Proceedings

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Fertilizer Research and Education Program and
Western Plant Health Association
Twenty Eighth Annual Conference

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INTRODUCTION

Fertilizer Research and Education Program

Welcome to the Fertilizer Research and Education Program (FREP) and Western Plant Health Association (WPHA) Nutrient Management Annual Conference. Over the last 28 years, this conference has provided a forum for FREP grant recipients to report project findings and for industry representatives to share valuable nutrient management information with an audience of crop advisors, growers, researchers, and other agricultural professionals.

Being virtual, this year's conference has provided the opportunity to bring together stakeholders from agricultural communities across the country. While California is unique, it shares common challenges and opportunities with agricultural systems throughout the world.

28th FREP WPHA Annual Conference

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

Dr. John Dickey will present his work with the Kings River Watershed Coalition to refine nitrogen (N) removal rates, the N removed from the field with harvested crops, for 23 crops grown in the Central Valley. These N removal rates will help California growers plan their N management more accurately and comply more effectively with water quality regulations. Dr. Dickey and his team are determining N removal values through three approaches: field sampling of harvested crops, estimating N in perennial tissues with crop growth models, and integrating data from other research projects.

Daniela Reineke will present her research with Dr. Patrick Brown on managing nitrate and salinity in almond orchards. This 5-year project is characterizing patterns of root nitrate uptake and plant response when plants grow in soils with heterogeneous salinity distribution. Using this information, they are producing a modeling platform for growers and crop advisors to develop site-specific irrigation design and scheduling practices for combined nitrate and salinity management.

Cole Smith will present his research with Dr. William Horwath on N contributions from organic fertilizer amendments in agricultural production systems in California. Mr. Smith and his team have conducted laboratory analysis and field trials to gather data for incorporation into the DayCent and COMET-Planner modeling tools.

Gerry Spinelli, with the Santa Cruz Resource Conservation District, will present the results of his extensive outreach and education efforts with Central Coast growers on the soil nitrate quick test. Soil nitrate, mineralized from soil organic matter, crop residues or organic amendments, can meet a part of crop N demands. The soil nitrate quick test is a tool to help growers account for this N pool when calculating N application rates throughout the growing season.

Past Research

Since 1991, FREP has committed over 22 million dollars in over 250 projects focused on nutrient management research, outreach, and the development of decision support tools. These projects address nutrient and irrigation management challenges and opportunities in several commodity areas and growing regions across California (Figures 1-3).

The Crop Fertilization Guidelines is an important resource resulting in part from FREP-funded projects. The 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 fertilizer application recommendations and decisions. You can access these guidelines here:

https://www.cdfa.ca.gov/is/ffldrs/frep/FertilizationGuidelines/

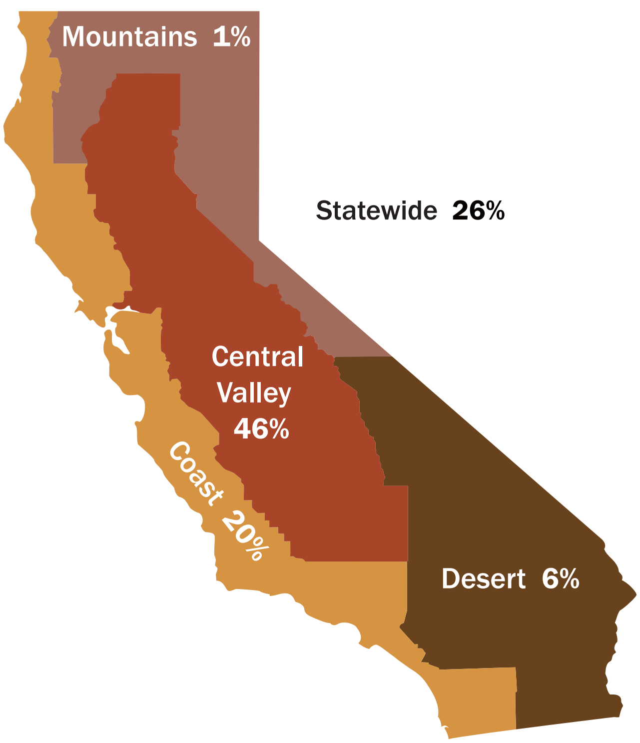

Figure 1. Locations where FREP projects have been conducted.

FREP has adapted the N 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 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 low desert of the Imperial Valley, Dr. Jairo Diaz and Dr. Roberto Soto is evaluating the effects of irrigation management and N fertilization rates on yield and quality of fresh onion bulb production in arid regions using saline water. They are achieving this by conducting field trials to evaluate the response of onion to drip irrigation regimes and compare onion production under different N fertilizer application rates.

On the Central Coast, Cooperative Extension Farm Advisor Richard Smith is researching the viability of using carbon-rich amendments to immobilize and sequester residual soil nitrate and reduce nitrate leaching during the winter fallow period. Mr. Smith and his team are conducting field trials with cooperating growers in commercial vegetable production fields, monitoring soil nitrate and the effect of these amendments on succeeding crop rotations.

Across California, Cooperative Extension Agronomy Specialist Dr. Mark Lundy and several Cooperative Extension Farm Advisors are working with wheat growers to develop a tool to helps wheat growers achieve more efficient N management.

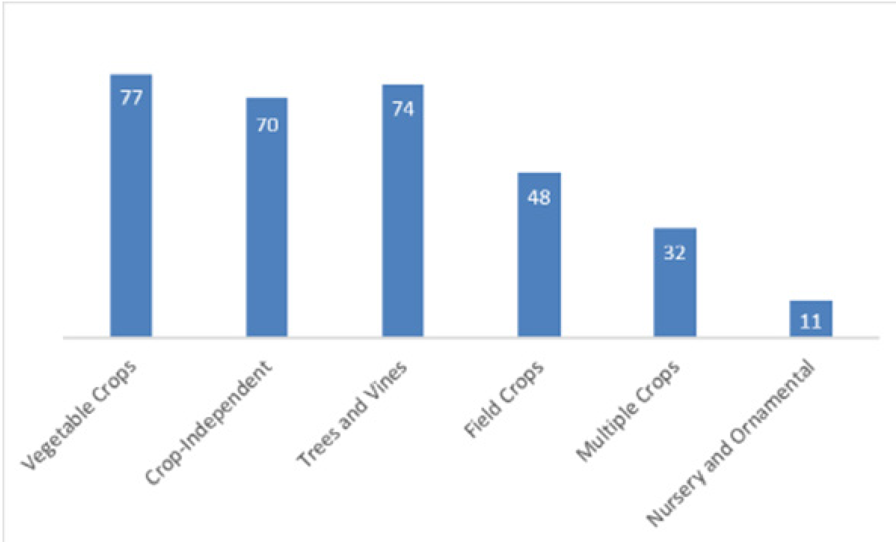

Figure 2. Distribution of FREP-funded projects by commodity

To learn more about other current and completed FREP projects, visit:
http://www.cdfa.ca.gov/is/ffldrs/frep/Research.html

Future FREP Projects

In 2020, FREP has committed to funding 11 new grant projects totaling a commitment of over two million dollars. The following are examples of the new projects starting this winter.

Figure 3. Hemp plant

In Yolo and Fresno counties, FREP is funding research to evaluate two biotypes of industrial hemp and assess the impacts of N management on tetrahydrocannabinol (THC) and cannabidiol (CBD) tissue content, including partitioning to harvested portions of plants. As information is developed, the project will provide data to appropriate grower groups, consultants and industry, receive feedback and refine N management approaches.

With the help of FREP funding, Dr. Anthony O'Geen at UC Davis will identify best management strategies for agricultural Flood-Managed Aquifer Recharge, based on dormant season N cycling in farm fields planted with tree or vine crops and select field crops. These strategies will consider circumstances that determine N transformations such as duration and frequency of water application, and the associated periods of anaerobic and aerobic conditions.

To better understand site-specific N mineralization, Dr. Daniel Geisseler will validate N mineralization estimates in field trials across the Central Valley, characterize the chemical composition of soil organic matter using Fourier-transform infrared (FTIR), and develop user-friendly, site-specific online N fertilization calculators for various crops. Dr. Geisseler's goal is to develop robust site-specific estimates of the contribution of N mineralization to the plant-available N pool for different regions in California.

Acknowledgements

We are grateful to members of the fertilizer industry for their support in providing funds for the FREP. 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. Marja Koivunen, DD Levine, David McEuen, Dr. Jerome Pier, Dr. Steve Petrie, Dr. Tom Bottoms, Dr. Suduan Gao, Dr. Lisa Hunt and Dr. Ben Faber 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, Christopher Gallo, Doug Graham, Jay Irvine, David McEuen, Melissa McQueen, Edward Needham and Gary Silveria.

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 Mark Cady, Senior Environmental Scientist (Supervisory); Nicole Crouch, Environmental Scientist; Dr. Emad Jahanzad, Senior Environmental Scientist (Specialist); Natalie Jacuzzi, Senior Environmental Scientist (Specialist) and Jennifer Harmon, Associate Government Program Analyst.

