysis have not been developed in citrus. In this project we will be monitoring highly productive groves of mandarins and orange in Kern, Fresno, and Tulare Counties during two growing seasons. A holistic nutrient management protocol will be developed to guide the fertilization rate and time of fertilizer application as well as in season monitoring to adjust fertilizer rate to optimize yield and reduce leaching of nitrate to ground waters.

OBJECTIVES

Develop nutrient demand curves to guide the quantity and time of fertilizer application in mandarin and orange based on crop phenology.

- Develop an Early Season leaf sampling and nutrient prediction model for mandarin and orange.
- Develop and extend nutrient Best Management Practices for citrus species.

DESCRIPTION

Activity 1. Develop nutrient demand curves that guide the quantity and time of fertilizer application in mandarin and orange (Years 1 and 2).

12-15 year old highly productive groves of each mandarin and orange were selected in Fresno County and another additional orange grove was selected in Tulare County. Trees that represent optimum leaf N concentrations (2.4-2.6% for oranges) and not showing any deficiency of other nutrients were selected.

We monitored three replicated blocks of trees of each species in Fresno county and one additional orange grove in Tulare county for changes in nutrient concentration in annual (leaves and fruits) and perennial organs (roots, trunk, scaffold, canopy branches and small branches) six times during the season at different phenological stages. This is being replicated in the second year of the project (January-December 2018) by monitoring the same trees for changes in nutrient concentration and biomass.

Activity 2. Develop Early Season Nutrient Prediction Model and extend nutrient Best Management Practices for major species of citrus (Years 1-3).

25 highly productive orchards of each mandarin and orange were selected in Fresno, Tulare, Kern and Ventura Counties. A composite leaf samples from 20 trees in each grove were collected from fully expanded leaves from the spring flush. In summer, 4 months old leaves from the same tree were collected.

The combination of nutrient budget, seasonal changes in tree N content and in-season prediction of tissue nutrient status will help in developing a robust new fertilizer management tools for citrus growers of California. The findings from the research will help to develop the 'Right Rate' and 'Right Time' to guide N applications in citrus. A computer-based model is being developed that will be available for the grower to estimate their crop fertilizer needs based on phenology, plant age, environment, crop load and yield.

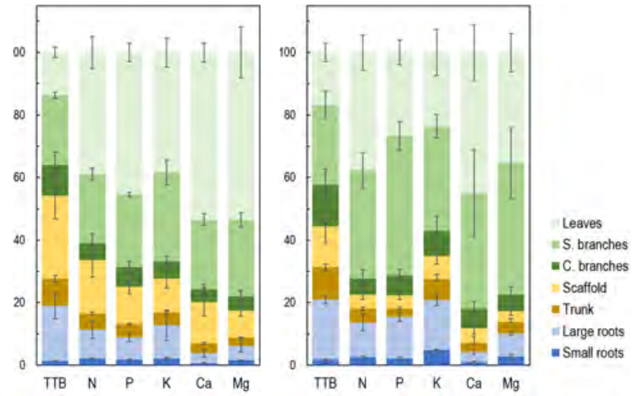

Figure 1. Tree partitioning (% of total) of total tree biomass (TTB) and macronutrients (N, P, K, Ca, and Mg) content. Data refer to Orange (A), and Mandarin (B). Bars represent standard errors.

RESULTS AND DISCUSSION

Tree biomass and nutrient content

Total nutrient amounts per tree was obtained by summing the nutrient content of tree organs calculated by multiplying the dry weight of each tree organ by its nutrient concentration. Data refer to the average of three trees excavated in 2017-2018 for each block. Small branches and leaves accounted for the majority of the biomass (~40%) in both orchards. Small branches and leaves also included a notable fraction of nutrients present in aboveground tissues as shown in Figure 1.

Dynamics of Nitrogen uptake during the season

Seasonal N content in perennial organs (trunk, scaffold, canopy branches and roots), leaves and fruits of orange and mandarin trees are shown in Figure 2. Data refer to the average of 9 trees per orchard of each species. In general, the accumulation of N was rapid until the end of July/August for both species, while continued later with a lower rate. Low net accumulation of N after late October/early November was observed. From December to February the amounts

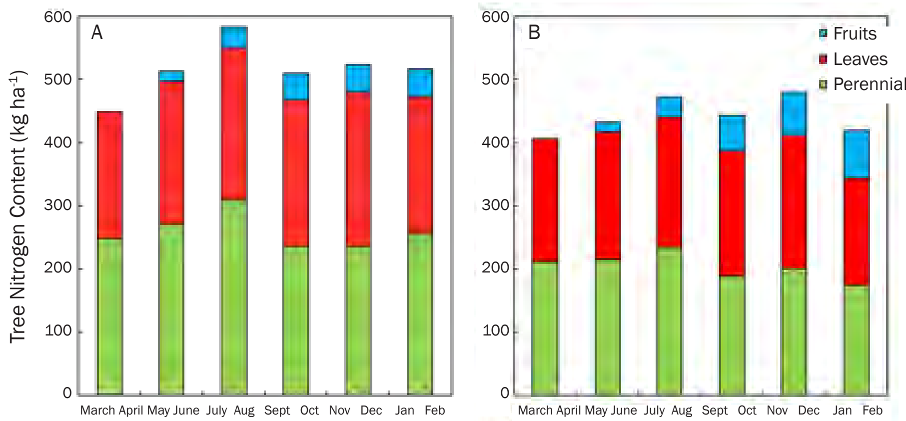

***Figure 2.** Seasonal trends in Nitrogen partitioning in fruits, leaves, and perennial organs (trunk, scaffold, canopy branches and roots) of mature orange (A) and mandarin (B) trees.*

of N present in the tree canopy remained stable or decreased, likely suggesting N translocation to fruits.

Seasonal pattern of nutrient accumulation in fruits

The patterns of N, P, K, Ca and Mg accumulation during the season are presented in Figures 3 and 4. The pattern of N accumulation over the season was generally consistent in both orange (Fig. 3) and mandarin (Fig. 4) fruits. Nitrogen accumulation occurred rapidly in the early season with 90% and 80% of the total N accumulated by September/October in orange and mandarin, respectively.

Phosphorus, K, Ca and Mg accumulation pattern in fruits over time resembled the N accumulation curve in both species. In general, the concentrations of N, P, and K was high at the beginning of the season and stabilized until fruit harvest. Ca and Mg concentrations in fruit was high at the beginning of the season and declined until fruit harvest.

The seasonal demand of N in citrus is high early in the season from April-May through July-August. Knowing the dynamics of nutrient uptake during the season is a requirement to allow the management of the timing of nutrient supply with nutrient needs. Preliminary data suggest that nutrients should be available in the soil for root to uptake by citrus trees from March-April to October-November, corroborating those findings from Raccuzzo et al. (2012). In contrast, from December to February, no net increase in nutrient was observed during this period.

It is important to note that the data shown in this report is a preliminary data from years 1 and 2 of a 3-year project, then no conclusive data are shown. Our goal is to develop knowledge of the pattern of nutrient uptake and allocation during three seasons (2017-2019) in citrus trees to develop an early season leaf sampling and nutrient prediction model for mandarin and orange to guide fertilizer application based on crop phenology for the State of California.

TAKE-HOME MESSAGE

Fruits are an important sink for nutrients and the pattern of nutrient accumulation through the season is largely driven by the pattern of fruit growth with most nutrients accumulated from cell division to cell enlargement. Fertilizer rate decisions in citrus orchards should be based on nutrient export

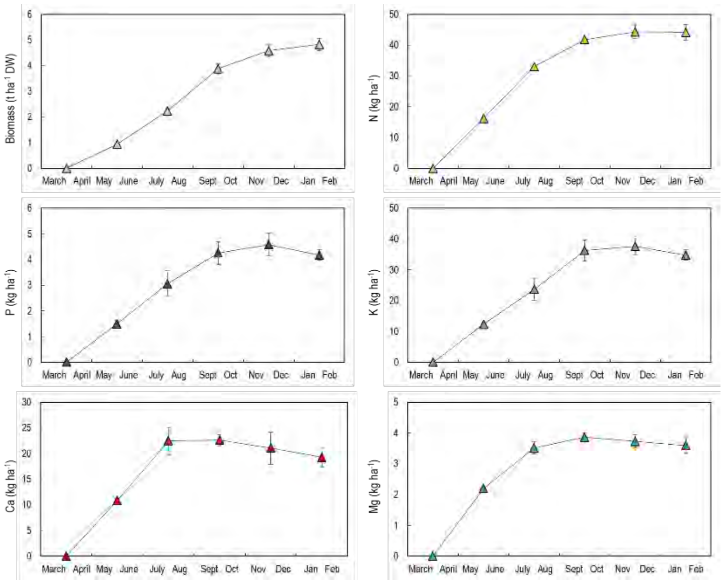

Figure 3. *Seasonal trends in biomass and macronutrients accumulation in fruits of orange trees. Bars represent standard errors.*

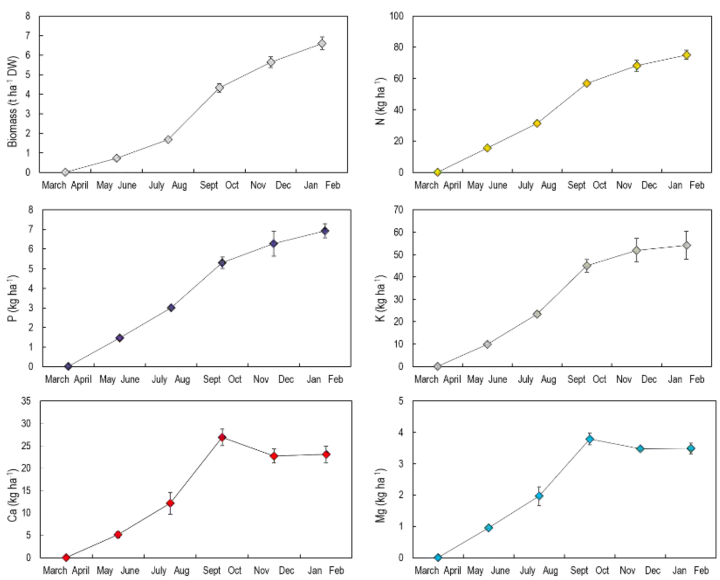

Figure 4. *Seasonal trends in biomass and macronutrients accumulation in fruits of mandarin trees. Bars represent standard errors.*

in expected yield while fertilizer application timings should be based upon the pattern of nutrient accumulation in fruits.

LITERATURE CITED

Embleton, T.W., W.W. Jones, C. Pallares and R.G. Platt, 1978. Effects of fertilization of citrus on fruit quality and ground water nitrate-pollution potential. In: Proc. Int. Soc. Citriculture. pp: 280-285.

Labanauskas, C.K. and M.F. Handy, 1972. Nutrient removal by valencia orange fruit from citrus orchards in california. . California Agriculture(December): 3-4.

Roccuzzo, G., D. Zanotelli, M. Allegra, A. Giuffrida, B.F. Torrisi, A. Leonardi, A. Quinones, F. Intrigliolo and M. Tagliavini, 2012. Assessing nutrient uptake by field-grown orange trees. European Journal of Agronomy, 41: 73-80.

ACKNOWLEDGEMENTS

We would like to thank California Department of Food and Agriculture (CDFA) and the Fertilizer Research and Education Program (FREP) for funding this research. We also would like to thank growers and citrus industry for material as well as providing human resources for the experiment.

Training on Crop Management that Integrates Climate, Soil and Irrigation System Data to Minimize Nutrient Loss and Optimize Irrigation Efficiency

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INTRODUCTION

As technology in irrigation, chemigation and fertigation advance, there is an increased need to provide information for agricultural workers on best management practices. The East Stanislaus Resource Conservation District (ESRCD) addresses local resource concerns through a variety of outreach programs such as irrigation and nutrient management workshops, which include material on integrated management practices. The workshops and trainings help ensure that decision makers are using water efficiently, can accurately monitor nitrogen application levels and are able to better manage the health of their soil for optimum productivity all while preventing deep percolation of nitrates that are known contaminates to groundwater. The assessment portion of the program collects in-field data to determine uniformity and efficiency of their irrigation water management. It is then followed by a detailed report summary with recommendations from industry sources to improve management and/or maintenance. Trainings and the assessment are followed up with one-on-one technical assistance to document changes and improvements. The project has benefited 165 growers to date with continuing education units and irrigation evaluations.

OBJECTIVES

1. Promote best management practices through workshops for agricultural workers in English and Spanish based on existing resources from University of California Cooperative Extension, USDA-Natural Resource Conservation Services, NCAT/ATTRA and CDFA-FREP.
2. Establish training materials and workshops that can be approved for continuing education credits towards maintaining certifications through Irrigation Association, California Certified Crop Advisors and Department of Pesticide Regulation.
3. Encourage irrigators to share individual challenges and successes in workshops, which will create a networking environment for ongoing farmer-to-farmer education.

DESCRIPTION

1. Conducted initial evaluations on farms to determine individual needs; evaluations included an irrigation system assessment using the Cal-Poly ITRC program, a soil health assessment using USDA-Natural Resource Conservation Service programs, and an interview of the decision maker for the property on current management and practices.
2. Submitted educational material and workshop agenda for qualification for CEUs for Nitrogen Management certification program through CURES.
3. Hosted pre-irrigation season workshops that presented information on system planning and scheduling, general maintenance, nutrient management and monitoring methods.
4. Provided recommendations on best management practices tailored to their needs. Continued technical assistance will be provided to the attendees of the workshops so materials can be developed to address challenges and success in post –irrigation season workshops.
5. Presented training results to regional partners such as West Stanislaus Resource Conservation Districts, as well as submitted presentations for Californian Association of Resource Conservation Districts and Almond Board of California annual conferences.

RESULTS AND DISCUSSION

To date, there have been four workshops in English and Spanish with attendance total of 120 producers. Fourty-six properties were provided technical assistance, covering 2,953 acres with an average distribution uniformity (DU) at 86.5%. The lowest global DU found was 59% which was a result of running the system at a low pressure; however the flow distribution uniformity was at 89%. Only one field was found to have both, low global DU and low flow DU as a result of a poorly designed and aged system. Combined with not irrigating according to soil properties, this resulted in a poor performing field with visible stress. See soil map (Fig. 1).

Majority of the fields had a global DU of over 83%, which is considered satisfactory. The most common issues identified in all evaluations were related to lack of maintenance and operation errors, such as flushing hoses, leaks, plugged emitters, plugged hose screens, running systems below recommended operating range, high pressure losses across filters, not operating system as designed and poor scheduling. These issues will be addressed in upcoming workshops in both English and Spanish.

After presenting the workshop materials to partner organizations, there has been interest from Farm Bureaus and Resource Conservation Districts to provide similar trainings to their growers, from Madera to Sacramento.

Figure 1. *Soil map*

TAKE-HOME MESSAGE

This project focuses on the FREP goal of improving input management through Irrigator Workshops and increasing the level of penetration of information regarding best management practices in local agricultural companies. Thus far, the project has documented and confirmed the need for continued education for growers and farm managers on best management practices. Despite years of experience, there were many growers that were able to identify issues with their system operation or maintenance which they can improve on immediately, that will have a long-term impact of how efficiently they apply irrigation water and fertilizers.

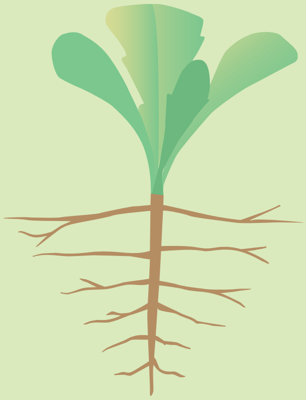
There will be a significant positive environmental impact resulting from the MAT program due to the connection being made between irrigation system uniformity and the effectiveness of nutrient application. This positive environmental impact has a direct correlation with a positive economic impact. Through working to increase the producers' soil health, irrigation system, fertilizer application efficiency, minimizing water and nutrient waste, the amount of money spent on yearly inputs needed for crop health will significantly decrease. Lastly, the MAT program will have a positive agronomic impact on the participants in the form of increasing awareness of new technology available to both producers and employees to help

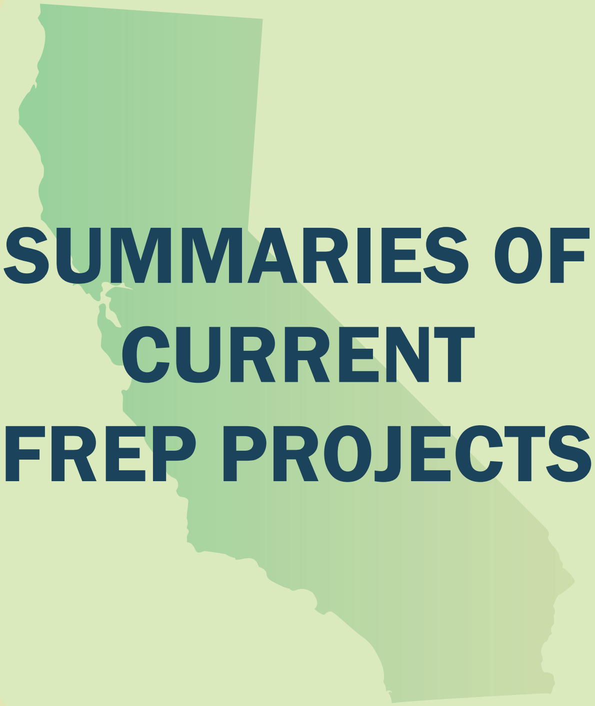
Figure 2. *Hose flush, plugged emitter, and hose screen*

increase efficiency, increase soil health and stability, monitor actual nutrient and water levels, and finally provide options to create or improve a precise schedule for nutrient and water application.

ACKNOWLEDGEMENTS

Funding for this project was provided by the California Department of Food and Agriculture's Fertilizer Research and Education Program. Special thanks to the University of California Cooperative Extension both local advisors and state specialists for assisting in the development of the training curriculum as well as the National Center for Appropriate Technology for curriculum and translation services. Recognition is also deserving for the Almond Board of California for their continued leadership in sustainability and willingness to share resources and their Irrigation Specialist to mentor the interns during in-field irrigation evaluations. Modesto Junior College has proven to be an excellent partner with their equipment and resources as well as students from the Irrigation Technology Program.





SUMMARIES OF CURRENT FREP PROJECTS

Evaluation of the Multiple Benefits of Nitrogen Management Practices in Walnuts

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INTRODUCTION

Nitrate is a major contaminant in groundwater in the Central Valley region. Elevated concentrations are primarily attributed to applied nitrogen fertilizers leaching past the root zone. Growers in the Central Valley are under new requirements through the Irrigated Lands Regulatory Program (ILRP) to keep an "on farm" Nitrogen Management Plan (NMP) to track nitrogen fertilizer applications. The key objective of requiring that growers complete an NMP is to provide them with a planning tool that they can use to manage their nitrogen applications.

While the planning tool may point to the need for better nitrogen management, fertilizer applications can best be managed by applying nitrogen at the right time, right place, with the right type, and the right rate (4R's). The 4R's are crop-specific practices that prevent leaching, and by extension, provide nitrogen to the plant when the plant is taking up nitrogen from the soil. Consequently, while the general recommendations for fertilizer management are useful, very little is known about the amount of nitrate moving past the root zone in most crops under most management regimes. It is imperative that additional studies on specific management practices be conducted to determine the potential movement of nitrate past the root zone. Because of this need, agricultural coalitions in the Central Valley are required through their General Orders to implement a Management Practices Evaluation Program. The MPEP has several specific objectives including identifying management practices that are protective of groundwater quality, determining whether newly implemented management practices are improving or may result in improving groundwater quality, developing an estimate of the effect of member's discharge of nitrogen on groundwater quality and utilizing the results to determine whether practices need to be improved.

There are data gaps in understanding the effectiveness of management practices on reducing the amount of nitrate moving past the root zone in walnut orchards. The focus of this project is to evaluate the management of nitrogen on two walnut orchards over a two-year period. This project documents the amount of nitrogen applied and measures the amount of nitrate moving past the root zone using a combination of soil cores and pore water samples. Measurements capture the movement of nitrate during both the irrigation seasons and periods of winter rain.

OBJECTIVES

1. Identify the management practices being implemented to reduce the amount of nitrate moving through the root zone for two orchards (Orchard 1 and Orchard 2) of similar size.
2. Determine the amount and timing of nitrate moving past the root zone.
3. Identify the multiple benefits of nitrogen management practices implemented in Orchard 1 and Orchard 2 including potential cost savings (reduced water costs, reduced amount of money spent on fertilizer) and groundwater protection (reduction in the amount of nitrate that is moving past the root zone).
4. Determine if additional practices could be implemented to further reduce the amount of nitrate moving past the root zone.
5. Disseminate results to growers of walnuts and develop outreach materials.

DESCRIPTION

The walnut orchards utilized in this study were located near Ceres, CA. The irrigation practices on both orchards include a combination of microsprinklers and flood irrigation. Fertilizer was applied by fertigation and pellets/granules amended into the soil. The orchards were approximately 5.8 acres and 4.0 acres. Each block was sectioned into a grid system containing 15 grid cells. Each grid cell was sampled by a combination of lysimeters to collect pore water, soil cores for nitrogen and carbon content, and moisture sensors to collect volumetric water content (Figure 1 and 2).