Conference Program

28th FREP/WPHA Annual Conference

Wednesday, October 28, 2020

Facilitator: Dr. Rob Mikkelsen, Director of Communications, African Plant Nutrition Institute

8:00 **Welcome**
Karen Ross, Secretary, California Department of Food and Agriculture

Session 1: Sampling Techniques and Analyses

8:20 **Assessment of Harvested and Sequestered Nitrogen Content in California Crops**
Dr. John Dickey, Technical Program Manager, South San Joaquin Valley Management Practices Evaluation Program

8:50 **Assessing the Accuracy and Precision of Soil Chemical Analyses Performed by Eight Agricultural Laboratories**
Andre Biscaro, Irrigation an Water Resources Advisor, Universtiy of California Cooperative Extension, Ventura County

9:20 **Questions**

9:30 **Coffee Break**

Session 2: Irrigation and Salinity Management

9:40 **Improving Nitrate andn Salinity Management Strategies for Almonds**
Daniela Reineke, Soils and Biogeochemistry Graduate Group, University of California Davis

10:10 **Importance of a Good Distributio Uniformity**
Brian Hocket, District Manager, North West Kern Resoruce Conservation District

10:40 **Questions**

10:50 **Coffee Break**

Session 3: Efficient Management Practices in Almonds

11:00 **Practical Advances in Almond Irrigation Sustainability**
Luke Milliron, Orchard Systems Advisor, University of California Cooperative Extension, Butte, Glen, And Tehama Counties

11:30 **Practical Advances in Almond Nutrition Sustainability**
Dr. Franz Niederholzer, Orchard Systems Advisor, University of California Cooperative Extension, Yuba, Sutter, and Colusa Counties

12:00 **Questions**

Thursday, October 29, 2020

Facilitator: *Dr. Jerome Pier, Agronomist, Crop Production Services*

8:00 **Welcome**
Renee Pinel, President/CEO, WPHA

Session 1: Soil and Crop Nutrient Management

8:10 **Evaluation of Certified Organic Fertilizers for Long-term Nutrient Planning**
Cole Smith, Staff Research Associate, University of California Cooperative Extension, Santa Clara and Monterey Counties

8:40 **Soil Nitrate Quick Tests and Nitrogen Management in Strawberry Production**
Dr. Gerry Spinelli, Agricultural Technical Specialist, Santa Cruz Resource Conservation District

9:10 **Hemp for Essential Oils: Water and Nutrient Management Considerations**
Dr. Bob Hutmacher, Cooperative Extension Specialist and Center Director, University of California West Side Research and Education Center

9:40 **Questions**

10:00 **Coffee Break**

Session 2: Managed Aquafir Recharge on the Central Coast

10:10 **Water Resource Management in the Pajaro Valley**
Brian Lockwood, General Manager/Hydrogeologist, Pajaro Valley Water District Management Agency

10:40 **Enhancing Groundwater Recharge in the Pajaro Valley**
Dr. Andrew Fisher, Hydrogeology Professor, University of California, Santa Cruz

11:10 **Questions**

11:30 **Closing Remarks**

SUMMARIES OF PRESENTED FREP PROJECTS

Evaluation of Certified Organic Fertilizers for Long-term Nutrient Planning

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INTRODUCTION

Understanding the release of plant available nitrogen (N) from organic fertilizers is critically important in order to achieve high N use efficiency (NUE) and minimize N loss to the environment, including from organically managed agroecosystems. With this information, growers will be empowered to more precisely manage nutrients according to seasonal and site-specific conditions. The challenge of understanding net N mineralization from organic fertilizers is directly related to complex interactions between weather, soil biology and physical properties, organic input quality and chemistry, and intensive management practices (Cabrera et al., 2005; Schomberg et al., 2009). Although, in general, inorganic N can be released quickly from high-N containing fertilizers (Joseph et al., 2017), there is limited information on the degree to which biotic and abiotic factors influence characteristics of nutrient release, for example the release rate, total plant availability or the significance of short-term verses long-term immobilization processes.

In the laboratory, the N mineralization potential, i.e. the availability of plant-available N 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 N mineralization potential of different amendments and soil N. Yet, the lack of information on the N mineralization kinetics of organic fertilizers within different soil types and/or temperatures has limited the ability to make clear application recommendations. The inclusion of mineralized N from organic sources of N into fertilizer recommendations is essential to improving NUE and optimizing agronomic planning. Underestimation of the contribution of organic soil amendments and fertilizers to plant-available N can result in excess reactive N 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 N release from organic sources and sync N supply with crop N demand.

OBJECTIVES

The overarching objective is to provide baseline data to inform N 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

Here we combine data gathered from the literature, aerobic lab incubations and field trials to better understand plant available N release dynamics from organic nutrient sources added to the soil. Using this empirical data, we will be able to validate the daily time step version of the CENTURY biogeochemical model – DayCent. Establishing projections of seasonal variability and long-term nutrient value of selected organic fertilizers, including impacts on soil carbon reserves and multiyear soil nutrient increases will aid immensely in developing fertilizer recommendations for organic growers. Modeling N mineralization responses will help us to better understand repeated annual applications of organic fertilizers on long-term soil N availability. Information on net N mineralization generated by this project will also assist in the broader effort to parameterize the DayCent model, so that the model can accurately predict N mineralization rates at different soil temperatures under soil conditions in California throughout the year. These models often use default N mineralization values resulting in poor prediction outcome for soils under California's Mediterranean climate. Our results will provide adjustments for nutrient management guidelines depending on organic fertilizer sources, soil type, and climate data. The information generated in this research will be used by UC ANR Extension, CCAs and farmers to reassess N management across a variety of crops. This is a three-year project and to date we have accomplished literature review, multiple laboratory incubations and one season field trial. The laboratory incubations are on-going and a field litter bag decomposition trial is in progress.

RESULTS AND DISCUSSION

Literature Synthesis: Data has been collected from 47 aerobic incubation studies totaling 181 incubated amendments over various lengths of incubation period. Criteria for inclusion into the dataset include reporting measured inorganic N as an outcome variable and having at least one tested material determined to be an organic amendment or fertilizer. Preliminary results show that across the amendments with different C/N ratios, the strength of the relationship to N release is stronger for high-N containing amendments such as organic fertilizers (Figure1). Additionally, the temperature responses appear to be heterogenous across the organic fertilizers with low C/N ratios as shown in Figure 2.

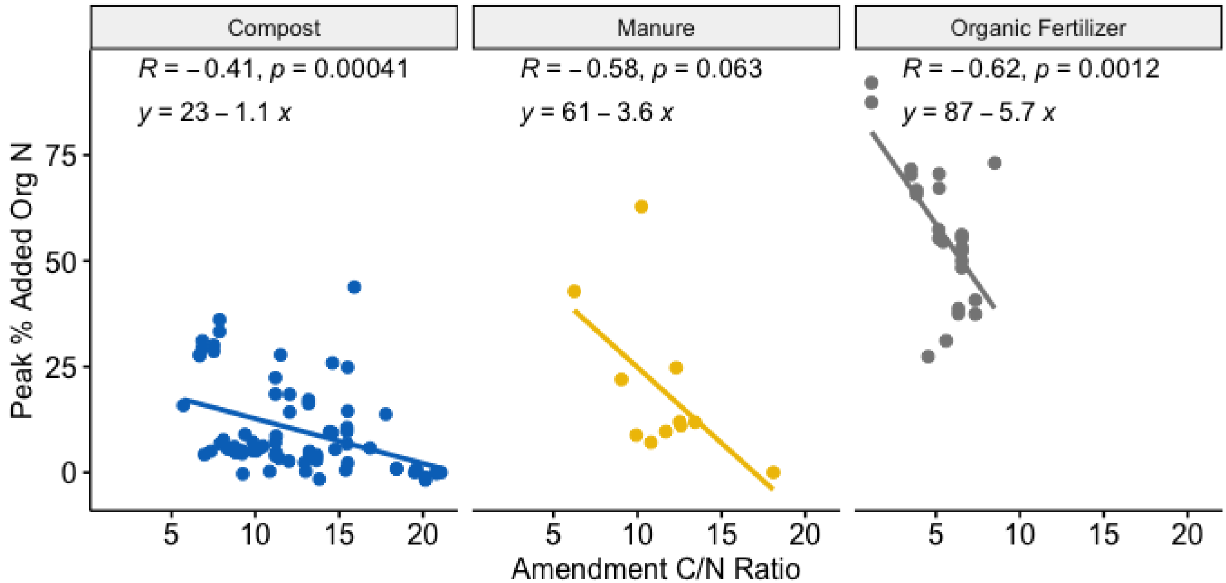

Figure 1. Net mineralized nitrogen shown as the maximum percentage of added organic N reached during the incubation regardless of length. Model fits are linear regression lines with amendment C/N ratio as a single predictor of percentage of organic N mineralized as net inorganic N.

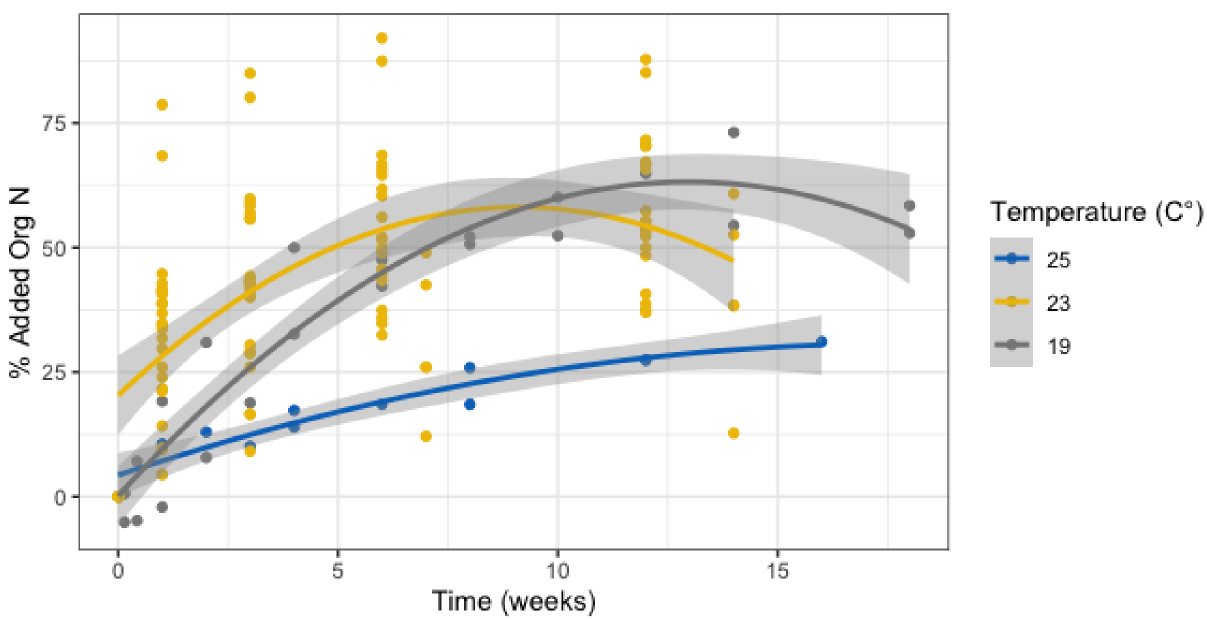

Figure 2. For organic fertilizers only (C/N ratio ≤ 10), mean total percentage of added organic N mineralized as net inorganic N for each time point. All time point data was collected on week intervals. A second-degree linear polynomial model was fit to the data with confidence intervals representing 95% certainty.

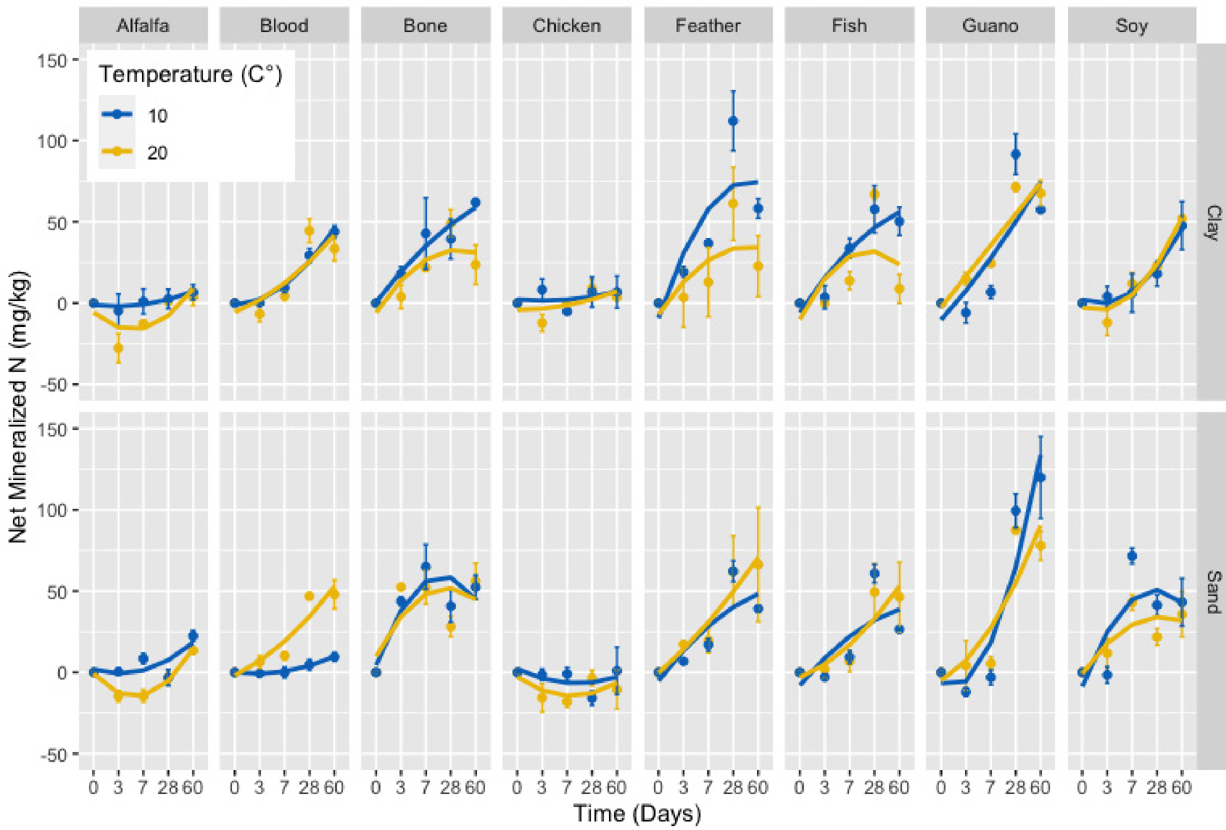

Figure 3. The summation of two separate 60-day aerobic laboratory incubations measuring net N release as net mineralized N (mg/kg d.w) which occurred during project year 2018-2019 with 3 replicates of each organic amendment, in two soil textural types at 10°C and 20°C. Vertical bars depict standard error (n=3).

Laboratory Incubations: Two full factorial 60-day aerobic Laboratory Incubations: Two full factorial 60-day aerobic laboratory incubations have been completed in contrasting soil textural types (clay vs. sand) under two temperature regimes (20°C and 10°C). Figure 3 shows data collected from separate aerobic incubations over 60 days. Our results show that both temperature and soil type have inconsistent impacts on net N release. Kinetic model fitting is currently on going and will aid in quantifying the impact these factors have on net N release.

TAKE-HOME MESSAGE

At this stage, our project results indicate 1) Organic fertilizers have diverse mineralization responses across different temperatures and soil textures. Further, the magnitude of these impacts appears to be variable depending on specific conditions. This finding has significant implications for long-term agronomic planning, potentially allowing growers to reduce applications within certain soil types as well as adjust for seasonal temperature fluctuations.

2) C/N ratio may be an appropriate single predictor for homogenous, high-N containing

fertilizers, but additional factors are necessary to understand nutrient release for more complex amendments such as composts. Additional research is required to determine specifically why amendments that may have similar general characteristics mineralize N differently. Research related to this project will continue, including exploring additional factors within the literature derived dataset, aerobic incubations of more amendments at different temperature ranges, the conclusion of a buried litter bag field experiment, kinetic model fitting and DayCent model validation. Information generated by this project aims to increase grower confidence in using organic fertilizers and amendments.

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.

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.

Joseph, C.A., L. Khiari, J. Gallichand, and S. Bouslama. 2017. Classification and assessment models of first year byproducts nitrogen plant-availability from literature data. Sci. Total Environ. 586: 976–984.

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.

ACKNOWLEDGEMENTS

We would like to thank True Organics for providing organic fertilizers, Javier Zamora and JSM Organics for providing the field project site. Also, UC Davis and UCANR staff and student interns for help with laboratory and field projects.

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

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INTRODUCTION

As part of the Irrigated Lands Regulatory Program (ILRP), the Central Valley Regional Water Quality Control Board (Water Board) requires producers to implement management practices that are protective of groundwater quality, and to document the effectiveness of those practices. A key interest of the Water Board is the relationship between the amount of Nitrogen (N) applied to cropland compared to the amount of N removed in harvested products. This 'Applied - Removed' (A-R) metric was endorsed by the Agricultural Expert Panel (2014) as a way to gauge progress in reducing the mass of nitrate potentially leachable to groundwater. Growers in areas deemed vulnerable to groundwater degradation with nitrate are now required to report their N application rates together with an estimate of N removal with harvest. To comply with this reporting requirement, growers and their water quality coalitions need reliable data regarding the N removal per unit of yield for crops produced in the Central Valley. This information is also useful to growers in developing nutrient management programs to maximize efficiency of N fertilizer use. In the publication Nitrogen Concentrations in Harvested Plant Parts - A Literature Overview Geisseler (2016) surveyed the scientific literature and calculated N removal coefficients (lb N/ton of yield) for 72 crops, representing more than 98 percent of Central Valley irrigated lands. However, that report recognized significant limitations of the available data. Many of these removal coefficients were based on datasets that were small, out of date, or from production areas outside California. Of the 72 crops surveyed only 10 had sufficient data to establish N removal coefficients deemed representative of Central Valley conditions. This project was undertaken to develop N removal coefficients that are representative of Central Valley conditions for an additional 25 major crops.

OBJECTIVES

1. Assess N concentration of harvested material removed from fields for approximately 25 crops over several growing seasons. In this project samples of harvested material will be collected and analyzed for eleven of those crops; data for the remaining crops will come from other research projects.
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 N removal coefficients (lb N per ton of yield), and add N-sequestration rate estimates, for use by growers and 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 in N management planning and evaluation by growers, advisors and coalitions.

DESCRIPTION

We are coordinating the development of updated N removal coefficients for 25 crops. For some crops, data will be gathered by other research projects, and synthesized into our database. Within this project the following crops are being sampled: carrots, corn (grain and silage), peaches, pistachio, plums, pomegranates, raisins, safflower, sorghum (grain and silage), sunflower and processing tomatoes. By partnering with commodity organizations, growers, processors and packers, we have been able to procure hundreds of samples, representing a range of varieties and growing environments for each crop. Sampling spans several seasons to account for variation due to differences in weather conditions that affect yields and N use efficiency. Where possible, detailed information about source fields such as age of perennial crops, crop management practices, N application rate, variety, yield, quality, and dates of bloom or planting, are also being acquired. In this way, some of the factors that affect N content of the harvest can be investigated and explained. Sampling methods are specific to each crop and are designed to ensure results representative of the industry. Analyses include quality control involving use of "blind" duplicate samples to estimate reproducibility of sampling and processing methods. In the calculation of the N removal coefficients we are working to include non-marketable plant biomass removed from the field at harvest. The N removal coefficients developed by this project will be incorporated into an update of Geisseler (2016). Additionally, the Crop Yield to Nitrogen Removed Calculator (http://agmpep.com/calc-y2r/) developed by the Management Practices Evaluation Program of the Southern San Joaquin Valley Water Quality Coalitions will be revised to reflect the project's findings, and the results will be used to update the assessment and planning tools available to growers, grower advisors, coalitions, and regulators.

RESULTS AND DISCUSSION

Crop sampling completed to date clearly shows that N removal coefficients derived from existing scientific literature are not necessarily representative of Central Valley conditions (Table 1). Our sampling suggests that N removal in carrots, plums, pomegranates and safflower are lower per ton of yield than the estimates developed by Geisseler (2016), while N removal in peaches, sunflower and processing tomatoes are higher. Assessing N removal of pistachio is complicated by fact that material other than marketable nuts are removed from the field at harvest. The sampled values in Table 1 represent nuts as they are delivered to the processing plant, while the value from the Geisseler review represented 'CPC yield', a now outdated unit that has been replaced by a different unit representing processed pistachios at a defined moisture content. We are in the process of adjusting our results to account for leaves and other trash removed from the field, and for differences in moisture percentage, to be able to allow direct comparison to the new industry standard yield measure. Corn data are from a field trial with two varieties, 3 irrigation levels and 3 N levels. N contents in the 0 N treatment were significantly lower and were not included in this summary, as this is not a representative practice.