Prior to the beginning of the growing season, soil cores were collected from a random subset of grid cells in each orchard (Figures 1 and 2) to measure the immobile fraction of nitrogen. The concentration of nitrate in irrigation water was measured to determine the amount of nitrate applied via irrigation water. Lysimeters located below the root zone were used to evaluate amount of nitrogen moving past the root after fertigation and/or irrigation events. Soil samples were collected to determine the amount of immobile nitrogen at end of the irrigation season. Nitrogen was also measured in the walnuts prior to harvest to determine the amount of

Figure 1. The grid system and sampling device locations on the west block orchard.

Figure 2. The grid system and sampling device locations on the east block orchard.

nitrogen removed from the orchards. Volumetric water content was used to estimate the volume of water moving past the root zone. The data collected for this project is utilized as input parameters for 1-D HYDRUS to model nitrogen fate and transport in the field.

RESULTS AND DISCUSSION

In general, the median concentration of nitrate in lysimeters at 4-ft is lower than the concentration found at 10-ft although there is greater variability in concentration at 10-ft compared to 4-ft (Figures 3 and 4, respectively).

Nitrate leaching depends upon the amount and timing of N and water inputs, the storage capacity of the soil, and the amount and timing of N uptake by plants. Both the weekly mass balance and the Darcy flux indicate that nitrate leached past the root zone during the 2016 and 2017 growing seasons. Changes in application timing and fertilizer amount may minimize leaching losses. Losses are also a function of the irrigation practices. During 2016, the cooperator used a combination of sprinklers and flood irrigation during the period of fertilizer applications. In 2017, the cooperator used sprinklers exclusively for fertigation and rotated to flood irrigation after applications were completed. Despite the change in irrigation practices, nitrate was detected in the lysimeters at 4-ft in both 2016 and 2017, and in the 10-ft lysimeters in 2017. Although the 4-ft lysimeters could be within the root zone, 10-ft lysimeters are almost certainly below the root zone where active uptake of N by the tree occurs. It is likely that leaching to groundwater is occurring although it is difficult to determine the relative contribution of nitrate in the irrigation water and the nitrate applied as synthetic fertilizer. A

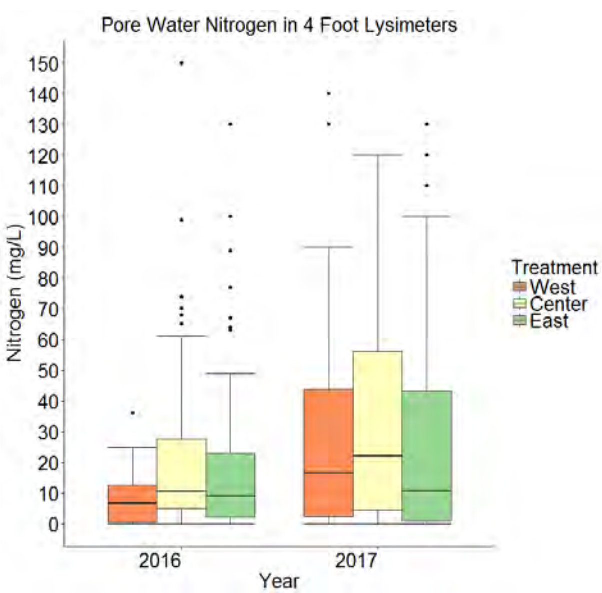

Figure 3. Nitrogen present in pore water samples collected from 4-foot lysimeters in the West, Center, and East blocks of the walnut orchard in 2016 and 2017. Outliers greater than 150 mg/L N are excluded from this graph but are included in boxplot calculations.

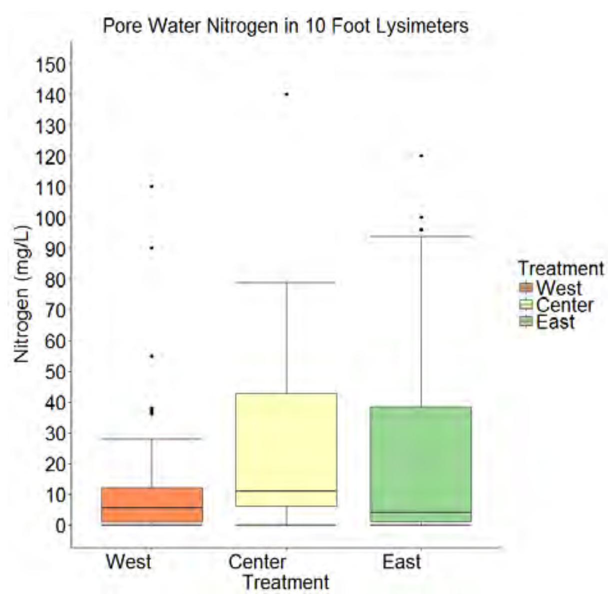

Figure 4. Nitrogen present in pore water samples collected from 10-foot lysimeters in the West, Center and East blocks of the walnut orchard in 2017. Outliers greater than 150 mg/L N are excluded from this graph but are included in boxplot calculations.

relatively elevated concentration of nitrate in groundwater used for irrigation would result in nitrate being found in any irrigation water moving past the root zone, even if no residual nitrate from fertilizer was present.

ACCOMPLISHMENTS

This project was successful in improving our understanding of how split applications affect leaching of nitrate to groundwater, as well as supporting FREP's goal to advance the environmentally safe and agronomically sound use of nutrients and the reduction of agricultural contributions of nitrate to groundwater. A combination of pore water collected by lysimeters, soil samples, collection of irrigation water, and crop tissue analyses allowed us to estimate the nitrate present in the system. The main goal for this project was to identify the benefits of the different nitrogen management systems implemented in the two orchards, and to determine potential cost savings and groundwater protection benefits provided by each of these two management systems. By using a vadose ground fate and transport model, HYDRUS (developed using the grantee funds), additional management practices can be evaluated through computer modeling. Finally, these results have been disseminated to walnut growers at outreach events, such as Field Days held in 2018 and 2019.

ACKNOWLEDGEMENTS

Funding for this project was provided (in part) by a grant from the California Department of Food and Agriculture's Fertilizer Research and Education Program (FREP) and the Fertilizer Inspection Advisory Board, and five Central Valley ILRP Agricultural Coalitions (East San Joaquin Water Quality Coalition, Westside San Joaquin River Watershed Coalition, San Joaquin County and Delta Water Quality Coalition, Sacramento Valley Water Quality Coalition, Westlands Water Quality Coalition).

Train the Trainer: A Nitrogen Management Training Program for Growers

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INTRODUCTION

Nitrate is the most common contaminant in Central Valley groundwater and elevated levels are attributed primarily to leaching of nitrogen fertilizers past the root zone into aquifers. Growers who belong to Central Valley Water Quality Coalitions are under requirements adopted in 2012 per the Irrigated Lands Regulatory Program (ILRP) to keep "on farm" a Nitrogen Management Plan (NMP) or Irrigation and Nitrogen Management Plan (INMP) to track nitrogen fertilizer applications. The Waste Discharge Requirements (WDR) General Orders for the Central Valley allows growers to self-certify their own nitrogen management plans if they attend a training program approved by the California Department of Food and Agriculture.

The goal of the Train the Trainer program was to first ensure adequate numbers of NMP/INMP certifiers are in place to train growers. The current total of CCAs in California that can certify NMPs and INMPs is 760. There are approximately 30,000 landowners/ operators, with nearly 6 million acres of irrigated land in the Central Valley who are affected by the ILRP requirements to improve nitrogen application practices to protect groundwater. NMPs/INMPs require certification for lands in high vulnerability areas. From 2015 to 2019, 4,123 growers attended the course by participating in one of 85 Nitrogen Management Plan grower self-certification sessions. Of the 4,123 growers that took the course, 3,292 passed the exam and can self-certify their Nitrogen Management Plan (or INMP).

In the long-term, the grower INMP self-certification program will continue to contribute to measurable reductions in the likelihood of nitrates from fertilizer entering groundwater from farming practices in the Central Valley. This will reduce the regulatory compliance costs of all users of water, not just agricultural. Additionally, the reduction of impacts to groundwater reduces treatment costs and may allow expanded use of lower cost groundwater in some areas for both agricultural and domestic uses.

OBJECTIVES

1. Conduct outreach to attract potential trainers for the grower self-certification trainings.
2. Organize and conduct Train-the-Trainer sessions using the educational materials developed by UC for the grower self-certification trainings. Trainer would be considered qualified as a trainer for grower certification program.
3. Manage the interaction between those requesting a trainer for a grower training session and the trainer.
4. Provide grower testing, keep records of attendance, successful completion, and conduct trainer evaluation.
5. Manage and coordinate the self-certification requirement of continuing education.

DESCRIPTION

1. **Trainer Outreach Program:** The pool of trainers includes the following Certified Professionals: Certified Crop Advisors (CCAs) with a Nitrogen Plan Certification, Certified Professional Agronomists or Soil Scientists. Outreach materials were sent to all Central Valley CCAs in September 2015 and December 2016.
1. **Conduct Train-the-Trainer Sessions:** The instructional materials developed by UC were used in the train-the-trainer sessions. The same materials were also used in the grower certification sessions. A total of five training sessions were held from 2015 to 2017 in the Stockton and Tulare areas to facilitate training of CCAs who generally conduct grower trainings in those regions.
2. **Manage the Interaction Between Coalitions and Trainers:** Coalitions contacted CURES when a new meeting was set, and CURES facilitated pairing each meeting with two trainers and the necessary materials. CURES used grant funds for trainer fees, as well as printing/shipping meeting materials and certification letters, while the Coalitions were responsible for venue costs. CURES also advertised grower self-certification meetings on its website and ensured that coalitions and CCAs were provided the most up-to-date version of the curriculum.
3. **Facilitate NMP Self-Certification Trainings:** CURES helped to facilitate trainings, kept records of meeting attendance, graded and recorded test results, and conducted trainer evaluations for each training course. Figures 1 and 2 show the components of the curriculum used during trainings.
4. **Manage the Continuing Education Requirement:** A complimentary FREP grant was approved in 2017 to develop a process for reviewing the agenda and content of a proposed Continuing Education meeting that fulfills that Continuing Education Unit (CEU) require-

ment of the NMP certification process. Meeting organizers are asked to submit a request for continuing education credits. Once content is approved using specific criteria, the organizing entity is allowed to issue CEUs to growers.

RESULTS AND DISCUSSION

In 2015 and 2017, CURES hosted 5 CCA training meetings. There were 32 CCAs who were eligible to lead an NMP grower self-certification workshop. Of these, 20 presented at one or more grower training meetings. From 2015 to 2019, CURES facilitated 85 NMP/INMP grower self-certification sessions. 4,123 growers took the course during the program's duration and 3,292 passed resulting in an 80% pass rate. In addition, coalitions organized 58 test retake sessions that had an 86% pass rate. Table 1 below outlines the number of NMP/INMP Self-Certification trainings and office retakes per year, as well as the number of growers that have passed the exam with a 70% or above.

The FREP grant for this project ended in June 2019 and due to grower interest, all Central Valley Water Quality Coalitions have agreed to continue funding the program. It is crucial that the NMP/INMP Self-Certification Program stays in place to ensure that Central Valley growers in high vulnerability areas can obtain self-certification in the future.

ACCOMPLISHMENTS

The research-based information delivered to growers by this project supports FREP's goals to advance the environmentally safe and agronomically sound use of nutrients and the reduction of agricultural contributions of nitrate to groundwater in the Central Valley and agricultural regions throughout California. The BMP recommendations covered in the training curriculum are vital to approximately 30,000 landowners/ operators who farm a total of nearly 6 million acres of land in the Central Valley. All these growers are affected by the ILRP requirements to improve nitrogen and irrigation application practices for reducing salt and nitrate discharges to ground and surface water. This project ensures the timely implementation of a training program for certifiers who subsequently train growers to complete the mandatory NMPs. These trainers and the growers they train will advance the knowledge of proper nitrogen stewardship as attention by the public and policymakers continues to focus on the issue of nitrogen in groundwater.

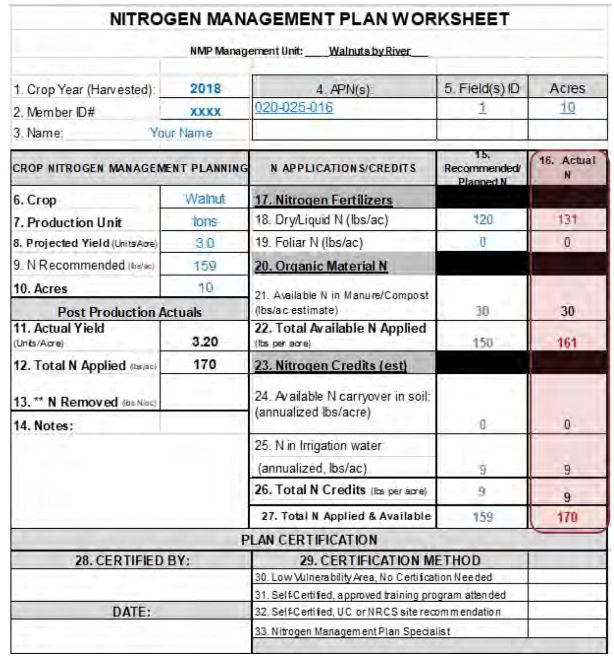
Table 1*. The number of NMP/INMP self-certification trainings and office retakes from November 2015 to June 2019, total number of attendees, total number of passed exams, and the average percent passed per year.*

Year	# of Grower Trainings	# of Office Retakes	Total # of Attendees	Total # of Passed Exams	Average Percent Passed
2015	3	0	186	154	82.7%
2016	32	22	1962	1571	80.1%
2017	22	22	1010	805	79.7%
2018	18	8	640	512	80.0%
Jan 2019 – Jun 2019	10	6	325	250	76.9%
TOTALS	**85**	**58**	**4123**	**3292**	**79.9%**

Figure 1. Nitrogen Management Training Curriculum, Revised December 2018. Front cover.

ACKNOWLEDGEMENTS

Funding for this project was provided by the California Department of Food and Agriculture's Fertilizer Research and Education Program. Special thanks to the University of California for assisting in the development of the training curriculum and to the Central Valley Water Quality Coalitions for hosting the training sessions for their members. Recognition is also deserving for the professional Certified Crop Advisors who are lending their skills and talents to train growers on ways to improve efficiency of nitrogen fertilizer applications to crops.



NITROGEN MANAGEMENT PLAN WORKSHEET

NMP Management Unit: ___Walnuts by River___

1. Crop Year (Harvested):	2018	4. APN(s):	5. Field(s) ID	Acres
2. Member ID#	xxxx	020-025-016	1	10
3. Name:	Your Name			

CROP NITROGEN MANAGEMENT PLANNING		N APPLICATIONS/CREDITS	15. Recommended/ Planned N	16. Actual N
6. Crop	Walnut	17. Nitrogen Fertilizers		
7. Production Unit	tons	18. Dry/Liquid N (lbs/ac)	120	131
8. Projected Yield (Units/Acre)	3.0	19. Foliar N (lbs/ac)	0	0
9. N Recommended (lbs/ac)	159	20. Organic Material N		
10. Acres	10	21. Available N in Manure/Compost (lbs/ac estimate)	30	30
Post Production Actuals				
11. Actual Yield (Units/Acre)	3.20	22. Total Available N Applied (lbs per acre)	150	161
12. Total N Applied (lbs/ac)	170	23. Nitrogen Credits (est)		
13. ** N Removed (lbs N/ac)		24. Available N carryover in soil; (annualized lbs/acre)	0	0
14. Notes:		25. N in Irrigation water (annualized, lbs/ac)	9	9
		26. Total N Credits (lbs per acre)	9	9
		27. Total N Applied & Available	159	170

PLAN CERTIFICATION

28. CERTIFIED BY:	29. CERTIFICATION METHOD	
	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	

Figure 2. Section 6 (pg. 86-107) of the curriculum shows step-by-step instructions on how to fill out the NMP/ INMP worksheet. This image is shown on page 98 of the Nitrogen Management Training curriculum.

New Fertigation Book

Project Leader

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INTRODUCTION

The goal of this work was to improve the understanding of good fertigation practices and equipment by practitioners (i.e., farmers, foremen, farm managers) and suppliers. The improved understanding will hopefully result in farmers implementing better irrigation and fertilization practices. Those good practices will improve crop yields while protecting the environment.

To meet the objective, the old (20+ years) Cal Poly ITRC Fertigation book was updated and re- published. A variety of 1-day Fertigation short courses have been held at ITRC, and two 1-unit Fertigation classes were provided to Cal Poly students.

OBJECTIVES

1. Consolidate up-to-date information on fertigation practices, science, and art into a single pragmatic sourcebook for practitioners.
2. Develop or organize new concepts and information to fill gaps in current knowledge as related to fertigation and include in the new book.
3. Provide outreach in the form of short courses to industry and students.

DESCRIPTION

The new book has 19 chapters, as follows:

1. Introduction
2. Safety
3. Chemical injectors
4. Proportional fertigation
5. SO_2, gypsum, and solids injection
6. Irrigation principles, leaching, and fertilizer uniformity
7. Injection techniques for various irrigation methods
8. Nitrogen transformations and processes
9. Nitrogen uptake, including nitrogen balances, Applied/Removed (A/R) ratio, and groundwater legislation and protection
10. Other nutrient processes
11. Specific fertilizers
12. Biostimulants
13. Organic fertilizers
14. Air and oxygen injection
15. Plant and soil testing
16. Specific crop requirements
17. Sample fertigation calculations
18. Drip system maintenance
19. Infiltration problems

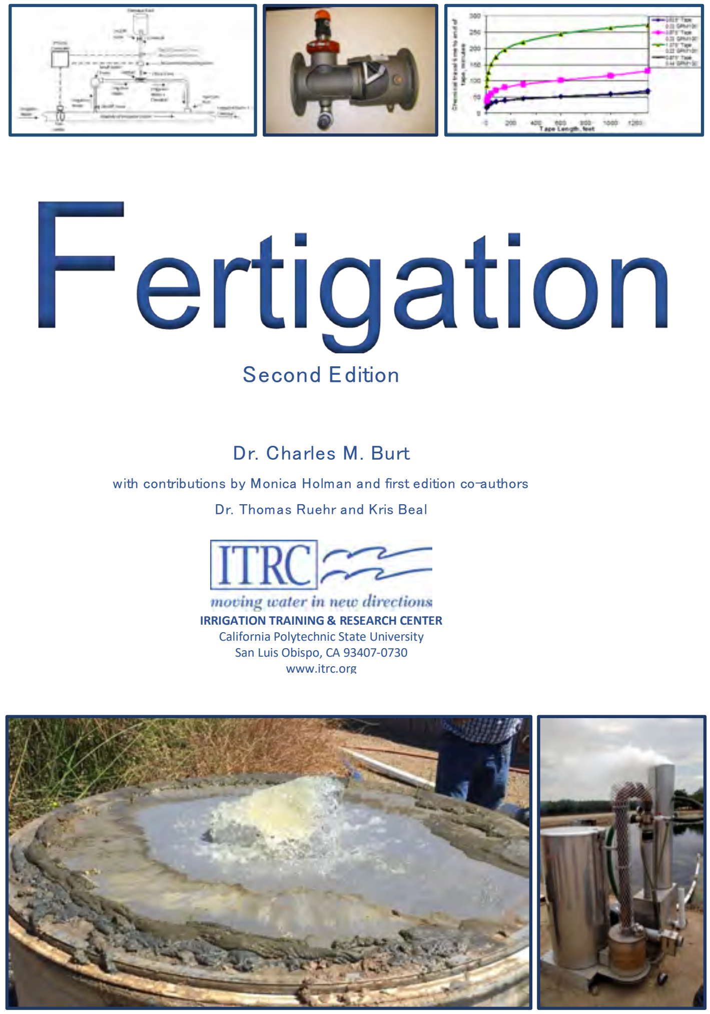

Figure 1. *Cover page of new book*

RESULTS AND DISCUSSION

The new book has hundreds of updates. Perhaps the most interesting for readers will be:

1. The discussion of the A/R ratio of nitrogen, that is of interest for many people that are concerned with groundwater protection and various rules. The section describes the uncertainties and challenges associated with applying even this "relatively simple" concept.
2. The move to proportional fertigation (automatically maintaining a constant ppm of a nutrient in the irrigation water) is slowly becoming more popular. The book describes multiple ways to achieve this and provides a recommendation of the best combination of equipment. The recommendations found in the book regarding proportional fertigation and the correct mix and timing of fertilizers have been adopted by commercial companies in California, which now provide large-scale contract service to farmers with remote monitoring and control.

RECOMMENDATION

The primary recommendations are:

1. Obtain the book at www.itrc.org
2. Attend one of the future 1 day short courses on Fertigation to be held at ITRC. These will be listed on the web site www.itrc.org under "classes".