N removal coefficients of all crops appear to be relatively consistent across years. However, within each crop substantial variability exists; coefficients of variation (C.V., the ratio of the standard deviation of the population to the mean) range from approximately 10-20% among the crops sampled. There are several potential sources of this variability. Varietal differences may be significant. In peaches, for example, early maturing varieties (harvested in June) averaged 3.5 lb N/ton, while later-maturing varieties harvested in August and September averaged 2.7 lb N/ton. Nitrogen application rate and yield level are undoubtedly also important. Within a given crop grower-reported N rates vary widely, as do yields; prior research has shown that

Table 1. Comparison of N removal coefficients derived from current sampling with estimates from existing scientific literature (Geisseler, 2016).

					Estimate from literature	
Crop	Year	# of samples	Ave. lb N/ton	C.V. (%)	Ave. lb N/ton	C.V. (%)
Carrot	2018	14	2.77	24	3.29	22
	2019	40	2.90	21		
Corn silage	2017	12	7.59	10.3	7.56	10.5
	2018	12	7.32	13.6		
Peach	2018	36	3.20	19	2.26	21
	2019	32	2.86	20		
Pistachio	2018	100	44.8	18	56.1	4
	2019	61	46.0	22		
Plum	2018	12	2.40	17	2.83	11
	2019	11	2.04	9		
Pomegranate	2018	10	4.41	20	15.2	15
	2019	19	3.45	14		
Safflower	2018	218	50.2	15	56.8	20
	2019	57	53.3	10		
Sunflower	2019	25	63.2	11	54.1	14
Tomato	2018	100	2.96	19	2.73	11
(processing)	2019	79	3.17	11		

crop N concentration increases as N rate per unit yield increases. Work continues on correlating crop N removal with field-specific management factors. Another important factor to consider when establishing N removal coefficients is the fraction of the crop that is culled at a packing or processing facility, and therefore not reflected in the marketable yield. We continue to work with packers and processors to account for this effect.

TAKE-HOME MESSAGE

Increasing regulatory focus on N management in crop production presents a formidable challenge to growers; meeting regulatory groundwater quality goals will require highly efficient N management. A prerequisite for efficient N management is an accurate understanding of crop N uptake and N removal with harvest. This project is the first phase of a longer process of developing such information for the wide range of crops produced in the Central Valley. Beyond the development of accurate N removal coefficients, understanding the relationships among N rate applied, crop N uptake, yield achieved and N concentration in the harvested material will improve our understanding of N utilization in crop production, and point the way toward more efficient management practices.

LITERATURE CITED

Agricultural Expert Panel. 2014. Recommendations to the State Water Resources Control Board pertaining to the Irrigated Lands Regulatory Program. In fulfillment of SBX2 1 of the California Legislature. September 9. Available at: http://www.itrc.org/swrcb/Files/Expert%20Panel%20Final%20Sept%209%202014%20-%20SWRCB.pdf

Geisseler, Daniel. 2016. Nitrogen Concentrations in Harvested Plant Parts – A Literature Overview. Available at: http://geisseler.ucdavis.edu/Geisseler_Report_2016_12_02.pdf.

ACKNOWLEDGEMENTS

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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 (N) fertilizers 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. Strict water quality regulations make correct N management more and more crucial for farming operations. 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 N 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 N management tools amongst this demographic. Earlier work has shown that soil nitrate quick tests are an excellent tool to manage in-season fertilization. Additionally, models of crop N 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

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

DESCRIPTION

Since the beginning of the project, staff provided supplies and one-on-one training and assistance to thirty-nine growers, ranch managers or other agricultural personnel to correctly use the nitrate test on their fields. Throughout the project, it became clear that many growers lack the knowledge to calculate a complete N balance, by summing contributions from organic matter mineralization, irrigation water, crop residue etc. Additional outreach materials were produced to estimate the contribution of irrigation water to the N balance and the training provided in the field included a discussion of various sources of N to the crop and how to estimate the contribution of each.

RESULTS

Due to the Covid-19 pandemic, the outreach activities for spring 2020 were put on hold. Instead, the project developed a series of videos in Spanish as outreach materials. The videos cover several topics in N management, including quick tests, the contribution of nitrate in irrigation water and adjusting N application for yields in strawberry. The videos are on YouTube at the links below:

How to collect soil and process a nitrate quick test:

https://www.youtube.com/watch?v=FkCt-QDGNx8

How to interpret the results of a nitrate quick test:

https://www.youtube.com/watch?v=Po-MA2I1GSv4

How to measure the N contribution of irrigation water:

https://www.youtube.com/watch?v=Kd-jE7U3yuw4

Complete N balance in strawberry and how to adjust N application to yield:

https://www.youtube.com/watch?v=Rr-cu_id9c5o

How to use different colorimetric strips with different units for a nitrate quick test:

https://www.youtube.com/watch?v=U-G005RUR218

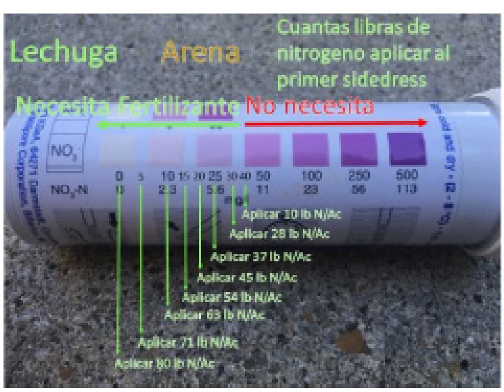

Figure 1. Example of soil-specific field sheet for interpreting quick test (left) and recommendations for a common fertilizer (right)

Libras de nitrógeno en el agua de riego

Libras totales de nitrógeno añadida al cultivo por el agua de riego para diferentes concentraciones de nitrato en el agua del pozo (filas) y para diferentes cantidades de agua de riego aplicada (columnas). Concentraciones medidas con tiras AquaChek de la compañía Hach.

Prueba de nitrato ppm de NO_3-N	Pulgadas de agua de riego aplicada										Estimado para un ciclo completo de cultivo			
											Fresa	Lechuga	Mora	Broccoli
	1	2	3	4	5	10	12	15	20	25	26	8	20	20
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	1	1	1	2	3	3	5	6	6	2	5	5
2	0	1	1	2	2	5	5	7	9	11	12	4	9	9
3	1	1	2	3	3	7	8	10	14	17	18	5	14	14
4	1	2	3	4	5	9	11	14	18	23	24	7	18	18
5	1	2	3	5	6	11	14	17	23	28	29	9	23	23
6	1	3	4	5	7	14	16	20	27	34	35	11	27	27
7	2	3	5	6	8	16	19	24	32	40	41	13	32	32
8	2	4	5	7	9	18	22	27	36	45	47	15	36	36
9	2	4	6	8	10	20	24	31	41	51	53	16	41	41
10	2	5	7	9	11	23	27	34	45	57	59	18	45	45
15	3	7	10	14	17	34	41	51	68	85	88	27	68	68
20	5	9	14	18	23	45	54	68	91	113	118	36	91	91
25	6	11	17	23	28	57	68	85	113	142	147	45	113	113
30	7	14	20	27	34	68	82	102	136	170	177	54	136	136
35	8	16	24	32	40	79	95	119	159	198	206	63	159	159
40	9	18	27	36	45	91	109	136	181	227	236	73	181	181
45	10	20	31	41	51	102	122	153	204	255	265	82	204	204
50	11	23	34	45	57	113	136	170	227	283	295	91	227	227
60	14	27	41	54	68	136	163	204	272	340	354	109	272	272
70	16	32	48	63	79	159	190	238	317	397	413	127	317	317
80	18	36	54	73	91	181	218	272	363	453	471	145	363	363
90	20	41	61	82	102	204	245	306	408	510	530	163	408	408
100	23	45	68	91	113	227	272	340	453	567	589	181	453	453
110	25	50	75	100	125	249	299	374	499	623	648	199	499	499
120	27	54	82	109	136	272	326	408	544	680	707	218	544	544

Figure 2. A table to look up the pounds of nitrogen per acre provided by the irrigation water (top) and training a group of irrigators and ranch managers (bottom)

Also, the project produced the following outreach materials:

1. Soil nitrate quick test guide for strawberry (English and Spanish)
2. Soil nitrate quick test field sheets for strawberry and lettuce depending on soil type (English and Spanish, Figure 1, left),
3. Common fertilizers recommendation sheets for lettuce sidedress depending on soil type (English and Spanish, Figure 1, right).
4. N contribution from irrigation water sheet (English and Spanish)

ACCOMPLISHMENTS

The project staff trained 39 irrigators and ranch managers on 19 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 a table for growers to test nitrate in well water and calculate the irrigation water contribution to the crop N budget. We made diagrams to estimate crop fertilizer need in pounds per acre and in gallons per acre for various fertilizers based on the quick test result.

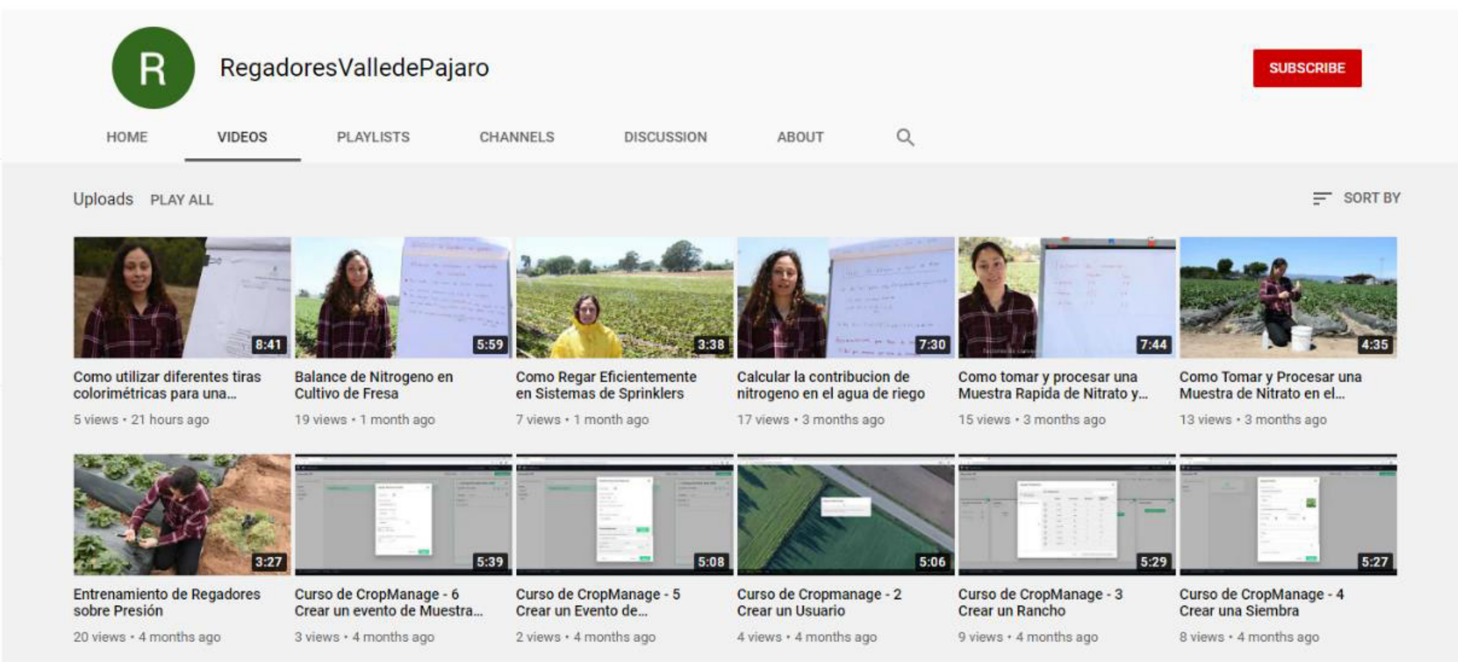

Figure 3. The YouTube channel in Spanish, showing videos on the nitrate test and other topics in nitrogen management

Figure 4. Training irrigators and ranch managers in the field

LITERATURE CITED

Using the Pre-Sidedressing Soil Nitrate 'Quick Test' to Guide N Fertilizer Management, T.K. Hartz Extension Specialist Department of Plant Sciences University of California, Davis.

In-Season Soil Nitrate Testing Explained, Tim Hartz, UC Davis and Richard Smith, Monterey County UCCE.

How To Use The Nitrate Quick Test, Standard Operating Procedures prepared for the Grower-Shipper Association of Central California by Stefanie Kortman with the assistance of Marc Los Huertos Spanish Translation by Gabriela Alberola.

Strategies for managing Nitrogen in Strawberry, Michael Cahn, UCCE Monterey County

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 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 (Simunek 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, 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 scenarios (T1: daily irrigation with saline water and daily fertigation, T2: daily irrigation with non-saline water and daily fertigation, and T3: irrigation every four days with saline water and fertigation every 8 days) are being tested (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.
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. 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.

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

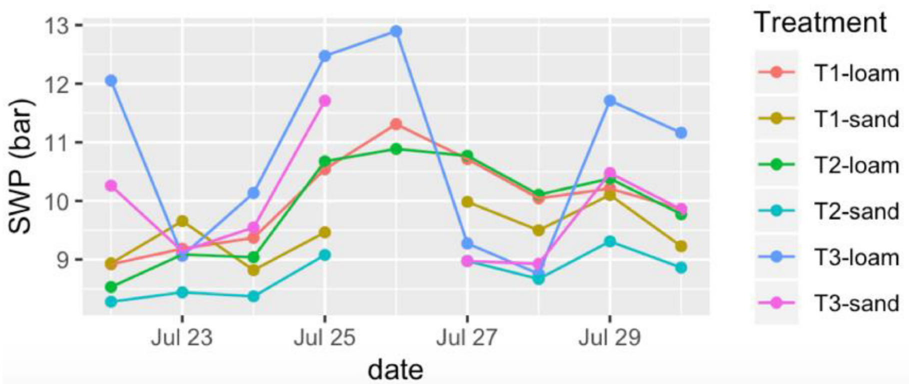

Figure 2. Average stem water potential in all treatments measured over the course of two irrigation cycles in July 2020.

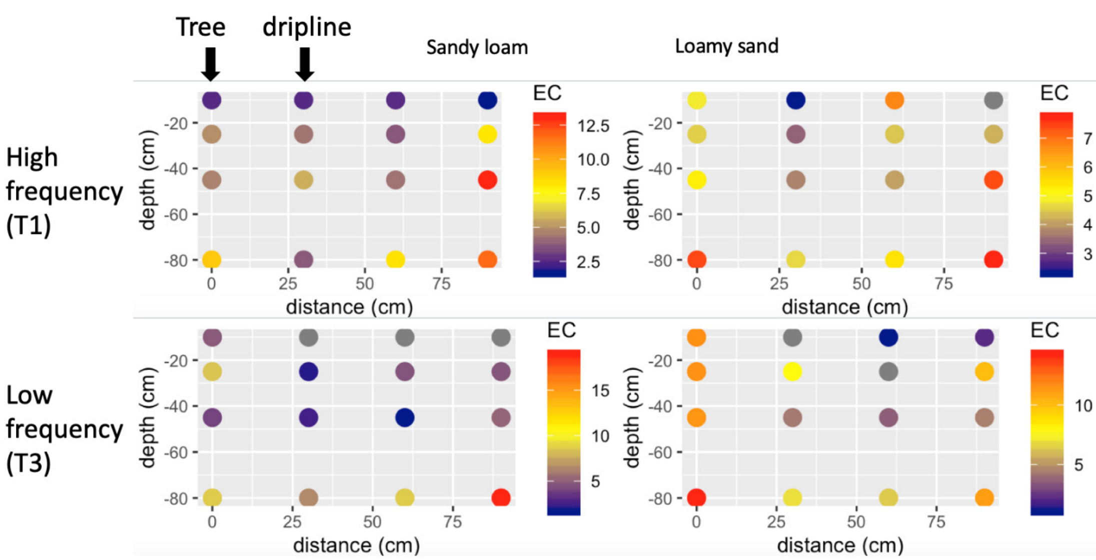

Figure 3. Distribution of soil water EC (dS/m) within the rootzone measured in July 2020 for the high irrigation frequency and low irrigation frequency treatment and for both soil types. The values represent averages of 3 replicates.

RESULTS AND DISCUSSION

Irrigation with saline water has resulted in an increase in average soil solution salinity to 5-8 dS/m in the saline treatments T1 and T3 over the course of a season as compared to 1.8 dS/m in the non-saline treatment T2. The differences in salinity have resulted in a difference in stem water potential between the saline treatment T1 and the non-saline treatment T2 (Figure 2). In the sandy soil, the stem water potential in the saline treatment T1 is consistently lower by about 1 bar than in the non-saline treatment T2 whereas no difference due to salinity can be observed in the loam soil.

Figure 3 shows the difference in spatial distribution of salinity between the high frequency irrigation treatment T1 and the low frequency treatment T3 for both soil types. In all treatments, salinity is relatively low in the vicinity of the drip emitter but reaches values of over 10 dS/m further away from the emitter. This is expected as the irrigation water salinity (1.5 dS/m) is relatively low compared to the soil salinity so that the water may be able to wash salt out of the zone close to the drip emitter.

ACCOMPLISHMENTS

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 under different irrigation and fertigation management scenarios. 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

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

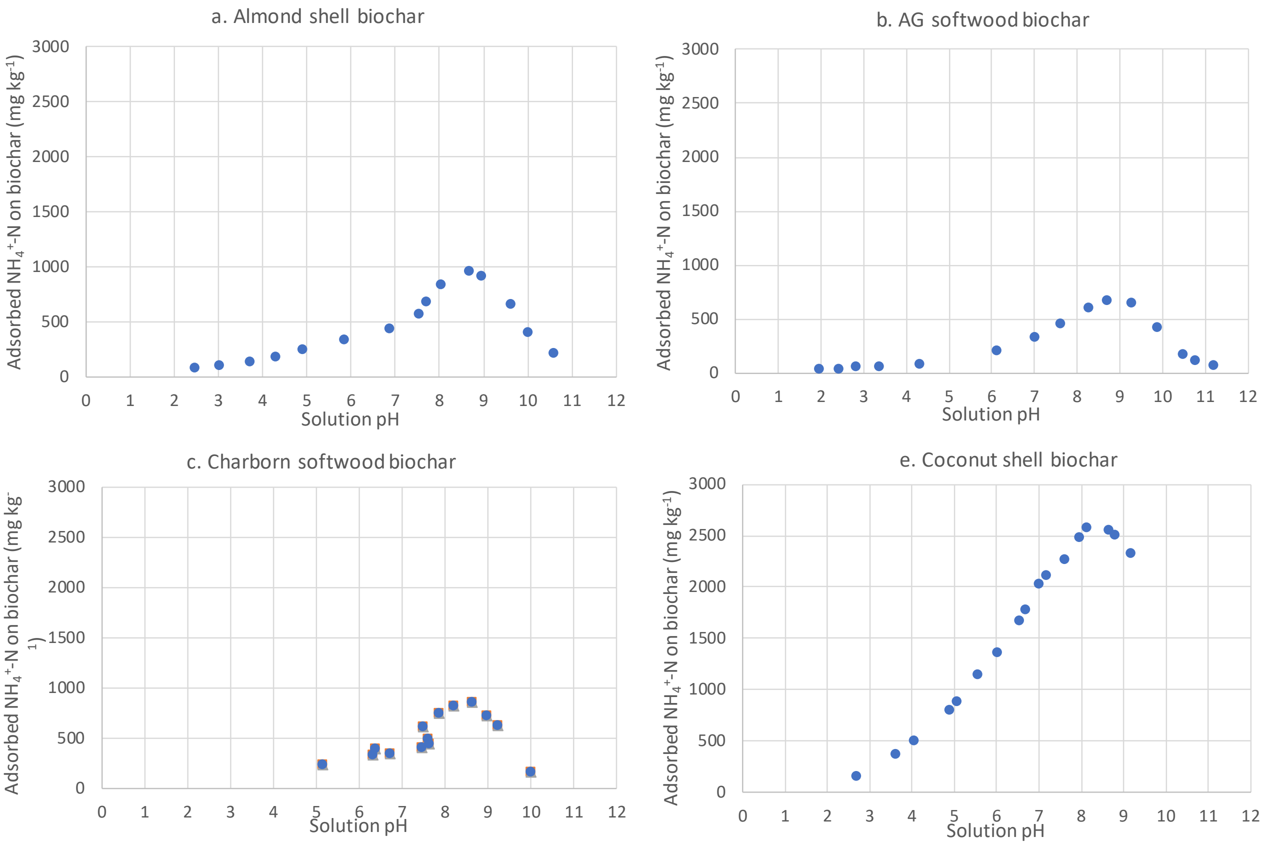

Figure 1. Adsorption envelope of NH4+ on biochar products from different biochars when initial solution concentration was 100 mg NH4+-N L-1 at a 50:1 (v/w) solution:biochar ratio.