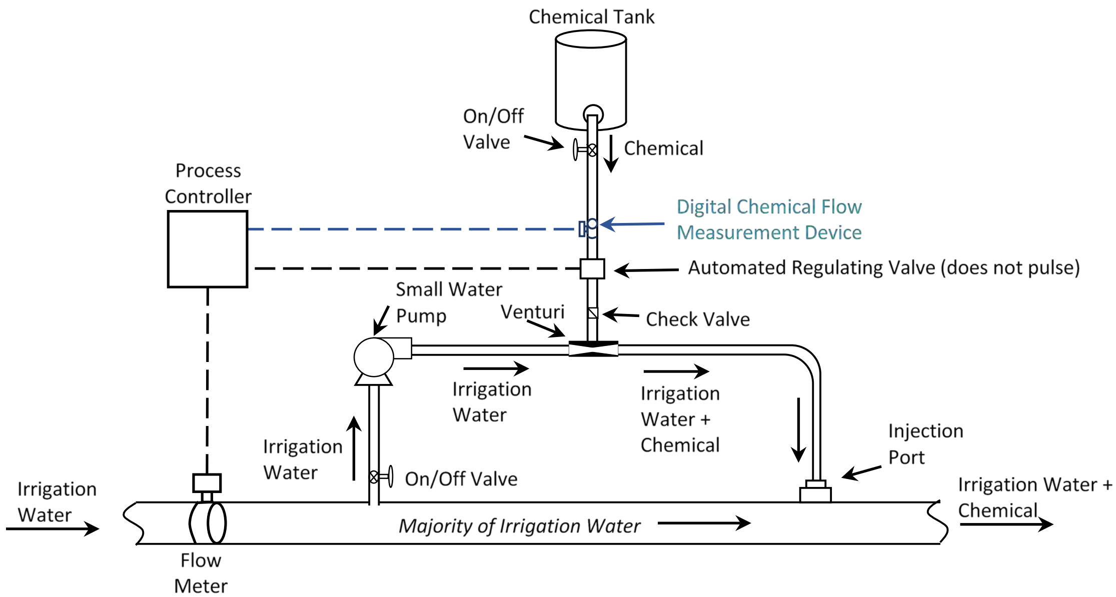

Figure 2. *Recommended configuration of hardware for proportional fertigation.*

ACKNOWLEDGEMENTS

This project has benefited from discussions with dozens of manufacturers and fertilizer sales personnel, as well as farmers. ITRC staff have included Monica Holman, Abraham Lozano, and Sarah Crable. The project was completely funded by the CDFA/FREP program.

Understanding Influences on Grower Decision-Making and Adoption of Improved Nitrogen Management Practices

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INTRODUCTION

Adoption of improved nitrogen (N) management practices by California growers is a required step in reducing N movement into surface and groundwater and maintaining economically viable cropping systems, while satisfying the Irrigated Lands Regulatory Program (ILRP) requirements. Research over the past decade has identified many practices that can improve N management and maintain economically viable cropping systems. These practices include the use of N budgets to balance N inputs and outputs for individual field units; implementation of the "4R's" (right rate, time, place, and source); the use of leaf and soil N sampling for verification of crop nutrient status and residual soil N; appropriate integration of fertilizers with irrigation; enhancing soil health to improve nutrient retention; and careful deployment and management of micro-irrigation systems for efficient water use. Despite progress in the development of N management practices, there is insufficient understanding regarding the current rate and barriers to practice adoption.

Recent research has suggested a number of possible factors influence grower decision-making, including perceptions of risk, economic and labor constraints, social norms, sources of trusted information, social capital and networks, farm characteristics including size and income, and participation in local policy forums (Knowler and Bradshaw 2007, Lubell and Fulton 2008, Prokopy et al. 2008). However, we do not have a robust understanding how these factors relate to adoption rates of improved N management practices across the diverse geographies and grower demographics of the Central Valley. This includes the role of different types of policy tools and outreach strategies for influencing farmer behavior.

This project aims to (i) develop an understanding of the current status of grower adoption of improved N management practices, (ii) determine the key influences on grower decision-making, and (iii) identify the key incentives and barriers to enhanced adoption of improved management practices. The information developed will inform stakeholder groups including regional Water Quality Coalitions, UC Extension, private consultants, State Water Boards, commodity groups and others to inform policy-making and improve N management.

OBJECTIVES

1. Develop a qualitative understanding of key influences and barriers to adoption of improved N management practices in the regions represented by the Colusa-Glenn Subwatershed Program (CGSP), the San Joaquin County & Delta Water Quality Coalition (SJDWQC) and the East San Joaquin Water Quality Coalition (ESJWQC).
2. Distribute, collect and aggregate quantitative survey following Dillman method data from growers in CGSP, SJDWQC and ESJWQC (Dillman et al. 2008).
3. Analyze both qualitative and quantitative response data to determine key motivations and barriers to grower adoption of improved N management practices.

DESCRIPTION

The project and research approach consisted of multiple steps of qualitative and quantitative data collection coupled with analysis and outreach. In order to qualitative understanding of adoption of improved N management practices, we conduct semi-structured interviews with growers in each of the regions to better understand their use of N management practices and the social, political, and economic factors influencing adoption of practices. In conjunction with regular meetings, we hosted voluntary grower focus groups. We quantified which practices are most in use in each region and why, perceived costs and benefits of each used and unused practice, greatest challenges to adopting new practices, additional soil health practices that appeal for multi-benefit purposes, sources of information most important in each region and their opinions on effective N management practices. Here we report our quantitative results.

RESULTS AND DISCUSSION

Results include grower meeting and mail surveys. Major themes emerged from these results:

Management practices are more easily adopted on large parcels and in permanent crops.

Growers operating on large parcels and in perennial crop systems report significantly higher adoption rates for nearly all practices and adopt a greater number of practices on average on their farms. These growers also name fewer challenges hindering practice implementation and associate a greater number of benefits with practice adoption.

Growers operating on large parcels report contact with more information sources on N management, with more than 50% of large parcel growers reporting contact with 4 or more different information sources (Fig. 3) WQCs and PCAs are only entities where there are not significant differences between large and small parcel growers, meaning these two entities act as an important source that have likelihood of equally providing info to large and small operations. Through qualitative work we have heard thoughts that elaborate on these findings: sources like UCCE are less helpful to small growers, powerful and well-resourced industry groups don't exist for annual crops; economies of scale matter; access and usefulness of "unbiased" information sources (UCCE and CDFA) on management practices have decreased and much of this information comes from private consultants and industry representatives.

The effect of water management on N movement is underappreciated by growers.

Fertilizer and soil management practices are more commonly adopted and more closely associated with improved N management, than irrigation practices.Nearly 50% respondents associate positive benefits of NUE and improved soil health with fertilizer and soil management practices. Nearly 40% respondents associate positive benefits of water savings, drought adaptation, excessive rainfall adaptation, extreme temp adaptation with irrigation practices. Mental models do not connect irrigation practices to N movement or soil benefits and vice versa.

Water source, surface water or groundwater, influences practice adoption (p=0.13), surface water users are more likely to adopt irrigation practices. We hypothesize this is because surface water users receive water in one delivery and must be strategic and careful with water use. Surface water users also associate greater benefits across all management practices. Qualitative work suggests that growers perceive a large change in consciousness and attention to water management post-drought and think that drip irrigation increases will assist in N management goals, but maybe aren't associated with that yet.

Uncertainty is the largest perceived challenge with adoption of any practice and improved crop yield & crop quality are the most commonly associated benefits with decisions to implement practices.

Adopters largely report no challenges with practices. This result confirms our hypothesis that higher adoption would be correlated with few barriers. Uncertainty named most commonly as challenge for every practice

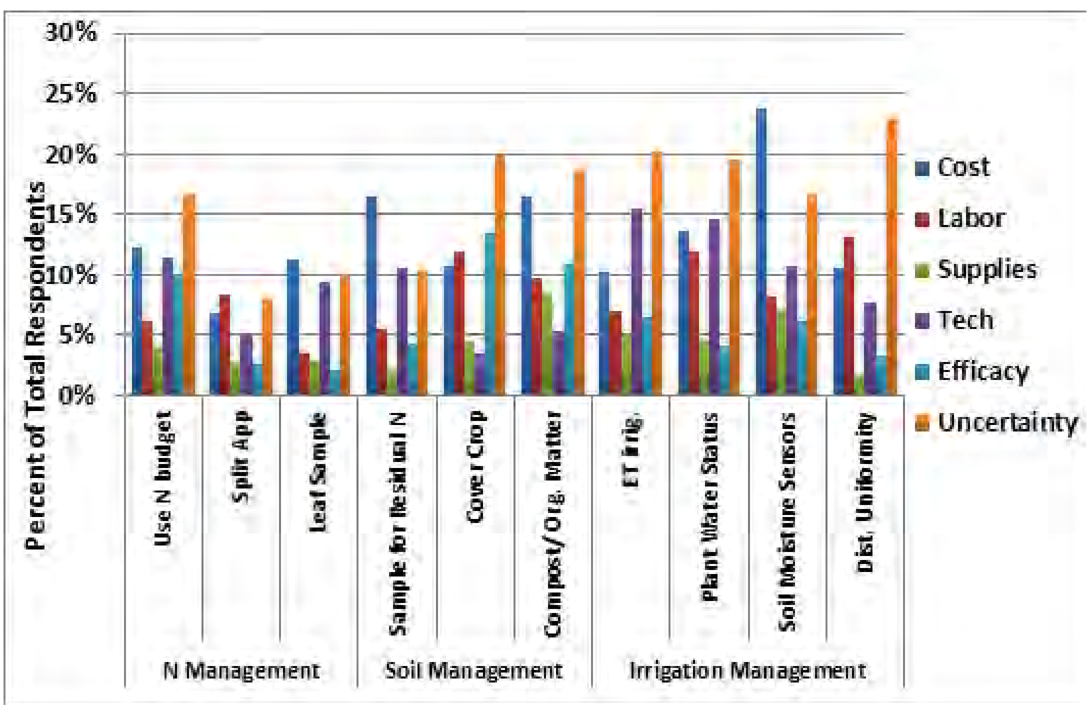

Figure 1: Growers were asked about 6 challenges (cost, labor, supplies, tech, efficacy, uncertainty) that may inhibit adoption of management practices. Uncertainty is the most commonly named challenge to practice adoption for 7 out of 10 practices.

(and more commonly on small parcels than large parcels for all practices but, cover cropping). Improving yield and crop quality are largest recognized benefits for all management areas; with ~70% of respondents indicating these benefits are important for them in making their management decisions. Qualitative work affirms that it is most important to discuss the on-farm reasons for doing something, and that messaging must address risk associated with practice and benefits to crop from practice, should emphasize end goal. If practices do not help the farm itself, they must be incentivized or subsidized. We expanded questions on uncertainty in the mail survey (Fig.1). Uncertainty on negative impacts of a practice on crop yield appears most important to growers.

Advances in the information source concepts of 'Familiarity breeds trust' and 'Information availability and reliability' were uncovered from mail surveys.

Growers seek information from many sources to base their nitrogen management decisions, but most important sources are PCAs (cited by 75% growers) and their own past experiences (84%) (Fig.2). Average ratings of the usefulness of different information sources correlate very closely with how commonly the information source is referenced.

LITERATURE CITED

Dillman, D. A., G. Phelps, R. Tortora, K. Swift, J. Kohrell, J. Berck, and B. L. Messer. 2008. Response Rate and Measurement Differences in Mixed Mode Surveys using mail, telephone, interactive voice response and the internet. Social Science Research 38:1–18.

Knowler, D., and B. Bradshaw. 2007. Farmers' adoption of conservation agriculture: A review and synthesis of recent research. Food Policy 32:25–48.

Lubell, M., and A. Fulton. 2008. Local policy networks and agricultural watershed management. Journal of Public Administration Research and Theory 18:673–696.

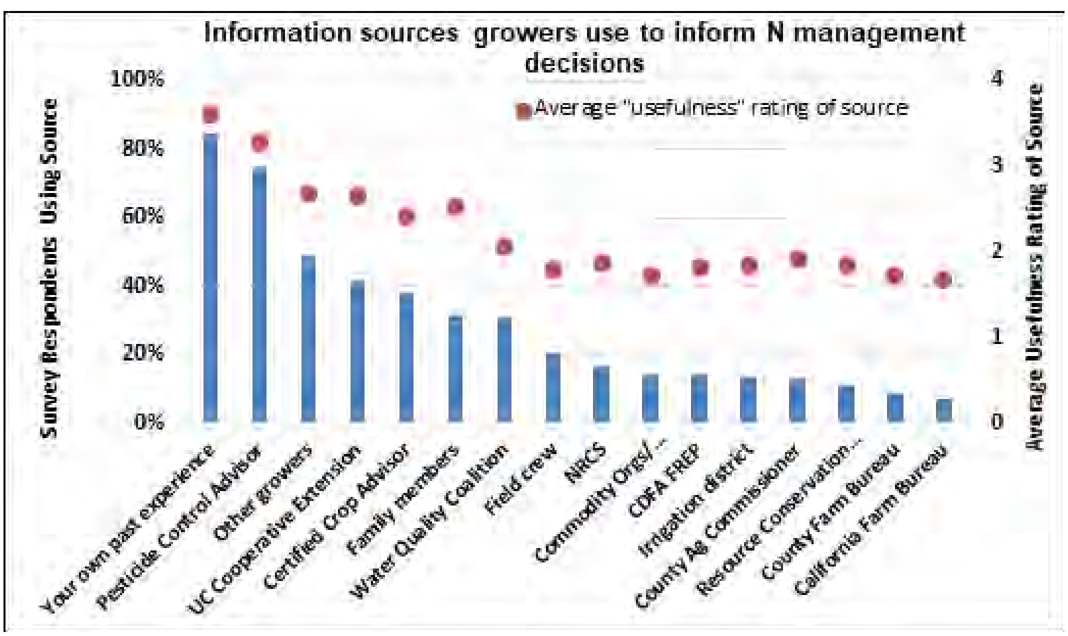

Figure 2: Growers seek information on N management from many potential sources and familiarity with source breeds greater trust (i.e. higher usefulness rating).

Prokopy, L. S., K. Floress, D. Klotthor-Weinkauf, and A. Baumgart-Getz. 2008. Determinants of agricultural best management practice adoption: Evidence from the literature. Journal of Soil and Water Conservation 63:300–311.

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Evaluation of Biochar for On-Farm Soil Management in California

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INTRODUCTION

Farmers, researchers, and policymakers are increasingly interested in the use of biochar, a carbon-rich material created from the thermochemical conversion of biomass in an oxygen-limited environment, as a soil amendment. Due to the unique chemical and physical structure of biochar, the material offers many potential solutions to pressing agricultural issues. These issues include nitrate leaching, low nutrient use efficiency, vulnerability of soils to drought conditions, and depleted soil carbon stocks.

Previous research shows inconsistent results on the ability of biochar to address these issues, due to differences in biochar feedstock, production methods, soil properties, climate, and cropping systems. Furthermore, these results have limited agricultural relevance, as biochar studies are dominated by short-term laboratory experiments that are difficult to extrapolate to field-scale. To inform the use and regulation of biochar, it is essential that farmers and policymakers have access to reliable, place-based data.

This study aims to fill a gap in literature by providing long-term, field-scale data about the potential of biochar for CA agriculture. Seven biochars of diverse feedstock and production temperatures were produced and amended in two one-acre plots in Yolo and Fresno Counties. Data will be collected from a minimum of three seasons under tomato production, on the impact of biochar on yield, plant nutrition, fertilizer use efficiency, and soil properties. Data will be evaluated along with fertilizer and biochar parameters, in order to assess the conditions most likely to lead to beneficial outcomes.

OBJECTIVES

The overarching objective is to provide data specific to CA regarding the potential for biochar to provide benefits for agriculture in the Central Valley. Specific objectives are:

1. Characterize biochars produced from local CA biomass
2. Evaluate the impact of biochar amendments on soil-water dynamics, nutrient use efficiency (including leaching), carbon stocks, and crop productivity
3. Evaluate soil conditions and biochar parameters, including biochar and fertilizer application rates, which are most likely to lead to beneficial outcomes
4. Create the California Biochar Initiative in order to provide a forum for growers, advisors, fertilizer producers, regulators, and other stakeholder groups to obtain objective information regarding the use of biochar in California agriculture.

DESCRIPTION

This three-year project will evaluate the use of biochars in on-farm, growth chamber, and laboratory experiments, as detailed in Table 1.

Task 1. Produce and Characterize Biochar

Seven biochars of local CA feedstocks were produced at low and high temperatures through commercial biochar companies. To date, these biochars have been analyzed for total carbon, nitrogen (N), oxygen, and surface area, as well as cation exchange capacity, pH, electrical conductivity, ash content, and dissolved organic carbon.

Task 2. Field Trials in Yolo and Fresno Counties

In fall 2017, one-acre plots were amended with biochar in two locations: UC Davis Campbell Tract and the Kearney Agriculture Research and Extension Center in Parlier. The two soils, a Yolo silt loam and a Hanford sandy loam, represent over 500,000 acres of CA soils. The experimental design is a randomized complete block design (RCBD) with three blocks and one treatment replicate per block. Biochars were subsurface banded directly above the drip tape to maximize contact with irrigation and fertigation, and to minimize application costs. Biochars were applied in two or three rates and combined with a low (150 lbs. N) and high (225 lbs. N) UAN-32 fertilizer rate.

Field sites are planted each spring with processing tomatoes and harvested each fall. In 2018, preplant and postharvest soil samples were taken from 0-30 cm, 30-60 cm, and 60-90 cm and analyzed for mineral N, total carbon and N, pH, and moisture content. Plant samples were collected and analyzed for yield as well as total carbon and N. A N budget was calculated to determine N losses, or the total of N volatilized and leached from each treatment (Equation 1) (Figure 1).

Table 1. Project work plan

Project Tasks	Year 1		Year 2		Year 3	
Task 1: Produce and characterize biochar	✓	✓				
Task 2. Field trials in Yolo and Fresno Counties		✓	✓	✓	✓	✓
Task 3. Growth chamber and laboratory trials		✓	✓	✓	✓	✓
Task 4. Life cycle assessment of biochar in CA.				✓	✓	✓

Equation 1. N losses (volatilization + leaching) = Preplant soil N + Fertilizer N + Irrigation N + Mineralized N - Postharvest soil N - Crop and vine N

In April of 2019, preplant soil samples were taken to 90 cm (as described above) from each site and analyzed for pH and mineral N. Determination of total carbon and N is ongoing and will be completed in October 2019. Fields were planted with processing tomatoes in May (Figure 2), to be harvested in fall for yield and plant nutrient analysis.

Task 3. Growth Chamber and Laboratory Trials

A series of growth chamber and laboratory studies have been conducted in order to observe plant-soil-biochar interactions with regards to yield, plant nutrition, and nitrate/ammonium retention. These studies include sorption experiments, soil columns, micro-CT scans, and pot trials with lettuce grown in soils with 0 and 2% biochar.

Task 4. Life Cycle Assessment of Biochar Amendments in CA

In the winter of 2018, a review of literature related to life cycle assessments (LCAs) of biochar and gasification/pyrolysis systems was conducted. The goal and scope of this future study has been defined, as well as the audience and system boundaries.

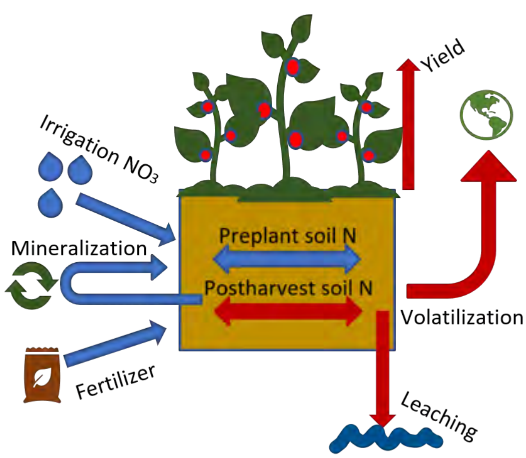

Figure 1. Conceptual diagram of N sinks and sources during crop production

RESULTS AND DISCUSSION

Figure 3 shows yields from season 1 (2018) processing tomato trials in Davis, CA. Few differences or trends can be identified between biochar treatments and the unamended control (N_0). Furthermore, there were not significant differences between the low and high fertilizer rates. This was also true for yields in Parlier, CA, though the data is not presented here. Likewise, biochar had no significant effect on nitrogen losses in either location in season 1. In a 2017 study from Davis, CA, biochar also had no effect on tomato yields in season 1, though season 2

Figure 2. Progress of processing tomato crop in season 2 field trials

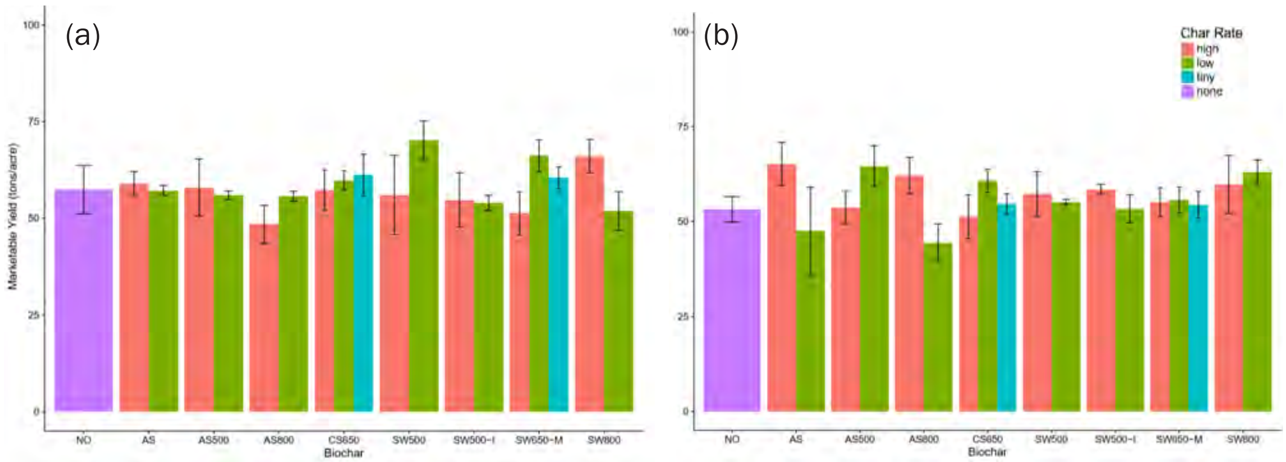

Figure 3. *Marketable tomato yield from season 1 field trials in Davis, CA, fertilized with (a) 225 lbs.-N/acre UAN-32 and (b) 150 lbs.-N/acre UAN-32.*

yields were significantly higher with biochar amendment (Griffin et al. 2017). Season 2 harvest is currently underway and will show if the effect of biochar changes over time for yield and N losses in our study.