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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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 properties of biochar, the material offers many potential solutions to pressing agricultural issues. These issues include nutrient 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 three seasons of processing 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

DESCRIPTION

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

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.				✓	✓	✓

Table 1. Project work plan

Task 1. Produce and Characterize Biochar

Biochar production was completed in August of 2017. These seven biochars were produced by working with commercial biochar companies to obtain mostly CA feedstocks and produce biochar at specified temperatures. Feedstocks include softwood, almond shell, and coconut shell. One biochar with a microbial inoculant was also obtained. To date, these biochars have been analyzed for total carbon, nitrogen, oxygen, hydrogen, and surface area, as well as cation exchange capacity, pH, electrical conductivity, ash content, dissolved organic carbon, and particle size distribution.

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 (YSiL) and a Hanford sandy loam (HSL), 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. In2018 and 2019, preplant and postharvest soil samples were taken from 0-30 cm, 30-60 cm, and 60-90 cm and analyzed for mineral nitrogen, total carbon and nitrogen, pH, and moisture content. Plant samples were collected and analyzed for yield as well as total carbon and nitrogen. A nitrogen budget was calculated to determine N losses, or the total of N volatilized and leached from each treatment. In 2020, samples were also collected for PLFA analysis to determine the impact of biochar on microbial communities after three years in the soil. Fields were planted with processing tomatoes in May 2020, to be harvested in fall for yield and plant nutrient analysis (Figure 1).

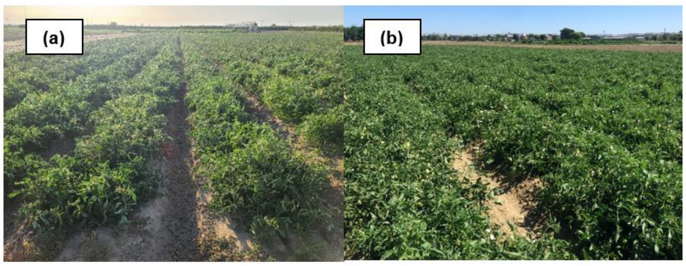

Figure 1. Progress of processing tomato crop in season 3 field trials on June 30th in a) Parlier and b) Davis

Task 3. Growth Chamber and Laboratory Trials

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

RESULTS AND DISCUSSION

Task 1: Carbon content, ash content, and pH generally increased with increasing production temperature. In the case of surface area, feedstock appears to play a larger determining role than production temperature, with softwood biochars having greater surface area than almond shell biochars. Cation exchange capacity and surface area appear inversely correlated to particle size distribution.

Task 2: In years 1 and 2 of processing tomato trials, no significant differences in yield or nitrogen use efficiency were observed in soils with any biochar at any rate. There was a slight and significant increase in pH in soils amended with almond shell pyrolyzed at 800°C (AS800), though the effect was not substantial enough to influence yield. More extensive analysis on yield, nitrogen use efficiency, pH, and other soil health indicators will be completed after the third and final year of data collection from field trials.

Preliminary results from the PLFA study show a significant difference in microbial community structure between sites, but no significant difference due to treatment within each site. Biochar appears to have had a greater impact on microbial community structure in the coarser textured HSL than in the YSiL, though results are not statistically significant. Further analysis on total biomass and microbial ratios (i.e., fungal: microbial, gram-: gram+) is underway.

Task 3: In batch sorption experiments, biochars exhibited little to no nitrate removal efficiency, but a relatively high affinity for ammonium. Based on sorption results, almond shell biochars produced at 500 and 800 ºC, and softwood biochar produced at 500 ºC (AS500, AS800, and SW500, respectively) were chosen for further study. Each biochar was amended at 0 and 2% (w/w) to HSL and YSiL in soil columns, to quantify the impact of biochar on saturated hydraulic conductivity (Ksat), nutrient leaching, and breakthrough curves for nitrate and ammonium. Biochar had a significant effect on Ksat, which varied by soil texture and biochar type. In HSL, AS500 and SW500 significantly slowed the movement of water through the soil profile. This effect was also observed due to the addition of AS800, though it was not significant. Similarly, AS500 and SW500 reduced Ksat in YSiL, while AS800 increased Ksat. Biochar also had a significant effect on nutrient leaching, slowing the pace and total quantity of ammonium release from HSL compared to the unamended control as follows: AS800 < AS500 < SW500 < Control.

The opposite trend was observed for nitrate, with SW500 and AS500 reducing nitrate leaching compared to the control, and AS800 increasing nitrate release. Results for nitrate leaching were not statistically significant except in the case of SW500. To investigate the physical properties of biochar that may have contributed to the above results, X-ray micro-computed tomography (micro-CT) images were taken of HSL and YSiL soils with 0 and 2% additions of AS500, AS800, and SW500 biochars. Images were also taken of the biochars themselves (Figure 2). Images will be processed to quantify porosity, mean pore size, and pore connectivity, in order to correlate these physical properties with the observed differences in Ksat and nutrient leaching.

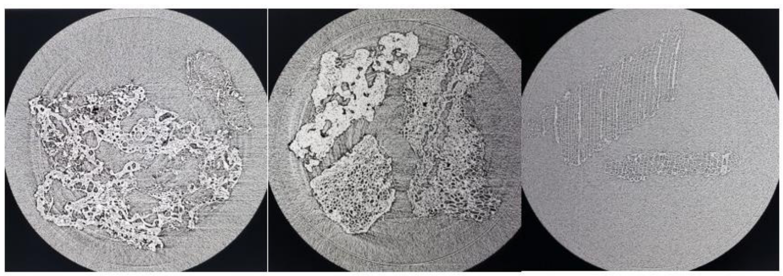

Figure 2. X-ray micro-computed tomography (micro-CT) images of, from left to right, AS500, AS800, and SW500 biochars.

TAKE-HOME MESSAGE

While biochar did not increase tomato yield in years 1 and 2, evidence from literature suggests that the effect of biochar may be delayed as biochar weathers. Year 3 trials may still show an effect on yield. The increase in pH from AS800 may also suggest that this biochar could have a greater effect in more acidic soils than those chosen for this study. Results from lab trials reveal that almond shell biochars best retained nitrate and ammonium at multiple pyrolysis temperatures when compared to coconut shell and softwood. This suggests that almond shell biochar may be an appropriate material for use as a soil amendment to reduce nitrogen loss, an amendment in composting to retain biomass/compost nutrients, and in the treatment of wastewater.

ACKNOWLEDGEMENTS

We thank the following for funding: CDFA FREP (#16-0663-SA), The Almond Board California (#17-ParikhS-COC-01-0), and other support: Pacific Biochar, Karr Group, Premier Mushrooms, and Community Power Corporation.

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).

Twenty-five 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.

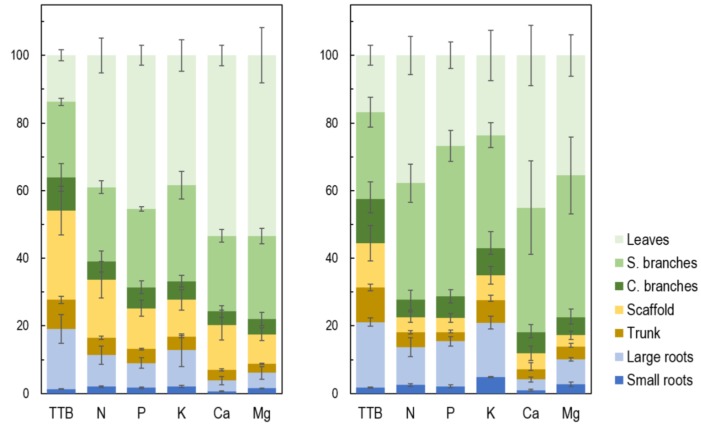

Figure 1. Tree partitioning (% of total) of total tree biomass (TTB) and macronutrients (N, P, K, Ca, and Mg) content. Data refer to Orange (A), and Mandarin (B). Bars represent standard errors.

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.