ACCOMPLISHMENTS

Several outreach activities were conducted for various audiences, including academics, growers, and members of industry. These events include, among others, an invited talk at the Russell Ranch field day in June 2019, a poster at the Soil Health Institute meeting, and a workshop for the Almond Board of California Leadership Class. The first manuscript related to this project was published in May 2019, entitled, An emerging environmental concern: Biochar-induced dust emissions and their potentially toxic properties (Gelardi et al. 2019). Season 1 field trials were successfully completed, and season 2 data collection is well underway. Method development for all laboratory experiments has been completed and trials are ongoing.

LITERATURE CITED

Gelardi, D.L., C. Li, and S.J. Parikh. 2019. An emerging environmental concern: Biochar-induced dust emissions and their potentially toxic properties. Science of the Total Environment 678, 813–820. https://doi.org/10.1016/j.scitotenv.2019.05.007

Griffin, D.E., D. Wang, S.J. Parikh, and K.M. Scow. 2017. Short-lived effects of walnut shell biochar on soils and crop yields in a long-term field experiment. Agriculture, Ecosystems and Environment 236, 21–29. https://doi.org/10.1016/j.agee.2016.11.002

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Evaluation of Certified Organic Fertilizers for Long-term Nutrient Planning

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INTRODUCTION

Nitrogen management, and predicting crop nitrogen availability through mineralization of soil nitrogen and organic fertilizer amendments is a challenge in cropping systems due to the complexities and interacting forces of weather, soil biology and physical properties, organic input quality and chemistry, and intensive management practices (Cabrera et al., 2005; Schomberg et al., 2009). The value of organic fertilizer nitrogen amendments cannot be overstated. It is generally accepted that using organic fertilizer nitrogen sources increases nitrogen use efficiency. Combined with conventional mineral fertilizers, organic fertility sources can achieve equivalent or larger yields and often provide for greater yield stability than conventional mineral fertilizers alone (Poudel et al., 2001). One of the reasons for higher yield potential is that soils amended with organic nutrient sources, often increase the mineralization of native soil nitrogen compared to those receiving only mineral fertilizers (Doane et al., 2009; Moreno-Cornejo et al., 2015).

In a research setting, soil nitrogen mineralization potential, i.e. the availability of plant-available nitrogen over a given time, is often assessed with laboratory incubations of soil and or mixtures of soil and amendments (Stanford and Smith, 1972). The method is accurate in predicting the nitrogen mineralization potential of different amendments and soil nitrogen. For example, Heinrich and Pettygrove (2012) demonstrated that about 48% of nitrogen mineralized from a range of dairy manures after 63 days of incubation in a class 1 fine sandy loam soil. The use of organic fertilizers provides several nutritional benefits for crop systems; however, the heterogeneous content of organic amendments can lead to diverse outcomes for N availability and use efficiency. The lack of information on the nitrogen mineralization kinetics of organic fertility sources has hampered our ability to effectively use organic fertilizers in crop management to increase the efficacy of nutrient plans.

The inclusion of mineralized nitrogen from soil and organic sources of nitrogen into fertilizer recommendations is essential to improving nitrogen use efficiency in agronomic systems. Underestimation of the contribution of organic soil amendments and fertilizers to plant-available nitrogen can result in excess reactive nitrogen being released into the environment. Over fertilization has been shown to result in increased nitrous oxide emissions (Stehfest and Bouwman, 2006) and the pollution of groundwater with nitrate (Harter and Lund, 2012). To avoid such serious consequences of over-fertilization, it is necessary to accurately predict nitrogen release from organic sources and sync nitrogen supply with crop nitrogen demand.

Recent research has shown that nutrient release from organic amendments is highly dependent on the quality of the material, inorganic N content and overall C:N ratio (Gómez-Muñoz et al., 2017)in which diverse types of urban (human urine, sewage sludge, composted household waste. Given this, it is important that these factors are considered in the analysis of the materials. Taking a categorical approach, we are seeking to evaluate amendments based on both organic/inorganic carbon and nitrogen amounts in order to develop a generalized material characterization table. These values will be compared to the values recorded in the literature review. Additional confounding factors in the rate of nitrogen release from organic amendments include both moisture and temperature variability under field conditions (Agehara and Warncke, 2005). Using laboratory incubations under different temperatures we seek to determine a rate constant to better understand these materials as a function of temperature variability.

OBJECTIVES

The overarching objective is to provide baseline data to inform nitrogen management plans specific to CA where organic fertilizer amendments are used in agricultural production areas. Specific project objectives for this project are:

1. Conduct an extensive literature review on soil N mineralization and crop N availability as affected by organic based N fertilizers.
2. Determine seasonal N mineralization and N mineralization potential in soils repeatedly amended with organic fertilizer in CA.
3. Conduct field trials to assess and confirm lab and DayCent model results and to inform the COMET–Farm.
4. Conduct extensive engagement and outreach to inform on the value and to reassess organic fertilizer amendment rates to avoid N loss and promote healthy soils.

DESCRIPTION

We proposed a combination of literature values, lab incubations and field trials to calibrate and verify the DayCent model to predict the seasonal and long-term nutrient value of organic fertilizer amendments for soil productivity improvement and nutrient management. We specifically determined nitrogen mineralization responses to predict the long-term effects of repeated annual applications of organic fertilizers on soil N availability. Key to effectively use the information on nitrogen mineralization generated in this project is the parameterization of the DayCent model, so that the model can accurately predict nitrogen mineralization rates at different soil temperatures under soil conditions in California throughout the year. Most models use default values resulting in poor prediction outcome. Our results will provide for adjustments of nutrient management guidelines depending on organic fertilizer sources, soil type, and climate data.

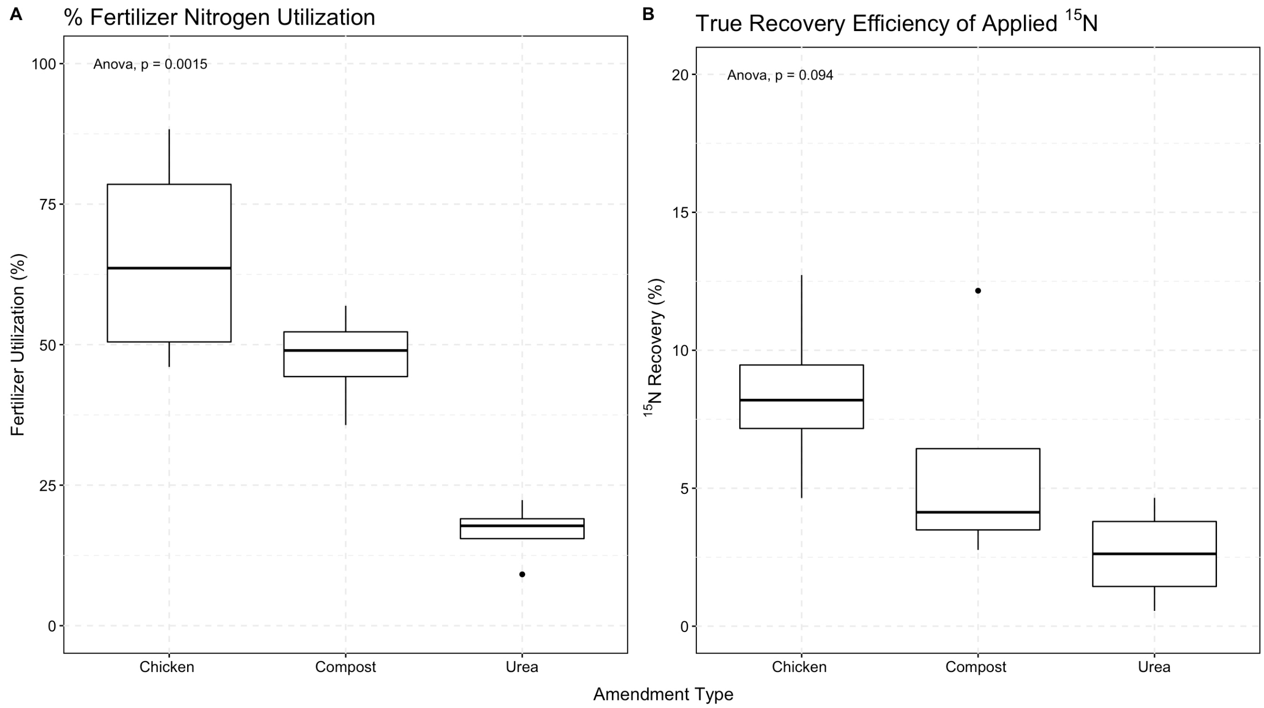

Figure 1. *Calculated fertilizer and nitrogen use efficiencies as related to amendment inputs. A) Calculation of fertilizer utilization using ratio of labelled fertilizer to total fertilizer application rate. B) True 15N recovery as calculated by the total amount of 15N in crop fruit and biomass divided by the total amount of 15N added as fertilizer.*

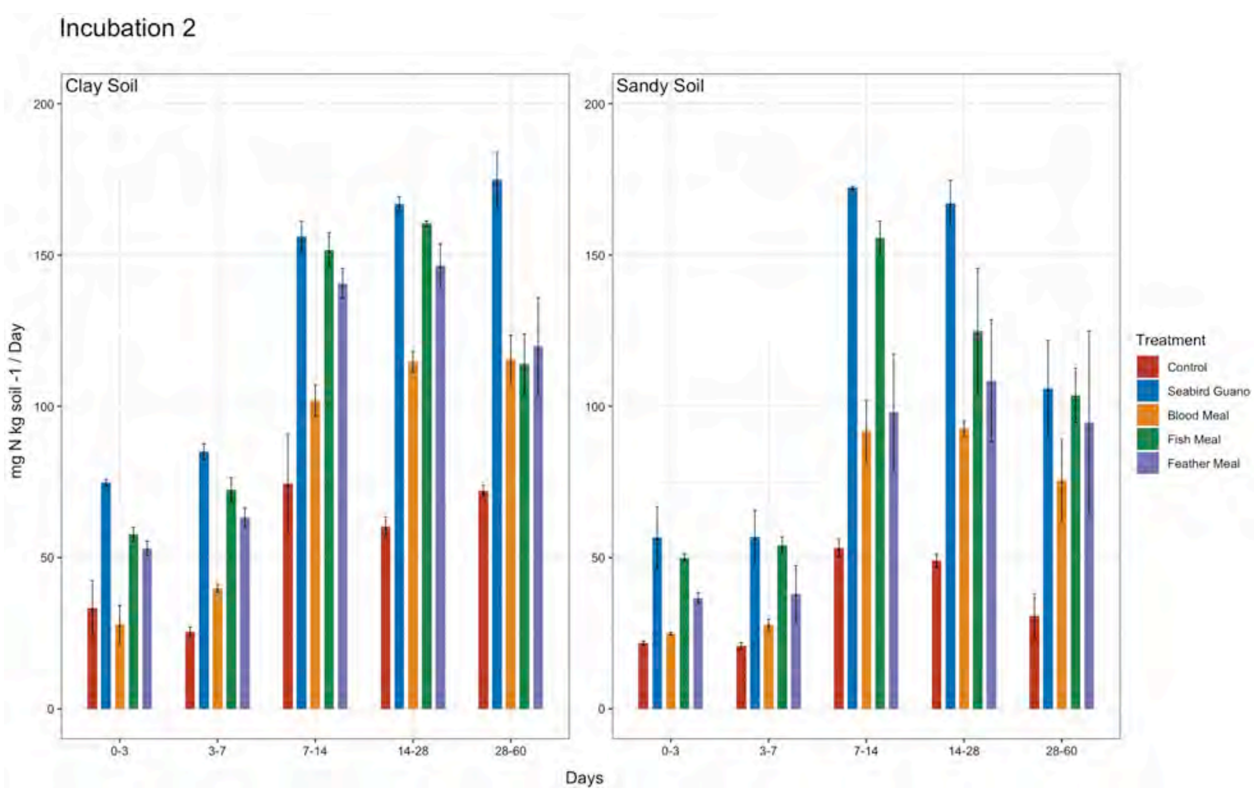

Figure 2. *60-day aerobic laboratory incubations during project year 2019 with 3 replicates of each organic amendment, in two soil types both at 20°C.*

The information generated in this research will be used by UC Extension, CCAs and farmers to reassess nitrogen management across a variety of crops. This is a three-year project and to date we have accomplished literature review and one season field trial. The laboratory incubation is on-going and a second season of field trials is being conducted. The outcome of this research will allow for adjustments of nutrient management plans to maintain and increase crop productivity, reduce the potential for N loss to groundwater, and minimize greenhouse gas emissions.

RESULTS AND DISCUSSION

Field Trials: Each organic amendment treatment, green-waste compost and pelletized chicken manure, increased fertilizer nitrogen utilization compared to the control (urea only). Calculated as the fraction of total fertilizer taken up by the crop by using enrichment difference in both the crop fruit and biomass divided by the percent enrichment of the applied fertilizer, fertilizer utilization was significantly higher ($p=0.0015$) for organic amendments (figure 1a) than for urea alone. The true recovery of applied ^{15}N was also calculated (Hauck and Bremner, 1976) as a percent of labelled fertilizer directly taken up by crops and it showed no significant difference ($p = 0.094$) among organic amendments. However, the ^{15}N enrichment data showed that fertilizer N was evenly distributed between crop residue and fruit.

Laboratory Incubations: Multiple laboratory incubations are currently in progress, the data in Figure 2 is collected from aerobic incubations lasting 60 days. These initial results indicate that soil type has an influence on the rate of nitrogen mineralization for a select number of organic amendments but not others. Statistical modelling to assess the magnitude of environmental influences is currently on-going.

The nitrogen mineralization rate of soils amended with urea or the low C: N ratio amendment (i.e chicken pellets) was higher in the sandy soil than in the clay soil. However, for the high C: N ratio amendments (i.e. compost), higher N mineralization rate was found in the clay soil than in the sandy soil. A similar result was detected during the second incubation of different organic amendment, for example seabird guano and fish meal responded similarly in each soil type but feather meal and blood meal different.

TAKE-HOME INFORMATION

From this ongoing project, we found that: 1) When synthetic N fertilizer (Urea) is applied in combination with select OAs, fertilizer use efficiency is improved compared to the use of urea alone. This likely because organic amendments initially immobilized the applied fertilizer N, which was released via mineralization process throughout the growing season. The organic amendment with the lowest carbon-to-nitrogen ratio (chicken manure pellets) had the highest eventual FUE which was an unexpected result. This finding has significant implications for long-term agronomic planning, potentially reducing nitrogen input needs and cost associated with fertilization. 2) Soil type is a factor in determining mineralization rate of only select amendments, and not others. More research is required to determine which amendments are influenced by soil characteristics, including how this impacts long-term N availability from these amendments. Research related to this project will continue, including additional amendments to be evaluated using aerobic incubations, field N mineralization evaluation using buried litter bags and statistical modelling.

LITERATURE CITED

Cabrera, F., Martín-Olmedo, P., Lopez, R., and Murillo, J. M. (2005). Nitrogen mineralization in soils amended with composted olive mill sludge. Nutrient cycling in agroecosystems 71, 249-258.

Doane, T. A., Horwath, W. R., Mitchell, J. P., Jackson, J., Miyao, G., and Brittan, K. (2009). Nitrogen supply from fertilizer and legume cover crop in the transition to no-tillage for irrigated row crops. Nutrient cycling in agroecosystems 85, 253-262.

Harter, T., and Lund, J. R. (2012). "Addressing Nitrate in California's Drinking Water: With a Focus on Tulare Lake Basin and Salinas Valley Groundwater: Report for the State Water Resources Control Board Report to the Legislature," Center for Watershed Sciences, University of California, Davis.

Hauck, R.D., and J.M. Bremner. 1976. Use of tracers for soil and fertilizer nitrogen research. Adv. Agron. 28: 219–266.

Heinrich, A. L., and Pettygrove, G. S. (2012). Influence of dissolved carbon and nitrogen on mineralization of dilute liquid dairy manure. Soil Science Society of America Journal 76, 700-709.

Moll, R.H., Kamprath, E. J. and Jackson, W.A. (1982). Analysis and interpretation of factors which contribute to the efficiency of nitrogen utilization. Agronomy Journal 74, 562-564.

Moreno-Cornejo, J., Zornoza, R., Doane, T. A., Faz, Á., and Horwath, W. R. (2015). Influence of cropping system management and crop residue addition on soil carbon turnover through the microbial biomass. Biology and fertility of Soils 51, 839-845.

Poudel, D., Horwath, W., Mitchell, J., and Temple, S. (2001). Impacts of cropping systems on soil nitrogen storage and loss. Agricultural Systems 68, 253-268.

Schomberg, H. H., Wietholter, S., Griffin, T. S., Reeves, D. W., Cabrera, M. L., Fisher, D. S., Endale, D. M., Novak, J. M., Balkcom, K. S., and Raper, R. L. (2009). Assessing indices for predicting potential nitrogen mineralization in soils under different management systems. Soil Science Society of America Journal 73, 1575-1586.

Stanford, G., and Smith, S. (1972). Nitrogen mineralization potentials of soils. Soil Science Society of America Journal 36, 465-472.

Stehfest, E., and Bouwman, L. (2006). N2O and NO emission from agricultural fields and soils under natural vegetation: summarizing available measurement data and modeling of global annual emissions. Nutrient Cycling in Agroecosystems 74, 207-228.

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University of California Nursery and Floriculture Alliance Fertilizers and Plant Nutrition Education Program

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INTRODUCTION

According to the 2017-2018 Agriculture Statistics Review, the value for Nursery Products in 2017 was $3.05 billion and for Floral Products was $774 million for a combined total of $3.82 billion. This places the combined Nursery and Floral Crops as the number 4 agricultural crop commodity in the state below, in order with values provided in billions: Grapes ($7.12), Milk and Cream ($6.64), and Almonds ($6.49). In addition, Nursery and Floricultural crops are in the top 10 agricultural commodities in 34 of California's 56 counties that reported agricultural production in the survey. According to CDFA, there are 2,664 nurseries in the state licensed as "producers", growers of nursery and floriculture products. Horticultural crops are grown in highly intensive systems, high plant densities and shortened crop times, so there is also a high demand for resources including water, energy, labor, and nutrients in these production systems. Managing their use is imperative to optimize efficiencies, minimize waste, and mitigate pollution.

Fertilizers are an essential part of greenhouse and nursery plant production. Crops in these production systems are generally grown in containers and not in the ground. Containerized plant production uses growing substrates that are "synthetic" in that they contain no natural mineral soils. Since there is little to no fertility provided by these substrates, all of the nutrition must be provided for healthy and productive growth using fertilizers or organic supplements.

Improper management of plant nutrition can affect crop health. Both under- and over-applying fertilizers can result in poor crop quality, which not only has negative economic impacts, but also can pollute surface and ground water.

OBJECTIVES

The project objective is to provide greenhouse and nursery growers with knowledge to improve crop plant nutrition and fertilizer management. An educational program for greenhouse and nursery growers on the proper and efficient use of fertilizers will be developed and extended to achieve this. The five objectives for this project are to:

1. Improve the workshop program that is currently delivered based on input from attendees and instructors. Topics may be reduced, expanded, and others added. Topics for consideration to be added include training on how to read soil and water analyses and how to interpret the information for greenhouse and nursery crop fertility and irrigation management.
2. Deliver the improved workshops to nursery and greenhouse growers in the regions of the state where there are concentrations of growers such as San Diego, Ventura, San Joaquin Valley, and Watsonville/Salinas areas.
3. Utilize the delivery of the improved workshops to produce videos on specific topics. Videos would be topic specific, brief, and recorded in both English and Spanish. The UC Agriculture and Natural Resources Division (ANR) videography group will be utilized to produce the videos.
4. Post the videos online at the UC Nursery and Floriculture Alliance (UCNFA) website (UCNFA.UCANR.edu).
5. Measure impact through surveys of workshop attendees to assess implementation of nutrient management methods.

DESCRIPTION

The existing program provided by the UCNFA, ABCs of Fertilizers and Plant Nutrition, was reviewed, modified, and presented to growers. The original format was a full day in English followed by a second full day presenting the same program in Spanish. It was determined based on informal interviews of growers that half-day programs would be more attractive since employees would not be away from work for a full day all-at-once. A set of pilot workshops in the half-day format was presented in Salinas, CA on January 10 and February 20, 2018. Surveys and discussions with attendees immediately following each workshop provided information to make additional adjustments to the programs. Additional workshops in the modified content were provided in Fresno on September 25 and October 25, 2018. A third set of workshops is now being presented in San Marcos, CA on August 21 and September 18, 2019.

Production of instructional videos was initiated by outlining the topics presented at the workshops. It was determined that there could be as many as 33 separate videos on topics ranging from nitrogen nutrition to irrigation scheduling. Due to the extensive range of topics that are discussed at the workshops, videos on only basic, primary topics were to be developed.

RESULTS AND DISCUSSION

Workshops were split into two half-day programs.

The topics covered on Day 1 include:

Essential Plant Nutrients

- Essential Nutrients
- Nutrient Uptake
- Nutrient Allocation in Plants
- Plant Nutrient Disorders

Developing Fertilizer Programs

- Irrigation Water
- Planting Media
- Crop Type
- Cultural Practices

The Day 2 topics are:

Fertilizer Types

- Sources and Formulations
- Soluble Fertilizers
- Granular Fertilizers
- Organic Fertilizers

Monitoring Crop Fertility Status

- Irrigation Water
- Media
- Tissue

Draft videos were produced with the following titles in both English and Spanish:

- Essential Nutrients and Fertilizer Use in Nursery Production
- Nitrogen in Plant Nutrition Nitrogen: Deficiencies and Toxicities
- Phosphorus in Plant Nutrition
- Potassium in Plant Nutrition

TAKE-HOME MESSAGES

Each series of the two half-day workshops were provided three times with a total of 226 attendees.

Location	Date	Attendance
Salinas 1	January 11, 2018	English: 16, Spanish: 18
Salinas 2	February 20, 2018	English: 37, Spanish: 16
Fresno 1	September 25, 2018	English: 54, Spanish: 23
Fresno 2	October 25, 2018	English: 24, Spanish: 11
San Marcos 1	August 21, 2019	English: 17, Spanish: 10
San Marcos 2	September 18, 2019	—

The drafts of the 10 videos, 5 in English and 5 in Spanish, were posted for a brief period of 6 months for testing with minimal advertising and notification only to specific clientele. In that short period there were 552 views, 381 views of the English videos and 171 of the videos that were produced in Spanish. A comment from one grower was that they were of excellent quality and that they have been incorporated into their grower training programs. They are currently not posted and are being re-edited.

Although there are no additional workshops currently planned there have been requests by the Los Angeles Irrigated Lands Group to provide them to growers in the Los Angeles and Ventura areas.

ACKNOWLEDGEMENTS

We would like to thank Ray Lucas of UC Agriculture and Natural Resources Division Communications Services and Information Technology for his invaluable guidance and assistance in producing the videos. We thank CDFA FREP for providing the grant supporting this project (Agreement number 16-0678-SA).

Developing a Review Process for Continuing Education Courses for Growers Who Complete the Nitrogen Management Plan Training Course

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INTRODUCTION

Nitrate is the most common contaminant in Central Valley groundwater and elevated levels are attributed primarily to leaching of nitrogen fertilizers past the root zone into aquifers. Growers who belong to Central Valley Water Quality Coalitions are under requirements per the Irrigated Lands Regulatory Program (ILRP) to keep "on farm" a Nitrogen Management Plan (NMP) to track nitrogen fertilizer applications. For land in areas within High Vulnerability Groundwater Areas, Nitrogen Management Plans must be certified by a nitrogen management plan specialist. Growers may certify their own nitrogen management plans only after they successfully participate in a CDFA Nutrient Management Training class. FREP worked with UC Davis to develop a grower training curriculum and then awarded a grant to the Coalition for Urban and Rural Environmental Stewardship (CURES) to train CCAs who ultimately train growers to self-certify their Nitrogen Management Plans (NMP) through the program. To date, this program has qualified 3,292 growers in a joint effort with CDFA, CURES and UC. Upon successful completion of the course, a grower is able to certify the NMP for lands that they farm. After the initial grower self-certification, additional hours of continuing education are a requirement of the program approved by the Regional Water Board.

This phase (Phase 2) includes development and management of a process to review the agendas and contents of a proposed meeting or segment of a meeting that fulfills the Continuing Education requirement of the NMP certification process. Requests for continuing education credits must contain a CEU Approval Request Application, Basic Course Agenda and Comprehensive Course Agenda. The application is submitted online and contains basic contact information, as well as course date and location. The Basic Course Agenda is used for outreach and is posted on the CURES website upon approval. The Comprehensive Course Agenda must contain a detailed description of the presentation, including the session title, approximate start and end times, and the names and affiliation of all speakers. The content review is performed by Terry Prichard and CURES staff using criteria developed in conjunction with CDFA and UC. Once the CE meeting content is approved, the organizing entity is allowed to issue Continuing Education credits to the grower in the form of an attendance confirmation certificate. The grower is responsible for filing and maintaining records of attending CE events or courses.

OBJECTIVES

1. Develop a process to review the content of Continuing Education sessions in order for qualified growers to fulfill this condition of the NMP certification program; also develop criteria for evaluating a session proposal (CURES, PI and CDFA staff).
2. Review and approve requests from meeting organizers for Continuing Education sessions using criteria developed in conjunction with CURES, CDFA and UC; also provide support to meeting organizers to reach all certified growers needing to complete this condition of the NMP certification process

DESCRIPTION

Develop the Process and Criteria. Project Leader, Terry Prichard, and CURES staff worked with CDFA and UC to develop criteria for content. After criteria was developed, CURES staff designed the system for approval, including accompanying documents and a website portal needed to request Continuing Education Units for approval. Since the project's start, several activities have been conducted to promote the program. These include articles in coalition newsletters and trade publications, as well as presentations and CEU emails sent to Specialty Crops Council, Central Valley Water Quality Coalition managers, UC Cooperative Extension and Regional Water Board.

Manage and Coordinate the Continuing Education Sessions. Once agricultural organizations develop and submit the request for CEU approval, the project leaders and CURES staff review content by using developed criteria. Figure 1 shows the CEU application page on the CURES website. If an application meets the requirements, it is approved and implemented. The organizer will issue Continuing Education credits to the grower in the form of an attendance confirmation certificate. The grower is responsible for filing and maintaining records of attending CE events. CURES staff regularly notifies NMP self-certified growers of course availability via email. A schedule of upcoming courses is posted on the CURES webpage and is updated continuously. Every time a new course is added, an email notification is

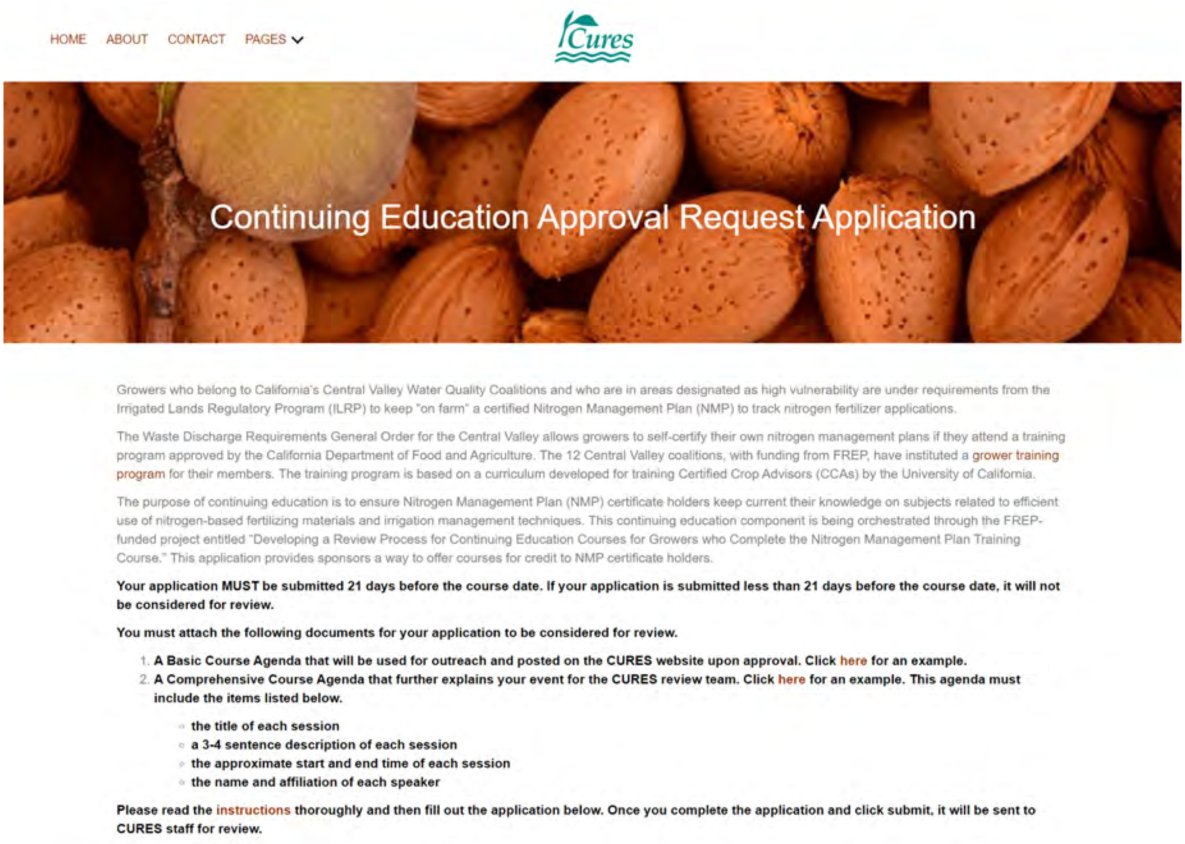

Figure 1. *Continuing Education Approval Request Application form on the CURES website (https://www.curesworks.org/continuing-education/).*

sent out to all growers who signed up to receive these notifications.

RESULTS AND DISCUSSION

Funds for this project are being used to develop and manage the process for reviewing and approving Continuing Education sessions in collaboration with agriculture organizations in the Central Valley for growers who have been certified to complete their own Nitrogen Management Plans. Since the start of the program, CURES has received 87 applications for Continuing Education sessions using criteria developed in conjunction with CDFA and UC. Out of the 87 applications, 80 were approved to issue Continuing Education Units to course attendees. Table 1 shows the number of applications received since the program's start in 2017.

ACCOMPLISHMENTS

The system and criteria that was developed by CURES staff, CDFA, and UC has been integral in implementing educational workshops to increase agricultural nitrogen use efficiency and reduce nitrate leaching potential. The information delivered to growers by this project supports FREP's goals to advance the environmentally safe and agronomically sound use of nutrients and the reduction of agricultural contributions of nitrate to groundwater in the Central Valley and agricultural regions throughout California. The BMP-related content of the Continuing Education Courses is vital to a significant portion of the approximately 30,000 landowners/operators, with a total of nearly 6 million acres of land in the Central Valley that are affected by the ILRP requirements to improve nutrient and irrigation application practices for reducing nitrate discharges to ground and surface water. This program also ensures the timely education of a diverse set of crop-specific topics via Continuing Education outreach sessions. The organizations and the growers they teach advance the knowledge of proper nitrogen stewardship, as attention by the public and policymakers continues to focus on the issue of nitrates in groundwater.

Through this project, there is now an increased awareness of the need for all types of farm organizations – water quality coalitions, commodity groups, University Cooperative Extension and County Agricultural Commissioners – to organize CEU courses on nitrogen and irritation management. It is expected that the program will continue to expand as water quality coalitions and farm organizations work to fulfill the ongoing need for its growers to obtain CEUs in nitrogen and irrigation management.

ACKNOWLEDGEMENTS

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Table 1. *The number of NMP Continuing Education applications received from October 2017 to September 2019. Total number of applications approved and denied are also included.*

Year	# of Applications Approved	# of Applications Denied	Total # of Applications
Oct – Dec 2017	13	1	14
Jan – Dec 2018	50	5	55
Jan – July 2019	17	1	18
TOTALS	**80**	**7**	**87**

Assessment of Harvested and Sequestered Nitrogen Content to Improve Nitrogen Management in Perennial Crops

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INTRODUCTION

As part of its Irrigated Lands Regulatory Program (ILRP), the Central Valley Regional Water Quality Control Board (Water Board) now requires producers to implement management practices that are protective of groundwater quality and to document the effectiveness of those practices by providing, among other things, information on field nitrogen (N) balances. In addition, the Agricultural Expert Panel convened by the State Water Resources Control Board recommended metrics composed of N applied (A) and N removed (R) to gauge program progress in reducing the mass of leachable N (Burt et al., 2014). This approach was adopted by the Water Board. To comply with this new reporting requirement, growers and their water quality coalitions need reliable data about N removed from fields in harvested crop materials. Also, growers can use rates of N removal in crops to plan nutrient management programs that reasonably minimize N at risk of leaching below the root zone.

Nitrogen Concentrations in Harvested Plant Parts - A Literature Overview (N-concentrations Report) by Dr. Geisseler (2016) presents yield-to-N-removed conversion factors for 72 crops, representing more than 98 percent of CV irrigated lands. However, that report noted that some of these factors are based on datasets that were small, more than 20 years old, or from outside the Central Valley with cultivars, yields, cropping systems, and soil types that may not reflect contemporary Central Valley conditions. The N-concentrations Report showed that well-established coefficients are available for only 10 of the 72 crops, accounting for approximately 12 percent of irrigated lands in the Central Valley. Further, there are even fewer data on the amount of N sequestered into perennial crop biomass, which growers need to know when planning N fertilizer programs for younger orchards, groves, and vineyards during rapid early growth of perennial tissues. To improve currently available estimates of coefficients for the remaining 62 crops from the N-concentrations Report, additional data need to be obtained by collecting recent crop samples from Central Valley fields over several years, and analyzing them for their N content.

OBJECTIVES

1. Assess N concentration of harvested material removed from fields (N removed [R]) for approximately 25 crops over several growing seasons. Samples of harvested material will be collected and analyzed for twelve of those crops. Data for the remaining crops will come from existing sources. As the project is evolving, it appears that more crops may be included in the study than originally planned.
2. Establish values for the annual amount of N sequestered in standing biomass for seven perennial crops. Tissue samples will be collected and analyzed for one of those crops. Data for the remaining crops will come from existing sources.
3. Refine crop yield (Y)-to-R conversion factors, and add N-sequestration rate estimates, for use by growers and grower advisors during nutrient management planning and by coalitions for large-scale performance assessment.
4. Promote and enable expanded knowledge and appropriate use of N-removal coefficients and N-sequestration rates (as part of routine N-management planning and evaluation) by growers, grower advisors, and coalitions.

DESCRIPTION

We are developing updated conversion factors for 25 crops. For some, information is coming from other research projects. However, we are sampling and analyzing harvested carrots, corn [grain and silage], peaches, pistachio, plums, pomegranates, raisins, safflower, sunflower, sorghum [grain and silage], and processing tomatoes. Pima cotton was also to be included, but that work is proceeding with funding from another project, the results of which will be available to update N removal information for this crop. By partnering with commodity organizations, growers, processors, and packers, it has been possible to procure hundreds of samples that represent a range of varieties and growing environments for each crop. In most cases, substantial information about source fields, such as age of perennial crops, crop management, variety, yield, quality, and dates of bloom or planting, are acquired and related to results. In this way, some of the factors that affect N content of the harvest can be investigated and explained.

These data will be incorporated into updates of Geisseler (2016) as part of this project. The existing Y-to-R calculator (http://agmpep.com/calc-y2r/) will be revised to reflect these findings, and the results will be used to update the assessment and planning tools available to growers, grower advisors, and coalitions.

RESULTS AND DISCUSSION

Work completed since the January 2018 grant award includes coordination of two years of sampling of 11 crops with grower/packer/shipper partners, along with preparation and analysis of the samples obtained.

Our efforts to work with growers, packers and shippers has been successful and efficient. Through our flexible approach with each collaborator, we have been able to get hundreds of representative samples from representative fields.

We are currently receiving samples for the 2019 growing season for carrot, peach, plum, and tomato. We are scheduled to get our first samples of safflower and pistachio in early September, and pomegranate in early October. Corn and sorghum samples

Table 1. Samples obtained to date with the assistance of various industry groups and grower/packer/shipper organizations.

Crop	Tissue	Industry Group	Number of Samples (Year-1)	Number of Samples (Year-2)	Field Years
Pistachio	Annual	CA Pistachio Research Board	99	60	159
Corn	Annual	CA Alfalfa & Forage Association	10	10	20
Sorghum	Annual	CA Alfalfa & Forage Association	10	10	20
Pomegranates	Annual	Pomegranate Council	40	20	60
Tomatoes, process	Annual	Processing Tomato Advisory Board	100	90	178
Pima cotton	Annual	California Cotton Ginners & Growers	10	0	10
Peaches	Annual	CA Fresh Fruit Association	36	32	71
Plums	Annual	CA Fresh Fruit Association	12	20	28
Carrots	Annual	CA Fresh Carrot Advisory Board	66	40	106
Raisins	Annual	California Raisins	90	30	120
Sunflower	Annual	National Sunflower Association	0	30	60
Safflower	Annual	California Safflower Growers Association	152	60	105
Total			**625**	**402**	**937**

are available but have yet to delivered for analysis. We are in communication with a representative from a raisin packer and are working to acquire samples from their archive. We recently identified a collaborator to provide sunflower harvest samples and should be receiving some within the coming months. Within the initial scope of the project, we planned to collect and analyze samples for Pima cotton, but our industry partner will collect and analyze samples, then supply us with the results. The cost of this analysis will therefore be absorbed by our partner, and those funds are being used for other crops. Bok choy, on choy and daikon (also handled by another project) have all proved difficult to orchestrate sampling for. We are uncertain if they will be successful.

During our second year, we have refined our sampling methods to better understand some unknown factors. An example of this refinement comes from the way in which we sample and analyze pistachios. When pistachios are harvested, green waste such as sticks, leaves and hulls are removed from the field along with the fruit. Through communicating with our pistachio partners, we have been able to gain an in depth understanding of how these samples are collected, therefore helping us increase our understanding of how representative these samples are. This knowledge has led us to increase the number of green-waste samples we receive each sampling date. This type of analysis gives a more robust understanding of actual N levels that are leaving the field, rather than only the N present in the harvested fruit.

The process of obtaining harvest and sequestered N content data from research partners is in its early stages.

TAKE-HOME MESSAGE

Sampling: Samples should be taken across a range of harvest dates, and results related to factors such as N applied, variety, or phenological information like growing degree hours between peach bloom until harvest. Samples should be composed of fruit proportionally representing the full range of fruit sizes and other material normally evaluated with the economic yield components from the field(s) in question.

Analysis: Samples should be placed in plastic bags and kept cold, if possible, during the transportation process and placed in a cold room at 4°C upon arrival to the lab. This ensures that moisture content will remain relatively stable until they are ready to be dried and ground for analysis.

N removal coefficients: These can be developed in several ways. The first would be an average rate of removal for the crop, to be applied across the entire range of harvest dates, size classes, moisture contents, etc. The second could be a series of removal rates pertaining to harvested material that vary in one of these types of factors. Either method will provide more reliable estimates of N removal rates for use in estimating N fertilizer requirements. The first updates are anticipated in early 2020.

LITERATURE CITED

Burt, C., et al. 2014. Agricultural Expert Panel. Recommendations to the State Water Resources Control Board

Geisseler, D. 2016. Nitrogen Concentrations in Harvested Plant Parts – A Literature Overview.

ACKNOWLEDGEMENTS

We are grateful for the assistance of partners, commodity organizations, growers, processors, and packers including Dirk Holstege (UC Davis Analytical Laboratory), Chris Valadez, (California Fresh Fruit Association), participating peach producers, Ted DeJong (UC Davis, Pomology), and Tim Hartz (MPEP Team).

We also thank the following for support and funding: the California Department of Food and Agriculture's Fertilizer Research and Education Program (FREP), the Southern San Joaquin Valley Management Practices Evaluation Program, and the Natural Resources Conservation Service (through a Conservation Innovation Grant).

Evaluation of Nitrogen Uptake and Applied Irrigation Water in Asian Vegetables Bok Choy, Water Spinach, Garlic Chives, Moringa, and Lemongrass

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INTRODUCTION

Asian specialty vegetables are grown intensively in open field and protected agricultural systems. In protected agricultural systems, some of the vegetables are grown 6-7 times per year in continuous rotations with a 15-day gap between each rotation. Grown primarily in Fresno, Monterey, Riverside, San Bernardino, Santa Clara, San Luis Obispo, and Ventura counties on around 7026 acres, Asian vegetables are valued at $79 million per year (California County Crop Reports, 2015).

In Fresno and Santa Clara Counties, these crops are grown primarily by limited-resource, small-scale, socially disadvantaged Chinese, Hmong, and other Asian immigrant farmers. Information is currently lacking on nitrogen uptake in many of these crops. With proposed regulations under the Irrigated Lands Regulatory Program (ILRP) by the Central Coast Regional Water Quality Control Board (CCWQCB) and the Central Valley Regional Water Quality Control Board (CVRWQCB) to control N losses, it is important to understand N uptake and removal in crops that have significant acreage but do not have commodity board support. Asian growers producing specialty vegetables and herbs are required to fill out the N management plan as part of the ILRP. However, they lack the information to complete this form accurately as there is no information on N fertilizer recommendations or N uptake for most of their crops.

The overall goal of this project is to provide detailed measurements of total N removal, N uptake, and the N uptake pattern of bok choy, water spinach (ong choy), garlic chives, moringa, and lemongrass.