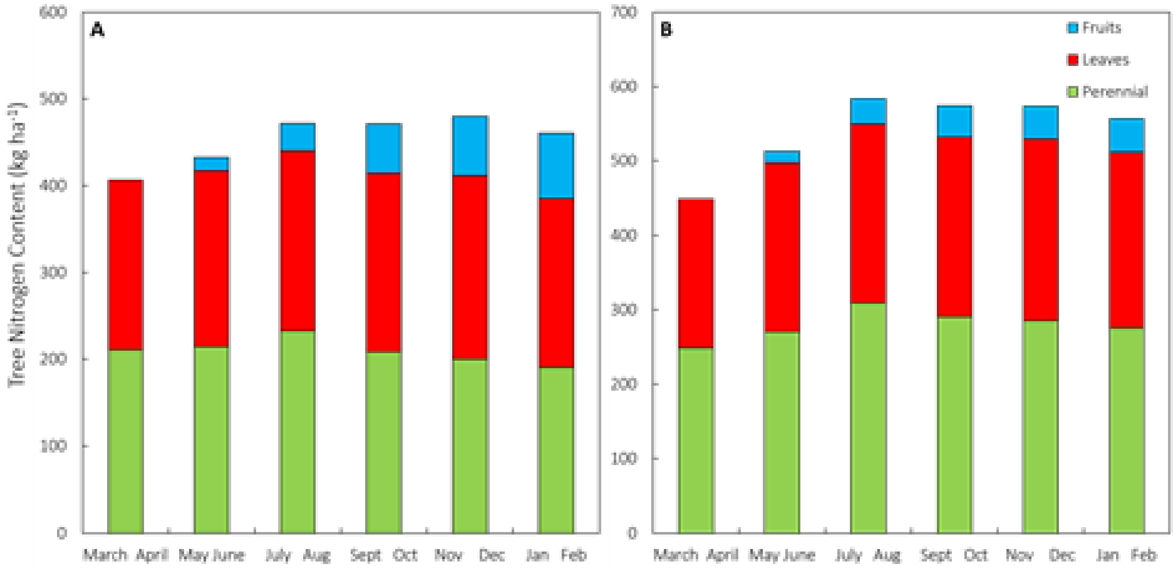

Figure 2. Seasonal trends in Nitrogen partitioning in fruits, leaves, and perennial organs (trunk, scaffold, canopy branches and roots) of mature orange (A) and mandarin (B) trees.

From December to February the amounts 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.

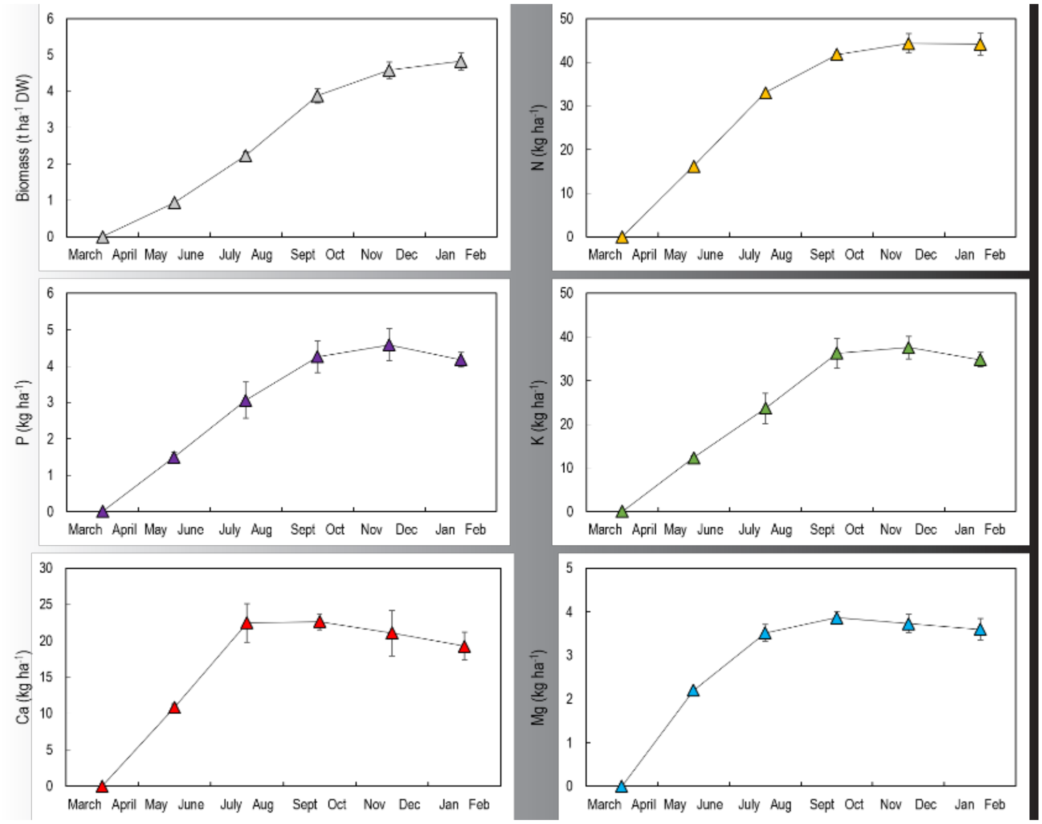

Figure 3. *Seasonal trends in biomass and macronutrients accumulation in fruits of orange trees. Bars represent standard errors.*

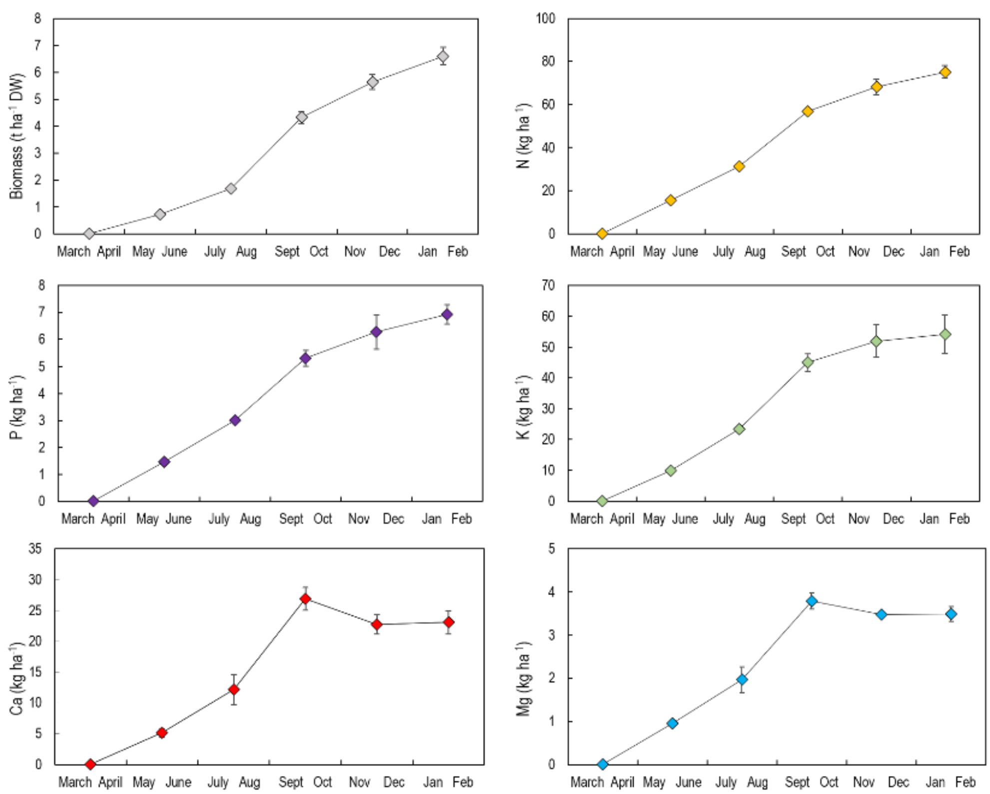

Figure 4. Seasonal trends in biomass and macronutrients accumulation in fruits of mandarin trees. Bars represent standard errors.

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 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

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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.

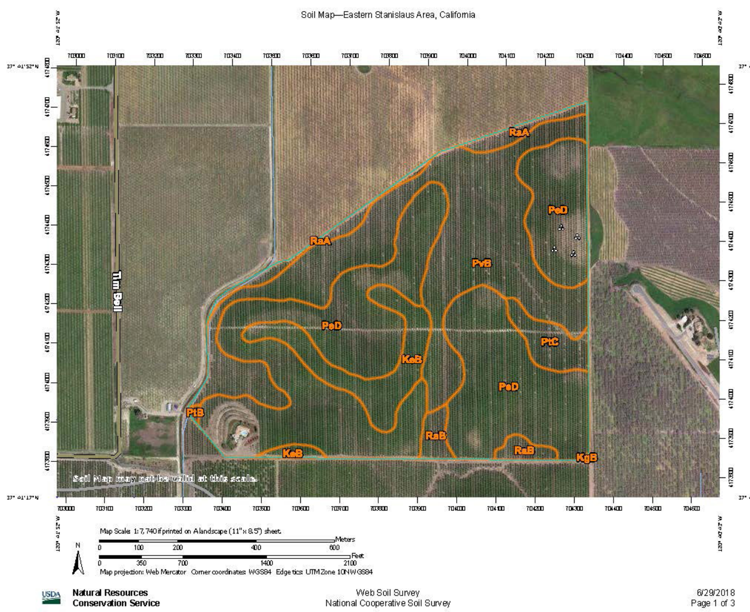

Figure 1. Soil map

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

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

awareness of new technology available to both producers and employees to help 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.

Understanding Influences on Grower Decision-Making and Adoption of Improved Nitrogen Management Practices in the Southern San Joaquin Valley

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INTRODUCTION

Adoption of nitrogen (N) management practices by California growers is a required step to reduce N loading to groundwater and to maintain economically viable cropping systems, while satisfying the Irrigated Lands Regulatory Program (ILRP) requirements. Research over the past decade has identified many promising practices that can improve N management and maintain economically viable cropping systems, including: the use of N budgets; implementation of the "4R's" (right rate, time, place, and source); leaf and soil N sampling; split application of fertilizers with irrigation; enhancing soil health to improve soil N retention; and careful deployment and management of micro irrigation systems.

Recent research suggests grower 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 influence grower decision making (Lubell et al., 2014; Niles et al., 2015; Shaw and Lubell, 2011). However, we do not currently have a robust understanding how these factors relate to adoption of N management practices across the diverse geography and grower demographics of the Southern San Joaquin Valley (SSJV). Furthermore, room for improvement exists to target outreach and education strategies to growers, Pest Control Advisers (PCAs) and Crop Control Advisers (CCAs).

This project aims 1) to develop an understanding of the status of grower adoption of improved N management practices in the SSJV; 2) to determine the key influences on grower decision making including the role of PCA/CCAs; and 3) to identify the key incentives and barriers to enhanced adoption of N 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 policymaking, improve N management and to reduce N loading to groundwater.