OBJECTIVES

Information on N uptake is crucial for viable crop production, but irrigation efficiency is important to retaining the applied N within the crop root zone. This project will also evaluate the current irrigation management practices of bok choy, water spinach, garlic chives, moringa, and lemon grass, compare them with the crops' water requirements and identify potential practices that may help reduce nitrate leaching. Together, the information collected will provide the basic information necessary for growers to better manage N inputs to these crops and protect water quality. Specifically, the following two objectives shall be addressed with the work proposed for this project:

1. Evaluate N uptake, N availability, canopy development and water application of bok choy, water spinach, garlic chives, moringa, and lemongrass.
2. Extend the findings of this research to Chinese and Hmong growers in the Central Coast and Central Valley regions to increase their understanding of N uptake, and publish results to provide documentation of the findings.

DESCRIPTION

On-farm work on the project began in Fall 2018. The following tasks were completed for year 1 of bok choy data collection in Santa Clara county:

Evaluations were conducted in grower fields with typical crop production practices for the region and crop – direct seeded bok choy; irrigation and fertilizer management practices also represent the typical practices for the region. These include sprinkler irrigation for the majority of the fields in Santa Clara County.

Work Plan Year 1

Task 1: Conducted N and irrigation evaluations of bok choy starting in Fall of 2018 and completed in Winter 2019 in Santa Clara County

Sub-task 1.1 Conduct N uptake pattern and total N uptake evaluations

3. During the growing season, we conducted above ground biomass, biomass N and soil nitrate evaluations 3 times for bok choy to generate N uptake curve. Each field was divided into three blocks (replicates). Separate samples will be taken from each block. When the crops are harvested, the harvested portion of the crops and the residues left in the field were sampled separately.
4. At harvest, samples were collected from 4 additional fields per crop and analyzed for fresh and dry weight, as well as N content to obtain a more robust estimate of the amount of N removed with the harvested po1tion of the crops (expressed in lbs/ton fresh weight).
5. At key stages of crop development, diagnostic sampling of leaves was done for analysis of total N.

Sub-task 1.2 Conduct crop canopy evaluations and irrigation application evaluations

6. We installed flow meters in the above-mentioned fields.
7. Using an infra-red camera, we took canopy photos of the crop every two weeks.
8. We installed and maintained soil moisture monitoring sensors.

Sub-task 1.3 Analyze all data and prepare mid-term report to FREP

Sub-task 1.4 Reports and extension

9. The initial findings were presented at the 2019 Irrigation and Nutrient Management Meeting held in Salinas that was attended by over 100 people. The results were also presented at the 2019 Western Nutrient Management Conference.

The grant fund accounts were established in May, 2018 and funds were available for expenditure from then onwards. As a result, the timeline for the field trials was moved from a Spring 2018 start time to Fall 2018. The project team including Co-PIs and project staff in Santa Clara and Fresno Counties received training on the assembly and use of tools for monitoring crop canopy development, soil moisture levels, and irrigation water flow from Michael Cahn (Farm Advisor, UCCE Monterey County) and David Chambers (Staff Research Associate, UCCE Monterey County).

In Santa Clara County data was collected for the first year for bok choy starting in Fall 2018 and completed in Winter 2019. During the growing season, we collected samples for conducting above ground biomass, biomass N and soil nitrate evaluations 3 times for bok choy to generate N uptake curve (Figure 1). Each field was divided into three blocks. Separate samples were collected from each block. The crop canopy images were collected and analyzed (Figure 2a and b) and the data recorded.

Data collection in Fresno County has been delayed due to staffing difficulties and equipment costs. Due to unaccounted costs of dataloggers in the grant, a cost extension was requested and approved for the grant. Currently some of the parts needed for the assembling the tensiometer are out of stock with the manufacturer. Work on assembling the equipment and data collection for Fresno will commence once all the parts are available.

The plant samples, soil moisture data, and crop canopy data from the first year of bok choy in Santa Clara county were analyzed.

RESULTS AND DISCUSSION

Nitrogen uptake was slow during the first month after planting but then accelerated considerably until harvest after about 10 weeks (Figure 3). At harvest, the N concentration in the aboveground biomass averaged 6.0%. The total amount of N in the aboveground biomass at harvest was 215 lbs/acre. About 70% of the total N was in the harvested leaves, the rest was left in the

Figure 1: *Bok choy plant height at (a) 3 and (b) 12 weeks after first seed germination irrigation event.*

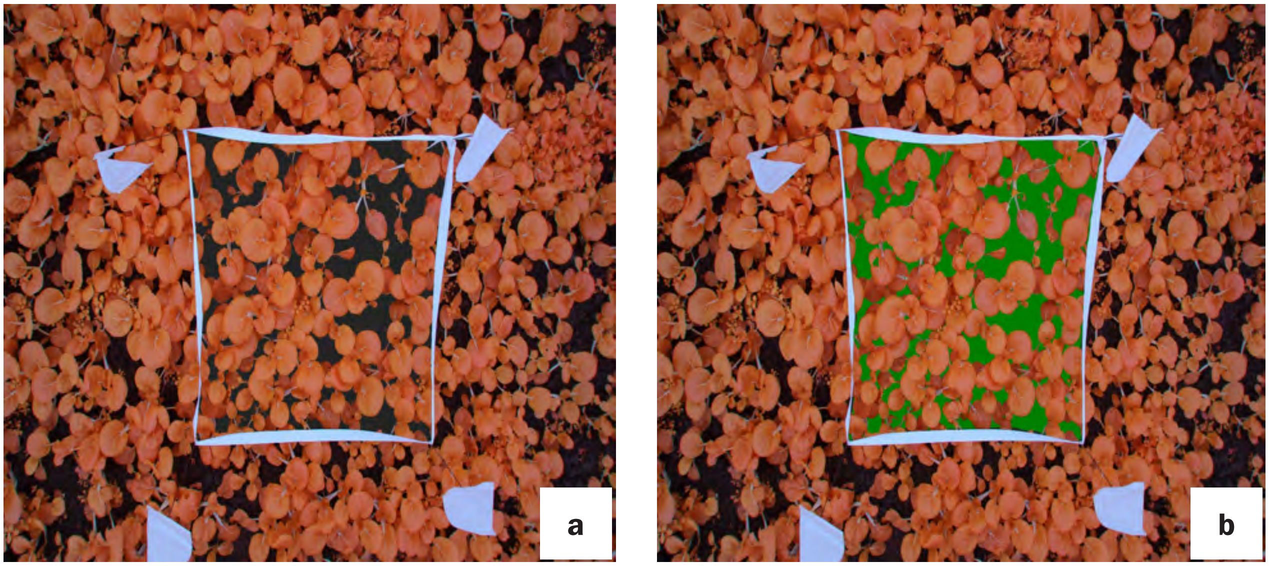

Figure 2 (a): *Crop canopy cover image with soil and weeds greyed out prior to canopy analysis with Tetracam Pixelwrench2 software.* ***(b)*** *Crop canopy cover image after canopy coverage has been quantified, 75.61% in this instance.*

ACCOMPLISHMENTS

The initial findings were presented at the 2019 Irrigation and Nutrient Management Meeting held in Salinas that was attended by over 100 people (mostly growers, Certified Crop Advisors, and agricultural production consulting personnel). The title of the presentation was "Water and nitrogen management of Asian vegetables/SWEEP and Healthy soils programs". The results were also presented at the 2019 Western Nutrient Management Conference that is attended by professionals working in the plant nutrient management field including. The title of the presentation was "Nutrient Management in Asian Vegetables".

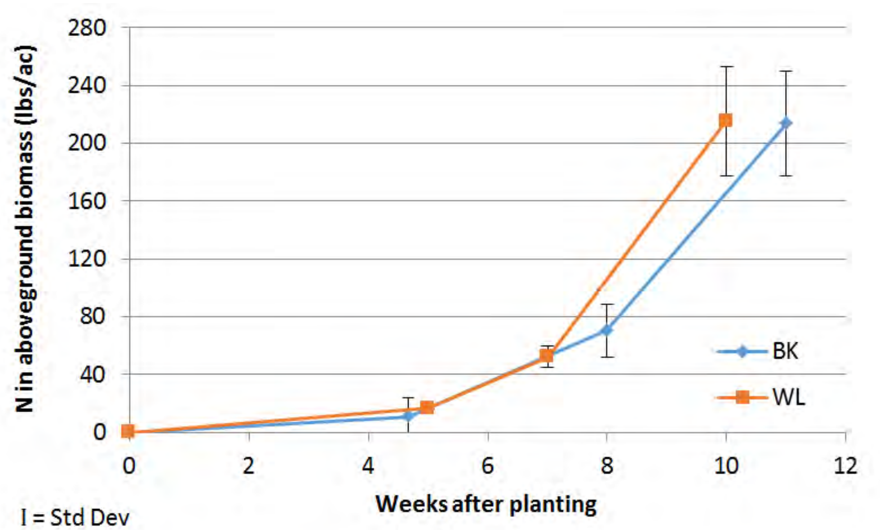

Figure 3: *Nitrogen in the aboveground biomass of bok choy. BK and WL refer to two different fields.*

ACKNOWLEDGEMENTS

We thank Michael Cahn and David Chambers for their support with crop canopy development and irrigation monitoring tools. Funding for this project was provided by the CDFA Fertilizer Research and Education Program.

A System Nitrogen Balance for Container Plant Production

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INTRODUCTION

The Central Valley Regional Water Quality Control Board requires the implementation of nitrogen management plans (NMP) by growers within the Central Valley Basin. The NMP consists of documenting annual nitrogen (N) inputs and outputs to calculate potential N available for leaching into groundwater. Inputs consist of total N in soil and fertilizer, organic amendments, and applied irrigation water. N output is based on yield and N content of harvested product.

The quantity of N in major crops, like almonds or table grapes, is readily available (Geisseler 2016). However, container-grown nursery crops do not fit neatly into the NMP worksheet. The whole product, including the roots and substrate, is "harvested" and shipped from nursery grounds to retail and other customers. The portion of N remaining in the container substrate at the time of shipment can range from 0-41% of applied N (Cabrera 2003, Narvaez et al. 2012, Narvaez et al. 2013). Losses due to denitrification can be significant, but have not been documented in a mass balance (Cabrera 2003, Narvaez et al. 2012, Narvaez et al. 2013). Denitrification reduces the amount of N that can potentially leach into groundwater but can also contribute to atmospheric N pollution as nitrous oxide (N_2O).

To help growers fulfill the NMP requirement, it is necessary to identify losses of applied N during production. Additionally, mitigating environmentally harmful discharges of N will help the nursery industry meet environmental regulations. The development of an N balance for the whole container plant production system, including the growing bed, will fill these knowledge gaps. After the N balance is developed, mitigation strategies to reduce environmentally harmful N discharges will be tested and improve nitrogen use efficiency.

OBJECTIVES

1. Develop a system N balance for container plant production.
2. Determine the mechanisms and pathways of N loss from a container plant nursery in California

3. Use the results from this study to inform development of a nursery specific N management plan
4. Test strategies that mitigate environmentally harmful N losses from nursery production systems
5. Use information on N mitigation strategies to help growers increase N use efficiency, thereby reducing costs and increasing profitability
6. Analyze costs associated with best management practices (BMPs) and mitigation strategies
7. Extend research results to industry, regulators, and scientific community

DESCRIPTION

Nitrogen inputs and outputs at a commercial container plant nursery were quantified to develop an N balance. After the initial N balance was developed, environmentally harmful discharges were identified, and BMPs are being tested now.

Two different experimental growing bed systems were installed at a nursery in California's Central Valley and tested from May 4 to July 24, 2018. The first style consisted of a typical system with plants placed directly on gravel over soil (unlined). In the other system, the growing bed was lined with polyethylene sheeting and weed barrier fabric, then covered with gravel, to prevent water infiltrating soil within the growing bed (lined). Four experimental growing beds, measuring 40 ft. x 15 ft., of each type, lined and unlined, were constructed. Each bed had *Lagerstroemia indica* 'Whitt II' plants potted into #5 containers of soilless substrate. A controlled release fertilizer was incorporated in the substrate and a urea-formaldehyde topdress was applied after planning. The two systems had identical irrigation programs, growing substrate composition, and fertilizer application.

Prior to the initialization and at the conclusion of the experiment, plant and substrate samples were collected and analyzed for NO_3^--N, NH_4^+-N, and TKN concentration. For the plants, the difference in total N at the beginning and end indicates how much N the plants utilized. For the substrate, the difference indicates how much N was removed from the substrate. Bed water runoff volume and N concentration were used to calculate the total mass of aqueous N that exited the system.

To determine the amount of N lost as N_2O-N, gas samples were collected weekly from the substrate and growing bed soil and analyzed for N_2O-N. Nitrous oxide gas flux estimates were calculated from these gas samples.

RESULTS

The mean number of plants, total applied N, total N in plants sold, and emitted N_2O-N were not significantly different ($p > 0.05$) between lined and unlined beds (Table 1). Runoff N and unaccounted for N were signifi-

Table 1. The amount of nitrogen applied as fertilizer, sold (in growing substrate and plant), emitted as N_2O-N, in runoff, and unaccounted from polyethylene sheet-lined and unlined experimental beds.

		Nitrogen (lb. per bed)				
Bed type	**Plant #**	**Total Applied**	**Total Sold**	**N_2O-N**	**Runoff**	**Unaccounted**
Lined	153.00	13.92	8.41	0.12	1.24	4.16
Unlined	150.75	13.74	8.30	0.11	0.76	4.56
P-value	0.45	0.51	0.51	0.94	0.004	0.016

cantly greater in lined beds (Table 1).

DISCUSSION

The system N balance per acre (Table 2) was calculated by multiplying the experimental bed results by the number of experimental beds that fit in one acre (64) with a two-foot buffer between adjacent beds. Container plant nurseries typically use large amounts of N fertilizer (886 lb. per acre) to produce high-quality plants. However, only 60% of this fertilizer (535 lb. per acre) was either taken up by the plant or remained in the substrate when the plant was shipped from the nursery. After sale to the retail location, the plant may be unsold for over a year, so a fertilizer reserve in the growing substrate ensures the plant will maintain aesthetic appeal until retail sale.

Of the N applied before the 81-day production cycle, 0.8% was emitted as N_2O-N from the substrate, 5.5% was lost to runoff from the growing area, 3.4% infiltrated into the growing bed soil, and 29.7% was unaccounted for (Table 2). The runoff water N may reenter the production cycle through capture and reuse as irrigation water, a common practice by nurseries in California. The difference in runoff N between the lined and unlined beds (30.46 lb. per acre) was assumed to represent the amount of N that infiltrated into the soil (Table 2). The majority of unaccounted for N was likely lost as dinitrogen (N_2) gas resulting from denitrification, with a smaller part attributed to ammonia volatilization and NO_x. A very small fraction, only 0.1%, of applied N was emitted as gas, either N_2 or N_2O, from the saturated bed soil surface. This indicates that there is little denitrification occurring in the saturated growing bed soil and the N that infiltrates soil is not lost via denitrification.

This research was performed at a single nursery in the Central Valley of California. Nurseries with different site conditions or growing practices may yield different results. For example, a higher percentage of applied N could infiltrate the soil, and potentially contaminate groundwater, at a nursery that uses liquid feed fertilization and an irrigation system with poor application efficiency. In our experiment, the experimental beds were on a clay loam soil that has a low infiltration rate, so most of the pot-leached N ran off the growing area instead of infiltrating the soil (Table 2). On coarser soils with higher infiltration rates, more N may infiltrate the soil. Plants in the experiment were spaced on two-foot centers, resulting in about 9,700 plants per acre. However, if plants were placed “can-tight”, in which containers are touching each other and there is minimal space between them, all N values per acre would change because there would be more plants, substrate, and N fertilizer applied per acre.

Container plant production is an intensive system that uses high inputs of N fertilizer (886 lb. N per acre). A large portion of this N (60%) remains with the plant and substrate when the container is transported away from the nursery or is emitted as benign N_2 gas (30%). Seasonal N_2O emission as a

Table 2. *A container plant production system nitrogen balance. The first row below each category is the pounds of nitrogen per acre and the second row is the amount of nitrogen as a percentage of the total applied nitrogen.*

	Nitrogen						Bed N_2 +
	Applied	**Sold**	**N_2O-N**	**Runoff**	**Infiltration**	**Unaccounted**	**N_2O-N**
lbs./ac.	886.09	535.19	7.33	48.93	30.49	263.48	0.68
%	100.0%	60.4%	0.8%	5.5%	3.4%	29.7%	0.1%

percentage of applied fertilizer, or emission factor, is in agreement with estimated global averages (Bouwman et al. 2002). Therefore, adjusting fertilizer application practices may reduce N_2O losses and emission factor. Nine percent of applied N is leached from the container substrate, and 3.4% of applied N infiltrates bed soil. In an effort to decrease environmental impacts of N fertilizer in nursery production, future research will evaluate fertilizer application practices that could decrease N leaching and N_2O losses. Future mitigation strategies should focus on reducing N loss from the growing substrate to eliminate the need for additional nursery site BMPs.

LITERATURE CITED

Bouwman, A. F., L. J. M. Boumans, and N. H. Batjes. 2002. Modeling global annual N2O and NO emissions from fertilized fields. Global Biogeochemical Cycles 16(4).

Cabrera, R.I. 2003. Nitrogen balance for two container-grown woody ornamental plants. Scientia Horticulturae 97 (3-4):297-308.

Geisseler, D. 2016. Nitrogen concentrations in harvested plant parts - A literature overview. University of California, Davis.

Narvaez, L., R. Caceres, and O. Marfa. 2012. Effects of climate and fertilization strategy on nitrogen balance in an outdoor potted crop of Viburnum tinus L. Spanish Journal of Agricultural Research 10 (2):471-481.

Narvaez, L., R. Caceres, and O. Marfa. 2013. Effect of different fertilization strategies on nitrogen balance in an outdoor potted crop of Osteospermum ecklonis (DC.) Norl. 'Purple Red' under Mediterranean climate conditions. Spanish Journal of Agricultural Research 11 (3):833-841.

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Promoting the Adoption of Soil Nitrogen Quick Tests by Spanish-Speaking Operators on Strawberry Ranches in Santa Cruz and Monterey Counties

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INTRODUCTION

Mismanagement of nitrogen fertilizer in berry and vegetable production on the Central Coast of California reduces crop profitability and results in nitrate leaching and negative effects on the environment. Studies have indicated substantial potential for nitrate leaching due to rains during winter months and during spring and summer due to over-irrigation. Local efforts have been made to educate growers on nitrogen management, using management tools that target an English-speaking audience. However, fertilizer application decisions are often made by Spanish-speaking operators and there has been limited adoption of nitrogen management tools amongst this demographic. Earlier work has shown that soil nitrogen quick tests are an excellent tool to manage in-season fertilization. Additionally, models of crop nitrogen uptake have been developed, for example in the online decision-support tool CropManage. The goal of this outreach project is to promote the adoption of soil nitrate quick tests among Spanish-speaking agricultural operators that don't have access to CropManage and to other resources developed by local extensionists.

OBJECTIVES

Objective 1: Produce printed soil nitrate quick test guide; Objective 2: Provide in-field technical assistance to irrigators; Objective 3: Host or present at three outreach events per year; Objective 4: Evaluate the project impact.

RECURSOS

Resource Conservation District of Santa Cruz County (RCD)
820 Bay Ave, Ste 136
Capitola, CA 95010
(831) 464-2950
www.rcdsantacruz.org

Servicios: Asistencia tecnica y financiera prestamo de equipo, evaluaciones de riego, y mas.

Natural Resources Conservation Service (NRCS)
820 Bay Ave, Ste 136
Capitola, CA 95010
(831) 475-1967

Servicios: Asistencia tecnica y financiera para agricultura - programa EQIP.

Esta guía fue financiada por el Departamento de Alimentos y Agricultura de California, mediante su Programa de Educación e Investigación en Fertilizantes (FREP) y la Junta Consultora de Inspección de Fertilizantes. FREP ofrece financiamiento para realizar proyectos de investigación y educación que orienten el uso y manejo de fertilizantes de manera agronómicamente optima y segura para el ambiente.

PRUEBA RAPIDA DE NITRATO EN EL SUELO GUÍA PARA FRESA

GUÍA PARA TOMAR MUESTRAS DE NITRÓGENO DEL SUELO

Esta guía da información práctica para tomar una muestra de suelo y medir el nitrógeno mediante la prueba rápida de nitratos. Se recomienda tomar una muestra a un pie de profundidad, porque las raíces de fresa alcanzan hasta el primer pie de suelo, y la muestra nos dice si hay suficiente nitrógeno para las plantas.También se puede tomar una muestra más profunda a dos pies que nos dice si perdimos nitrógeno por drenaje.

Materiales Requeridos: *materiales en la foto

1. Varilla para muestrear suelo 7/8" x 33" - *(www.ams-samplers.com/7-8-x-33-sst-soil-probe-w-handle.html)
2. Un balde (3-5 galones)
3. Seis tubitos de centrifuga de 50 ml con gradilla para los tubitos *(www.amazon.com/SPL-Conical-Centrifuge-Racks-Sterile/dp/B01M04HGPJ)
4. Botella de chorro - *(www.amazon.com/Plastic-Squirt-Bottle-Lid-16/dp/B004BNC80C)
5. Cronometro o reloj con cronometro
6. Solución de cloruro de calcio - ***gratis con el RCD**
7. Tiras de papel con reactivo ("tiras reactivas") para la prueba rápida de nitratos - ***gratis con el RCD**

831-464-2950 or info@rcdsantacruz.org

MUESTRA DEL SUELO

1. Tomar muestras en 10 puntos al azar en el campo. **Si se toman muestras a dos profundidades, marcar los baldes para no confundir ni mezclar las muestras de distintas profundidades.** Insertar la varilla cerca de las planta hacia el centro de la cama a un ángulo para evitar de muestrear en la banda de fertilizante.

2. Mezclar las muestras en el balde hasta que todo el suelo de cada muestra esté uniforme. Si el suelo es muy arcilloso y no se mezcla, tomar una pizca de cada muestra de suelo.

PROCESAR LA MUESTRA

3. Llenar 4 tubitos con solución de cloruro cálcico hasta los **30 mL**. Dos tubitos son para cada profundidad.

4. Añadir suelo de cada muestra a los dos tubitos correspondientes, hasta que la solución llegue a los **40 mL**.

Añadir suelo

5. Sacudir vigorosamente hasta que todo el suelo esté disuelto.

6. Dejar los tubitos en la gradilla hasta que todo el suelo se haya depositado en el fondo y una capa de solución clara se desarrolle arriba. Normalmente este proceso tarda unos minutos, pero en suelos arcillosos puede tardar hasta media hora.

7. Mojar brevemente una tira reactiva en la solución de cada tubito y sacudirla para que se seque. Esperar un minuto y comparar el color del cuadrado más próximo al extremo de la tira con la escala de colores en el tubo de las tiras. Utilizar los números de arriba (ppm of NO_3^-), no los de abajo (ppm of NO_3-N).

Usar esta escala

La lectura de la muestra en la foto de abajo es aproximadamente 35 ppm de NO_3^- ya que el color del papelito esta entre 25 y 50 ppm de NO_3^- en la escala de arriba

CUANTO FERTILIZANTE APLICAR

Multiplicar por dos el resultado de la muestra a 12 pulgadas le da un estimado general de las libras de nitrógeno que hay en un acre de suelo hasta 12 pulgadas de profundidad. Por ejemplo, si el resultado es 25 ppm de NO_3^-, quiere decir que hay más o menos 50 libras de nitrógeno por acre en la capa de suelo de 0 a 12 pulgadas.

La Fresa absorbe menos que 25 libras por acre desde la siembra hasta finales de Marzo, y alrededor de una libra por acre por día desde Abril hasta la mitad de Septiembre. Así que las necesidades de la planta para toda la temporada son alrededor de 200 lb de nitrógeno por acre.

Manejo durante el invierno:
Se recomienda tomar una muestra de invierno al principio de Febrero.

Si los resultados de la muestra están por arriba de 15 ppm NO_3^-, no se necesita fertilizante.

Si los resultados de la muestra están por debajo de 15 ppm NO_3^-, se recomienda 10 o 20 lb/Ac divididas en dos aplicaciones.

Manejo durante primavera y verano:
Se recomienda aplicar nitrógeno con fertiriego en cantidades de aproximadamente **7 libras por acre cada semana o de 14 libras por acre cada dos semanas durante el periodo de Abril a Septiembre.** La tabla y figura abajo da recomendaciones según los resultados de la prueba de nitrato.

El agua de riego y la mineralización de materia orgánica del suelo también añaden nitrato al suelo. Un suelo más pesado con más materia orgánica mineraliza más N por acre por día que un suelo arenoso. Un suelo con más materia orgánica puede aportar bastante N solo por mineralización. Esto más el nitrato en el agua de riego (dependiendo de la cantidad) pueden dar suficiente N a su cultivo Por lo tanto se recomienda repetir la prueba de nitrato cada semana o cada mes para ajustar las aplicaciones de fertilizante.

Fresa

Si la muestra es (ppm of NO_3^-)	Aplicar libras de nitrógeno por acre por semana
0	14
5	10
10	7
15	5
20	4
25	2
>25	No se necesita fertilizante

Figure 1. *The soil nitrate quick test guide*

DESCRIPTION

Objective 1: The project produced a field guide in English and Spanish to collect, process and interpret a soil nitrate quick test (Figure 1). The guide is succinct and includes simple and well-illustrated instructions to perform the test in the field and to interpret its results and inform nitrogen applications.

RCD staff produced diagrams to obtain recommendations on fertilizer application amounts directly from the color of the nitrate test (Figure 2). While this approach is slightly less precise than the existing recommended procedure, it has the advantage of not requiring calculations and unit conversions. These represent barriers for some growers. Diagrams were produced for strawberry and lettuce for the most common liquid and dry fertilizers used in the area. Objective 2: RCD staff provided equipment and trained irrigators and ranch managers to perform the nitrate test. Staff provided follow-up assistance on the quantity of fertilizer to apply to match the crop nitrogen requirement. Some managers expressed interest in CropManage and were trained on how to input the soil nitrogen quick test result on CropManage.

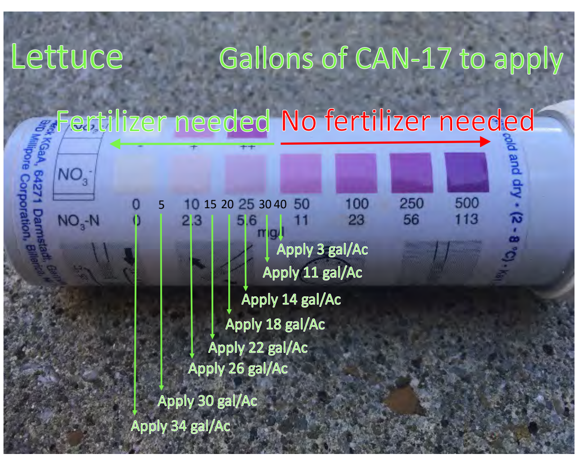

Figure 2. *A diagram showing the amount of fertilizer application from the soil nitrate test color*

ACCOMPLISHMENTS

The project staff trained 13 irrigators and ranch managers on 9 ranches. Staff produced a step-by-step guide in both English and Spanish for taking soil samples and interpreting quick test results for strawberry. We produced a field guide with table for growers to test nitrate in well water and calculate the irrigation water contribution to the crop nitrogen budget. We made diagrams to estimate crop fertilizer need based on the quick test result.

RECOMMENDATIONS

It is relatively easy to learn how to perform the test but many growers and ranch managers struggle with applying the test results for their fertilizer application decisions. Many growers use a common standard practice (e.g. apply 45 gal/ac at side-dressing) and there can be resistance in adopting new technologies. However, more often the calculations needed to use the test results to determine how much fertilizer to apply is a barrier. For example, if the quick test gave 5 ppm of NO_3-N and the UC recommends 20 ppm, how many gallons of CAN-17 per acre should be applied? A solution that avoid calculations would likely be more successful on small ranches and with growers with low education levels. In larger operations, an institutional change is needed to integrate in-season nitrate soil testing as a standard procedure in the management routine.

LITERATURE CITED

https://www.growershipper.com/userfiles/file/Appendix-B-In-Season-Soil-Nitrate-Testing-Explained-Hartz-and-Smith-ENGLISH.pdf

https://www.growershipper.com/userfiles/file/Nitrate-Quick-Test-SOP-FINAL-ENGLISH.pdf

https://afghanag.ucdavis.edu/irrigation-natural-resource/files/soil-nitrate-quick-test.pdf

ACKNOWLEDGEMENTS

The authors acknowledge the CDFA FREP program for funding the project and the NRCS Capitola office for supporting the project. Special thanks to Valerie Perez for helping in the field and to all the ranch managers and irrigators involved in the project.

Figure 3. Training irrigators and ranch managers in the field

Improving Nitrate and Salinity Management Strategies for Almond Grown under Micro-irrigation

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INTRODUCTION

The majority of almond growers currently provide N fertilization in liquid form through micro-irrigation systems (drip and micro-spray) and increasingly growers are utilizing groundwater that is saline. Irrigation strategies, fertigation management, nitrate leaching and salinity management are therefore linked and strategies must be developed that optimize productivity while minimizing nitrate leaching and avoiding salt-induced stress to almond trees.

While micro-irrigation (MI) methods are effective in boosting productivity and improving water/nutrient use efficiency, MI does result in a smaller rooting zone and in a highly non-uniform salt deposition (toward the edge of wetting pattern) in the active rooting zone. This has negative consequences for nitrate management since nitrate that is pushed into the high salt regions at the periphery of the wetted zone will not be available to plant roots and hence is vulnerable to leaching. Salinization of the margins of wetting pattern decreases the volume of soil in which roots can optimally function hence plant response to salinity will be determined not by bulk soil salinity but by the salinity within the active root zone and by the proportional distribution and activity/tolerance of roots in the saline (close to the edges of wetting zone) and non-saline (near the center of wetting zone) zones within the rooted profile.

The challenge of developing meaningful salinity management strategies under MI is further complicated by our relative lack of knowledge of the responses of almond to salinity. Almond is considered a salt-sensitive crop with a threshold EC of 1.5 dS/m, these values, however, was derived for Lovell rootstock under flood irrigation and are no longer relevant to modern almond systems. Rootstocks and cultivars of almond are known to vary dramatically in their sensitivity to salt induced water stress and vary in their susceptibility to the effects of toxic ions, Na and Cl.

Given the complexity of solute management under MI and the lack of information on almond rootstock response to salinity and the lack of information on the effects of salinity on root distribution and nitrate uptake it is very difficult for growers to make informed irrigation management decisions that satisfy the dual goal of minimizing root zone salinity while simultaneously minimizing nitrate leaching. Developing this understanding is the primary goal of this project.

OBJECTIVES

1. Characterize the patterns of root nitrate uptake and plant response when plants are grown with roots in soils of different salinity status (as typically occurs under micro-irrigation).
2. Use HYDRUS (Šimůnek et al., 2012) to model solute transport, plant response (water and nitrate uptake) to salinity, and specific ions (Cl, Na, B) under a variety of irrigation scenarios and different conditions such as soil type, environment, timing, distribution, irrigation system, and water quality.
3. Use the information in objectives 1 and 2 to develop site and cultivar specific models and guidelines for nitrate sensitive salinity management and to produce a series of written and online grower guidelines and tools for irrigation design and scheduling.
4. Produce a robust modeling platform for the advanced grower, consultant, advisor, irrigation industry representative and researcher to develop novel and site specific irrigation design and scheduling practices for nitrate sensitive salinity management.

DESCRIPTION

1. Twelve tomato truck bins measuring 28 x 8 x 5 ft (L×W×D) were equipped with drainage pipe at the bottom and filled with a sandy loam, a common soil type in almond orchards in California. Two almond trees were planted in each of the bins, one with a Viking rootstock and one with a Nemaguard rootstock. The trees are drip-irrigated and three different irrigation intervals (one day, two days, three days) are being applied (Figure 1).
2. Soil water content, salt and nitrate concentrations of the soil solution are being measured at different locations in the root zone. Plant performance under the different irrigation treatments is being evaluated using leaf tissue analysis and measurements of stem water potential and tree growth (Figure 2).
3. A computer model that is able to predict water and nutrient uptake of almond trees will be developed and calibrated for the use in almond orchards using the measured data obtained in step 2. In addition, measured values of soil hydraulic properties as well as plant physiological parameters determined in previously conducted greenhouse studies will be incorporated into the model. Once the model has been calibrated and validated sufficiently, soil salinity and plant water and nutrient uptake will be simulated for various soils and climatic conditions and for different irrigation and fertilization managements. The results will be used to improve recommendations on nitrate and salinity measurements in almond orchards.

Figure 1. *Field site. Left: drainage lysimeters, right: weighing lysimeter.*

Figure 2. *Instrumentation of the bins: Left: pore water samplers, center: soil moisture sensors, right: picture of the roots taken using the mini-rhizotron.*

RESULTS AND DISCUSSION

Experiments conducted in the greenhouse indicate that almond plants, when the roots are exposed to heterogeneous salinity conditions, react by preferentially taking up water from less saline regions (with over 80% of the water taken up from the less saline region). The response occurs within less than a day and can be reversed when the saline and less saline regions of the root system are switched. These results may have important implications for management of salinity in the field as they suggest that not only an average root zone salinity but also the distribution of salts in the root zone matters, which can be controlled by irrigation management.

A lysimeter experiment is being conducted to further elucidate the implications of these results for salinity management under field conditions. Figure 3 shows the depth trends of electrical conductivity and nitrate concentrations in the soil solution before the start of the different irrigation frequencies and salt addition. It is expected that the spatial patterns of nitrate and electrical conductivity will be affected by irrigation frequency, with the higher irrigation frequency resulting in a less uniform distribution of salinity with low concentrations at the top and salt accumulation at the deeper depths.

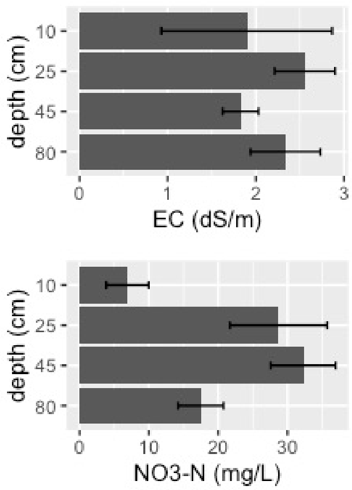

Figure 3. *Depth trends of electical conductivity (EC) and nitrate-N concentration of the soil solution before the start of irrigation treatments and addition of salt (average of all trees in July 2019; trees were irrigated daily prior to the start of the different irrigation frequencies).*

ACCOMPLISHMENTS

Greenhouse experiments have been conducted that investigate the physiological response of almonds to heterogeneous salinity conditions and suggest that considering these responses may be important for salinity management. A web application has been developed to demonstrate the effect of irrigation and fertilizer injection timing on the distribution patterns of nitrate and soil moisture in the root zone and will be published on the lab's website soon. The tool shows results of simulating a single irrigation event on a moderately dry soil using the software HYDRUS 2D/3D (Šimunek et al., 2012), which numerically simulates the movement of water and solutes under unsaturated conditions in soils.

A lysimeter experiment has been set up that allows the quantification of nitrate leaching and simultaneously provides detailed information of the water, salt and nitrate distribution in the root zone of drip irrigated almond trees. The data from this experiment will help to improve the understanding of the interactions between irrigation management, salt and nutrient distribution in the root zone and plant response.

LITERATURE CITED

Šimůnek, J., M. Th. van Genuchten, and M. Šejna. 2012. HYDRUS: Model use, calibration and validation. Special issue on Standard/Engineering Procedures for Model Calibration and Validation, Transactions of the ASABE, 55(4), 1261-1274.

ACKNOWLEDGEMENTS

We wish to express our gratitude to the California Department of Food and Agriculture's Fertilizer and Education Program for funding the project.

Assessing Drip Irrigation and Nitrogen Management of Fresh Onions Produced in California Low Desert

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Coastline Family Farms
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INTRODUCTION

California is the largest onion producer in the nation. The 2017 farm gate value for onions in California was estimated at $359.29 million. In 2017, Imperial County growers harvested close to 13,000 acres of onions that generated over $79 million in farm gate value, equivalent to 22% of total onions produced in California. Onion production value in Imperial County ranked 8th in 2017. Irrigation excesses as well as municipal and industrial discharges from the Imperial, Coachella and Mexicali valleys flow into California's largest lake, the Salton Sea. Currently, the Salton Sea has high nutrient, salinity, and toxic compound concentrations. Adoption of improved irrigation and nutrient management practices by growers is needed in order to reduce water pollution from excess nutrients in California's low desert region.

Growers in the Imperial Valley are adopting more efficient irrigation systems (sprinkler and drip) and science-based irrigation scheduling methods (soil moisture, weather-based techniques) motivated by themselves and through the Imperial Irrigation District -IID On-Farm Efficiency Conservation Program. The current water transfer agreement between IID and the San Diego County Water Authority (SDCWA) calls for transfer of up to 303,000 acre-feet annually of Imperial Valley-Colorado River water to San Diego. From 2018 to 2026, most of the water available for transfer will have to come from on-farm water conservation programs. The purpose of this project is to enhance sustainability through evaluation of irrigation and nutrient management strategies that conserve water and minimize nutrient export. The use of irrigation technology based on plant needs along with soil moisture indicators can help create a healthy environment for crops and minimize the risk of nitrate losses to the groundwater.

The main goal of this project is to evaluate the effects of irrigation management and nitrogen fertilization rates on yield and quality of fresh onion bulb production in arid regions using saline water.

OBJECTIVES

1. Evaluate the response of onion to drip irrigation and regimes and compare onion production under different N fertilizer application rates.
2. Communicate findings directly to growers, as well as to crop advisors, academics, regulatory bodies, and agriculture industry.
3. Provide training opportunities to college students.

DESCRIPTION

Field assessment will be performed at the University of California Desert Research and Extension Center -UCDREC, Holtville, CA. The assessment will be carried out with four replicates in a split-plot design with drip irrigation treatments in the main plot and seven N-fertilization rates at the subplot level. Research plots will be 50 ft long and comprise 4 rows on 40-inch beds. Sixty four plots will be established (16 treatments and 4 replicates). Sprinklers will be used for germination and establishment in all treatments. Four irrigation levels will be established: 40, 70, 100, and 130% of crop evapotranspiration (ETc). Irrigation scheduling will be based on weather data from the UCDREC's CIMIS station and crop coefficients developed in the region. Watermark soil water tension meters will be installed in each of the irrigation treatments at 6, 12, and 24-in.

Four in-season nitrogen treatments will be assessed: pre-plant; pre-plant plus 75 lbs N per acre; pre-plant plus 150 lbs N per acre; and pre-plant plus 225 lbs N per acre. Seven weekly nitrogen applications through drip after bulbing start will be scheduled. Soil samples will be collected (pre-planting, during season, and post-harvesting) at different depths (from 0 to 36 in depth) and analyzed for NH_4 and NO_3. Irrometer soil solution access tubes will be installed at 6, 12, and 24-in. Water samples will be analyzed for pH, electrical conductivity and NO_3^-. Furthermore, bulbs and leaves will be analyzed for their N concentration during growing season to determine N uptake and removal in the different treatments. Water and biomass data will be collected 5 or 6 times after starting bulb formation until harvesting. Onion quality parameters, including size (minimum and maximum diameters), weight, mold, firmness, color, pungency, and overall quality will be measured, after onion harvest and curing.

RESULTS AND DISCUSSION

Our first planting for this project is scheduled for mid-October 2019. We will use Hornet, an early-maturing, short-day, yellow hybrid onion recommended by our local grower supporter. All irrigation treatments will use drip tape that delivers 0.67 GPM/100 ft with drip spacing every 8 in. DREC's soils are moderately alkaline and well drained. Irrigation water from the Colorado River is slightly saline.

ACCOMPLISHMENTS

Our grant account is set up and we will start our first field growing season mid-October.

ACKNOWLEDGEMENTS

We thank you CDFA FREP for providing funds for this project. We appreciate the comments and discussion provided by Mr. Larry Cox from Coastline Family Farms about commercial onion irrigation and nutrient management.

Efficient Water and Nitrogen Management Practices for Mixed Leafy Baby Green Vegetables in the Desert

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INTRODUCTION

Intensive vegetable production in the southwestern U.S. receives large annual applications of nitrogen (N) fertilizers. Amounts of N applied range from 200 to 400 kg/ha and crop recoveries are generally less than 50% (Mosier et al., 2004). There are numerous possible fates of fertilizer applied N in addition to the desired outcome of crop uptake (Sanchez and Dorege, 1996; Havlin et al., 2005). The urea and ammonium components of the N fertilizer might be lost through ammonia volatilization. The nitrate-N might be lost to leaching with irrigation water below the crop root zone possibly impairing surface and ground water (Sanchez, 2000). Nitrate might also be lost as N_2 and N_2O gasses via de-nitrification processes affecting air quality and climate. Furthermore, all forms of N might be immobilized into the organic soil fraction by the soil microbial population where availability to the crop is delayed. The global warming potential of N_2O is 300 times that of CO_2 and N fertilizer is estimated to account for one-third the total greenhouse gas production in agriculture (Strange et al., 2008). One study reported that N fertilization (inorganic or organic) accounted for 75% of the greenhouse gas emissions from agriculture production (including production, application, and nitrous oxide emissions) and after N is accounted for there are no significant differences between conventional, organic, or integrated farming practices (Hiller et al., 2009).

Over the past decade the production of high density mixed leafy green vegetables on large beds (80 and 84-inch beds) has increased significantly. These include various types of mixes for baby lettuce (often called spring mix), baby brassica, baby spinach, dandelions, and others. Work on the fertilizer requirements for these crops are lacking and many growers have simply utilized the fertilizer practices they currently use on full season iceberg, romaine, and leaf lettuce. While these crops are grown at a higher density than full season lettuce, they are harvested young and are short season (20 to 40 days) compared to the 80 to 150 day lettuce crops. We have no information how these factors affect fertilizer needs, no information on how irrigation interacts with N, and no information to modify N fertilizer recommendations for these crops. These data gaps are of concern since over 35% of the industry has converted to these high density large bed production systems and this acreage continues to grow.

OBJECTIVES

The objective of these studies is to evaluate various N management practices for mixed baby leaf conventional and organic production systems and calibrate "CropManage" for desert production. These experiment-demonstrations will be conducted in grower fields to hasten technology transfer.

DESCRIPTION

During winter-spring of 2019, we focused on objectives associated with Task 1, which were largely associated with collecting background data on water and N requirements for baby spinach and lettuce. We had experiment-demonstrations in Imperial County, California, and Yuma County, Arizona.

Figure 1. *Eddy Covariance system in spinach field.*

Evapotranspiration was measured using Eddy Covariance methodology (ECV) (Figure 1). Briefly, ECV measures four energy flux components- net radiation (Rn), ground heat flux (G), sensible heat flux (H), and latent heat flux (LE). Rn represents absorbed solar and infrared radiation, G is heat transported into the soil, H is turbulent heat above the crop due to air temperature gradients, and LE is latent heat energy due to ET. ECV data values are reported in energy flux units (W/m^2), with water-specific quantities also reported as depths over time (e.g. mm/day). Salt balance was monitored using sensors and data loggers during the season and conductance (EM 38) surveys conducted before and after the cropping season. Irrigation water amounts applied to all fields was also monitored using automated rain gauges. Ground measurements were used to calibrate ET estimates from space-based sensors. Satellite data used included Sentinel 2a/2b, LandSat 8, VENuS microsatellite data, and ECOSTRESS imagery.

N accumulation during the season was monitored by collecting aboveground plant samples and calculating N accumulation from total dry matter and N content, after laboratory analysis.

RESULTS AND DISCUSSION

In January 2019, we initiated a three-year project aimed at better water management for baby green vegetables in the desert. We were near the end of our growing period (September to early March) so only two field experiment-demonstrations were conducted in this reporting period. Preliminary data show cumulative seasonal ET for baby spinach and spring mix were approximately 10 and 18 cm, respectively. Data for spring mix is shown in Figure 2. Total above ground N accumulation ranged from 30 to 50 kg N/ha. These studies will be expanded during the 2019-2020 season and we will began to evaluate "Crop Manage".

ACCOMPLISHMENTS

As noted, we were near the end of our growing period when the contract was initiated. Activities during winter-spring 2019 were confined to Task 1. During fall-winter spring 2019-2020 we will complete objective associated with Task 1 and 2 and began objectives associated with Task 3. Calibration and validation of "Crop Manage" will begin this coming season.

LITERATURE CITED

Havlin, J., S., L. Tisdale, J. D. Beaton, and W.L. Nelson. 2005. – Soil Fertility and Fertilizers, 7th Edition. Pearson Prentice Hall, NJ.

Hiller, J., C. Hawes, G. R. Squire, A. Hilton, S. Wale, and P. Smith. 2009. The carbon foot prints of food production. International. J. Agric. Sustain. 7:107-118.

Mosier, A. R, Syers, J. K., and Freney, J. R. 2004. Nitrogen fertilizer: An essential component of increased food, feed, and fiber production. Pages 3-18 in: SCOPE 65: Agriculture and the Nitrogen Cycle: Assessing the Impacts of Fertilizer Use on Food Production and the Environment, A. R. Mosier, J. K. Syers, and J. R. Freney, eds. Island Press, Washington,

Sanchez, CA. 2000. Response of lettuce to water and N on sand and the potential for leaching of nitrate-N. HortScience 35:73-77.

Sanchez, C. A., and T. A. Doerge. 1999. Using nutrient uptake patterns to develop efficient nitrogen management strategies for vegetables. HortTechnology 9:601-606.

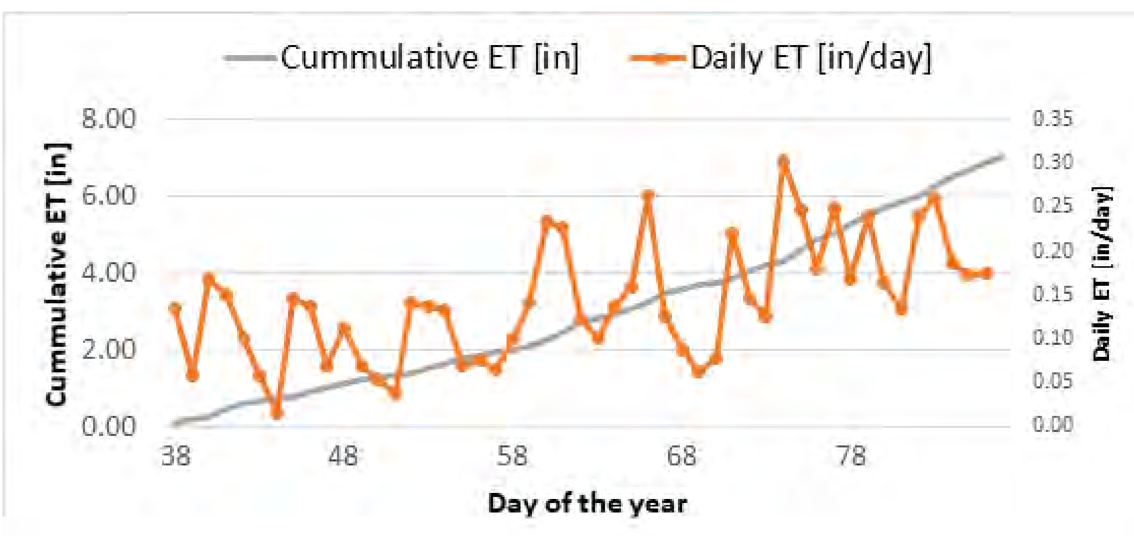

Figure 2. Measured ET for spring mix in winter-spring 2019.

Strange, A., J. Park, R. Bennett, and R. Phipps. 2008. The use of life cycle assessment to evaluate the environmental impacts of growing genetically modified nitrogen use

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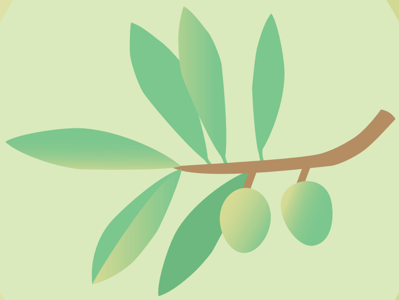

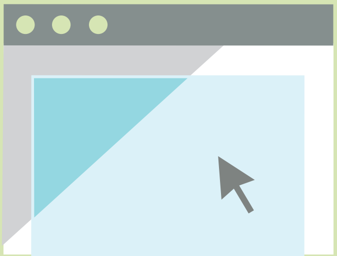

SUMMARIES OF INVITED SPEAKER PRESENTATIONS

Deficit Irrigation and Nutrient Management in High-Density Olive Orchards

Richard Rosecrance
Professor of plant nutrition and fruit tree physiology
California State University, Chico

Olive oil production has a long history in southern Europe and traditionally trees were grown under dry-land conditions. Trees were widely spaced to accommodate the lack of water and yields were typically low. During the late 1980s in Spain and Italy, the introduction of irrigation systems and improved methods of training trees enabled growers to move toward much denser plantings. Dense planting of olive trees using such methods began in California in 1999. In just a decade, acreage of super high density (SHD, typically between 500 and 900 trees per acre) olive oil orchards reached 17,000 acres. However, there is little information on production practices of SHD olive oil production in California.

In Europe, olive trees are typically grown under rain-fed conditions (Moreno, et al., 2009); however, studies in Europe have shown that irrigation can increase olive production (Lavee et al., 1990) thereby increasing total oil production per tree. However, studies have indicated that chemical and sensory characteristics of olive oil decline as applied water increases (Berenguer et al., 2006). Irrigation management can have a profound influence on olive oil production and quality.

The key finding of the study was that moderate water stress increased olive oil yield and quality, accelerated fruit maturity, and decreased vegetative growth. Probably the biggest advantage of regulated deficit irrigation (RDI) in SHD orchards is producing a compact tree that matches the tree structure and fruiting behavior with the dimensions of the over-the-row harvester. The use of stem water potential (SWP) as a tool in irrigation scheduling has proven useful in many other crops in addition to olives. We found that a SWP value of -1.3 MPa from full bloom until 55 DAFB (around mid-July), followed by a SWP value of -2.2 MPa improves oil yields and decreases vegetative growth for SHD olive orchards. Increasing SWP to -1.3 MPa three weeks prior to fruit maturity should also increase oil production.

REFERENCES

Berenguer, M.J., Vossen, P.M., Grattan, S.R., Connell, J.H.,Polito, V.S., 2006. Tree irrigation levels for optimumchemical and sensory properties of olive oil. Hort. Sci. 41,427–432.85

Lavee, S., Nashef, M., Wodner, M., Harshemesh, H., 1990. Theeffect of complementary irrigation added to old olive trees(Olea europaea L.) cv. Souri on fruit characteristics, yield,and oil production. Adv. Hort. Sci. 4, 135–138

Moreno, B., Garcia-Rodriguez, S., Cañizares, R., Castro, J. and Benítez, E., 2009. Rainfed olive farming in south-eastern Spain: Long-term effect of soil management on biological indicators of soil quality. Agriculture, ecosystems & environment, 131(3-4), pp.333-339.

A Normal California Farm, Farmed Abnormally

Scott Park
Scott Park Farming
Meridian, California

Park Farming, an organic farm 50 miles north of Sacramento has developed (and continues to develop) a farm system that relies on soil health to solve the various issues that California farmers face such as fertility, pests, crust, water retention, erosion, quality, yield, runaway inputs, the vagaries of weather (resilience), and the increase in government regulations.

By applying the 7C's- cover crops, crop rotation, conservation tillage, controlled traffic, conserving inputs, compost, and crop residue management Park Farming has serendipitously found a method of farming that enriches the soil microbiome. A healthy soil solves most of the farm's problems before they happen!

The application of the 7-C's will be covered by showing the various operations following corn harvest to producing a tomato crop. Then the issues mentioned above will be developed in further detail along with future goals of the farm.

Best Practices for Fertigation Design and Equipment

Franklin Gaudi
Project Manager
Cal Poly Irrigation Training and Research Center

Fertigation is widely used with drip systems, yet there are many details that get overlooked. These details could be during the design phase, the installation phase, or not performing proper maintenance to ensure long-term success. This presentation covers some of the best practices and features that your system should have to get the most out of your investment. Some of the areas where improvements can be made include:

1. Verifying the irrigation system applies water with a high distribution uniformity
2. Using the proper fertigation equipment
3. Spoon-feeding the nutrients, and
4. Understanding that some chemicals can interact with each other, which will plug emitters.

With so much to think about, growers may not know what questions to ask when purchasing a fertigation system. This presentation also covers the ITRC Irrigation Consumer Bill of Rights, which provides you with some basic questions to start a conversation with your local irrigation dealer. This can help minimize the details that get overlooked during the design and installation phase.

Characterizing Soil Texture for Water and Nutrient Management

Toby O'Geen
Professor and Soil Resource Specialist in Cooperative Extension
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University of California, Davis

Texture (the percent sand, silt and clay) influences all soil processes on earth. Texture governs the regulation of the water supply. Texture influences nutrient storage capacity and the availability of nutrients for plant uptake. Carbon sequestration is directly related to texture. Texture influences plant-root interactions and potential for erosion. Management practices cannot change soil texture, but characterizing soil texture is essential to good soil management. Soil texture typically varies with depth and also displays systematic spatial trends across California. With a focus on soil variability, this talk will discuss how knowledge of soil texture can be used to manage nutrients more efficiently. It will describe how knowledge of soil texture can be used to optimize the utilization of green water (soil stored precipitation) and reduce the reliance on blue water (surface water and groundwater). It will highlight available tools to understand variability in soil texture across California.

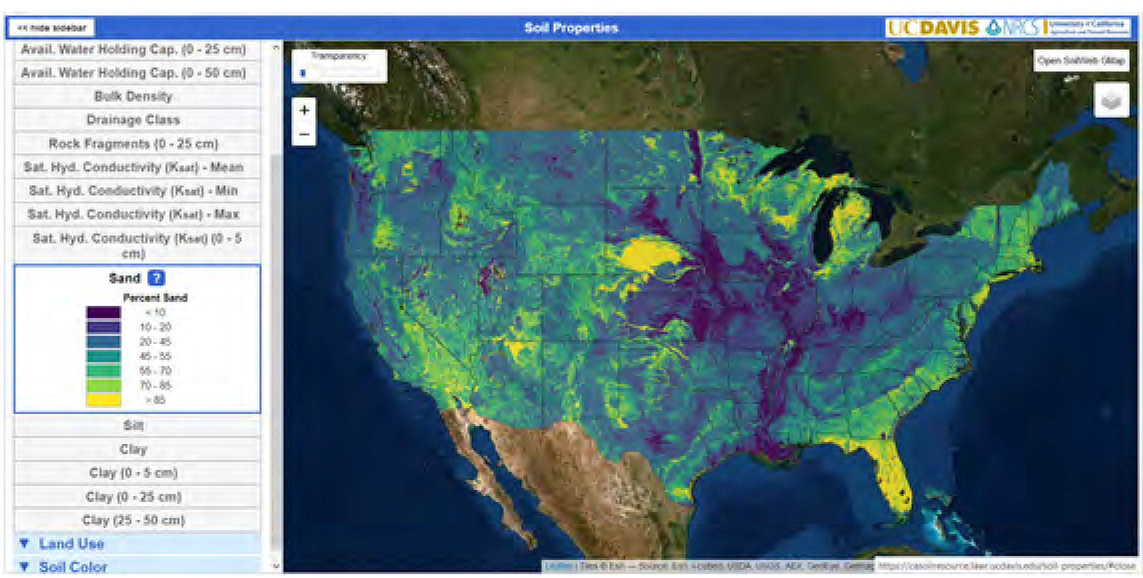

Figure 1. *Spatial extent of average sand content in soils across the US.*

Potassium Fertilization in Crops

Saiful Muhammad
Research Agronomist, QualiTech

Patrick Brown
University of California, Davis

Potassium is needed in largest quantities by higher plants. Potassium has important role in stomatal opening and cell expansion. It has a significant role in phloem loading of the newly formed carbohydrates from the leaves and their transport to the sink-fruit or roots. It helps plant in combating water stress. Potassium is mobile in plants and its deficiency first appear in older leaves. Potassium-deficient leaves begin showing symptoms in late spring to early summer. Leaves become pale and leaf size and shoot growth are reduced. In case of severe deficiency, leaf margins of older leaves become necrotic.
Potassium is present in soils as soluble K, exchangeable K, non-exchangeable K and mineral K. Only a very small amount of the soil K is available to plants and majority of the soil K is present in the mineral form. K mobility in soil depends on soil texture.

Crop demand for potassium changes during the season and depends on species. In most species, K demand is small at the beginning of the season which then increase during peak growth and fruit formation and maturity and diminishes as crop matures. Historically, K has been managed using critical values. Fully expanded leaves are collected and analyzed for K concentration and fertilization decisions are made.

Potassium fertilizer application should be based on soil and tissue analysis and understanding of K removal in crop. Soils previously rich in K, have now been depleted from continuous crop removal. If soil analysis shows inadequate levels of available K, potassium fertilizers should be applied to meet crop K demand. K fertilizers can be incorporated into the soil at planting of annual crops. In perennial crops with micro-irrigation system, dry K fertilizers can be applied in bands in winter which then can be incorporated by rains or irrigation water. When dry fertilizers applied in orchards using drip irrigation system, fertilizers should be placed close to the drip line. Liquid K fertilizers can also be applied through fertigation any time during the season.

In fruits like grapes, potassium can be applied to foliage through foliar sprays starting pre-Veraison to increase brix and achieve early harvest. This is however important to use potassium fertilizer source which is completely soluble and does not contain any nitrogen. Foliar K can be applied with pesticides and fertilizer compatibility with pesticide should be checked before making mixes.

LIST OF COMPLETED FREP PROJECTS

List of Completed FREP Projects

The following is a chronological list of final reports for FREP-funded research. Following the title is the name of the primary investigator and the project reference number. We invite you to view the full final reports by visiting the California Department of Food and Agriculture's Fertilizer Research and Education Program Database at www.cdfa.ca.gov/go/FREPresearch. You may also contact the program at frep@cdfa.ca.gov or (916) 900-5022 to obtain printed copies.

Expanding the California Fertilization Guidelines • *Daniel Geisseler, 16-0610*

California Certified Crop Adviser FREP Education Project • *Ruthann Anderson, 16-0076*

Improving Nitrate and Salinity Management Strategies for Almond Grown under Micro-irrigation • Patrick Brown, 15-0523

Prediction of Summer Leaf Nitrogen Concentration from Early Season Samples to Better Manage Nitrogen Inputs at the Right Time in Walnuts, Prunes, and Pears • Patrick Brown, 15-0492

Train the Trainer: A Nitrogen Management Training Program for Growers • Terry Prichard and Parry Klassen, 15-0392

Quantifying N2O Emissions under Different On-farm Irrigation and Nutrient Management BMPs that Reduce Groundwater Nitrate Loading and Applied Water • *Arlene Haffa and WIlliam Horwath, 15-0356*

Online Fertilization Guidelines for Agricultural Crops in California • *Daniel Geisseler, 15-0231*

Nitrogen Fertilizer Loading to Groundwater in the Central Valley • *Thomas Harter, 15-0454*

Plant Nutrients in the Classroom • Judy Culbertson, 14-0481

Development of Management Training Curriculum for Use in Grower Training for Self-Certification of Regional Water Board Nitrogen Management Plans • *Terry Prichard, 14-0585*

Field Evaluation and Demonstration of Controlled Resease N Fertilizers in the Western United States • *Charles Sanchez and Richard Smith, 14-0508*

A Data Driven Nitrate Leaching Hazard Index and BMP Assessment Tool • *Toby O'Geen, 14-0452*

Developing Testing Protocols to Assure the Quality of Fertilizer Materials for Organic Agriculture • *William Horwath and Sanjai Parikh, 13-0223*

Phosphorus and Boron Fertilizer Impacts on Sweetpotato Production and Long-Term Storage • *Scott Stoddard, 13-0266*

Improving Nitrogen Use Efficiency if Cool Season Vegetable Production Systems with Broccoli Rotations • *Richard Smith, Michael Cahn and Tim Hartz, 13-0268*

Nitrogen Management Training for Certified Crop Advisors • *Doug Parker, 13-0241*

Provide Nitrogen Training Program for CDFA • *Ruthann Anderson, 13-0145*

Determining the Fertilizer Value of Ambient Nitrogen in Irrigation Water • *Michael Cahn, Richard Smith and Tim Hartz, 12-0455*

Optimizing the Use of Groundwater Nitrogen for Nut Crops • *David Smart, 12-0454*

Measuring and Modeling Nitrous Oxide Emissions from California Cotton and Vegetable Cropping Systems • *Dave Goorahoo, 12-0452*

Development of Economically Viable Variable Rate P Application Protocols for Desert Vegetable Production Systems • *Charles Sanchez and Pedro Andrade-Sanchez, 12-0386*

Characterizing N Fertilizer Requirements of Crops Following Alfalfa • *Dan Putnam and Stu Pettygrove, 12-0385*

Evaluation of N Uptake and Water Use of Leafy Greens Grown in High-Density 80-inch Bed Plantings and Demonstration of Best Management Practices • *Richard Smith and Michael Cahn, 12-0362*

Phosphorus and Boron Fertilizer Impacts on Sweet Potato Production and Long-Term Storage• *C. Scott Stoddard, 13-0266*

Developing Testing Protocols to Assure the Quality of Fertilizer Materials for Organic Agriculture• *William Horwath, 13-0223*

Interagency Task Force on Nitrogen Tracking and Reporting System • *Suzanne Swartz, 13-0054*

Improving Pomegranate Fertigation and Nitrogen Use Efficiency with Drip Irrigation Systems• *James E. Ayars and Claude J. Phene, 12-0387*

Evaluation of a 24 Hour Soil CO2 Test For Estimating Potential N-Mineralization To Reassess Fertilizer N • *William R. Horwath and Jeffery Mitchell, 12-0384*

Assessment of Baseline Nitrous Oxide Emissions in Response to a Range of Nitrogen Fertilizer Application Rates in Corn Systems • *Martin Burger and William Orloff, 12-0453*

Fertigation Education for the San Joaquin Valley • *William Green and Kaomine Vang, 12-0390*

Survey of Nitrogen Uptake and Applied Irrigation Water in Broccoli, Cauliflower and Cabbage Production in the Salinas Valley • *Richard Smith and Michael Cahn, 11-0558*

Improved Methods for Nutrient Tissue Testing in Alfalfa • *Steve Orloff and Dan Putnam, 11-0469*

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European Pear Growth and Cropping: Optimizing Fertilizer Practices Based on Seasonal Demand and Supply with Emphasis on Nitrogen Management • *Kitren Glozer and Chuck Ingels, 10-0105*

Development of a Nutrient Budget Approach to Fertilizer Management in Almond • *Patrick Brown, 10-0039*

Development of Leaf Sampling and Interpretation Methods for Almond and Pistachio • *Patrick Brown, 10-0015*

Relationship of Soil K Fixation and Other Soil Properties to Fertilizer K Requirement • *G. Stuart Pettygrove, 10-0012*

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Developing Testing Protocols to Assure the Quality of Fertilizer Materials for Organic Agriculture • *W.R. Horwath, 09-0582*

Citrus Yield and Fruit Size Can Be Sustained for Trees Irrigated with 25% or 50% Less Water by Supplementing Tree Nutrition with Foliar Fertilization• *Lovatt, 09-0581*

Measuring and modeling nitrous oxide emissions from California cotton, corn, and vegetable cropping systems • *Goorahoo, 09-0001*

Development of a Comprehensive Nutrient Management Website for the California Horticultural Industry • *Timothy K. Hartz, 08-0629*

Evaluation of Low-Residue Cover Crops to Reduce Nitrate Leaching, and Nitrogen and Phosphorous Losses from Winter Fallow Vegetable Production Fields in the Salinas Valley • *Richard Smith, 08-0628*

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