OBJECTIVES

1. Develop an understanding of links between adoption rates and barriers to adoption of N management practices in the coalitions of the SSJV Management-Practices Evaluation Program (MPEP)
2. Distribute, collect and aggregate survey data from growers and pest control/certified crop advisors (PCA/CCAs)
3. Analyze data to determine key motivations and barriers to grower adoption and PCA/CCA recommendations of N management practices
4. Communicate these findings directly with the grower and PCA/CCA communities in which we work, as well as academic and regulatory body audiences
5. Outline key variables on linking adoption rates with barriers to adoption of N management practices within grower and PCA/CCA populations to tailor outreach, education and incentive programs

DESCRIPTION

In 2019, a mail survey was modelled after the survey instrument developed by Dr. Mark Lubell and colleagues that has been tested in the North San Joaquin and Sacramento Valleys. After integrating feedback from grower meeting surveys and the SSJV MPEP Committee, the first round of the survey was distributed by mail in June 2020, with a second round of the survey scheduled to be sent out in late September 2020. In 2020, an online survey for technical advisers was be designed based on the preliminary results from a CCA and PCA survey at the Fall 2019 California Association of Pest Control Advisers (CAPCA) Conference. The survey was designed to be synchronized with of the questions in the grower mail survey. After the revision and approval process, the survey will be distributed to PCA/CCAs at the Fall 2020 CAPCA Conference, with promotional help from CAPCA. To analyze the resulting survey data, we will identify key predictor variables influencing practice adoption (response variables) and estimate the magnitude of influence of each key predictor variable. We will correlate our survey responses with public information from each region to both validate the survey data and understand differences between intended and actual actions. We will interpret and present these results back to the SSJV MPEP Committee and the growers during annual coalition meetings, PCA/CCAs during education workshops and other events organized by WRCCAP, and to the FREP in 2019 and 2020. Along with a summary report for FREP and policy briefs to be distributed through grower networks, we will also develop extension articles for UC Extension and other peer-reviewed publications.

RESULTS AND DISCUSSION

While survey development, distribution, and analysis are still ongoing, there are several encouraging results that have arisen from our pilot studies. The following figures are from the pilot survey of technical advisers, conducted in Fall 2019. We ask advisers which N practices they recommend to growers, what types of advice growers seek, and what barriers they believe growers face in adopting N practices. Split N application and leaf sampling are the most frequently recommended practices, and while technical advisers are most frequently asked about crop protection and nutrition, many are also

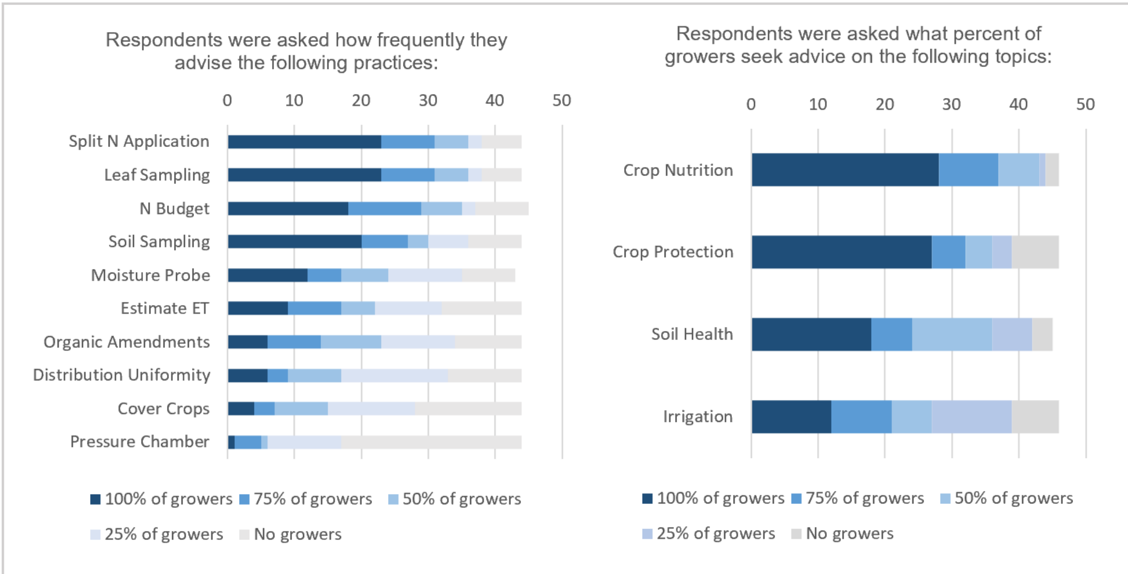

Figure 1. Technical adviser pilot survey results on practice recommendations and advice

considered valuable sources of informatioon soil health and irrigation. These preliminary results emphasize the importance of studying barriers to adoption on a practice-by-practice basis. A lack of technical knowledge is viewed as the largest barrier to adoption for many nitrogen practices, with practice efficacy often cited as another major concern. To technical advisers, costs are only seen as a major barrier for a few practices, such as leaf sampling, soil sampling, and split N application. We are interested to see if these responses hold for technical advisers in the larger survey, and if their beliefs about growers' barriers match up to growers' true responses.

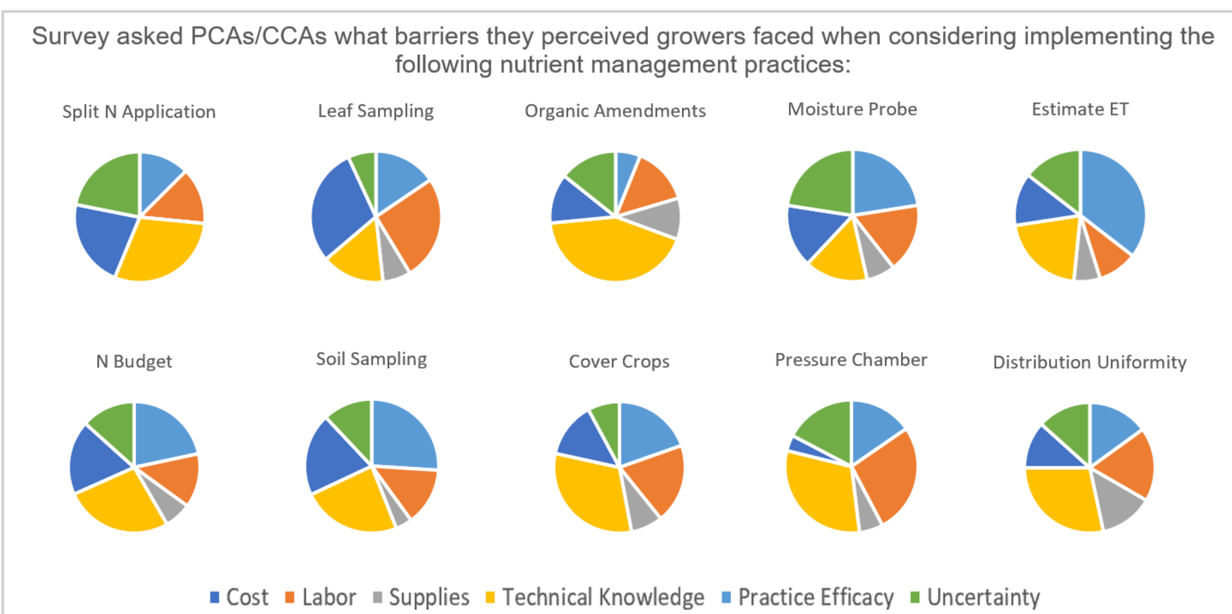

Figure 2. Technical adviser pilot survey results on perceived barriers to grower practice adoption

TAKE-HOME MESSAGE

Preliminary evidence suggests that technical advisers view technical knowledge as a major barrier to N management practice adoption, and are less likely to recommend these practices to growers. We look forward to learning more about SSJV growers' practice adoption and barriers by the close of 2020.

LITERATURE CITED

Lubell, M. N., M. T. Niles, and M. Hoffman. 2014. Extension 3.0: Managing Agricultural Knowledge Systems in the Age of Connectivity. Society and Natural Resources 27(10): 1089-1103.

Niles, M.T., M. N. Lubell, and M. Brown. 2015. How limiting factors drive agricultural adaptation to climate change. Agric Ecosyst Environ 200:178-185.

Shaw, L. and M. N. Lubell. 2011. The Evolution of Local Partnerships for Sustainable Agriculture. Society and Natural Resources 24:1078–1095.

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Promoting the Adoption of CropManage to Optimize Nitrogen and Irrigation Use through Low-Cost Data Loggers and Cellular Modems for Spanish-Speaking Growers in Santa Cruz and Monterey Counties

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INTRODUCTION

Over-pumping and overuse of groundwater resources is a serious issue in critically over-drafted basins like the Pajaro and Salinas river watersheds. Over-irrigation is strongly connected to nitrate leaching to groundwater and water runoff to surface water bodies with negative effects on the environment. From the grower's perspective, water is relatively cheap compared to the other inputs, particularly in high-value crops such as vegetables and berries, so when in doubt, it is common to over-irrigate, a practice seen as "cheap insurance". Nevertheless, water fees and pumping costs can still be substantial, so growers would adopt a system that gives recommendations on water applications if they could trust that this management would not reduce yield or product quality. The adoption of CropManage, https://cropmanage.ucanr.edu/, to obtain recommendations for water and nitrogen management appears to have great potential for reducing over-applications of irrigation water in berry and vegetable production in the Central Coast. CropManage was originally designed to allow growers to input each irrigation and fertilization event onto the program by connecting to the website. This system works well for fertilizer applications that are made with monthly or biweekly frequency. However, irrigations are applied several times per week, and it is impractical for agricultural operators to input every single irrigation into the website. Additionally, it is challenging for irrigators to keep track of the exact length of each irrigation application, with the risk of reporting low quality data into CropManage. With this in mind, CropManage also includes a feature to automatically import an irrigation data file that lists the irrigation events. Such a data file can be produced by installing a flowmeter and data logger in the irrigation system that record when the irrigation went on and off and the flowrate applied. This system allows CropManage to produce recommendations for future irrigations based on the time and quantity of applied water in addition to the weather and the soil type. This system was originally designed to work with research-grade Campbell Scientific data loggers and modems, so the CropManage server accepts data files in the format produced by Campbell Scientific data loggers. However, Campbell Scientific data loggers and modems are expensive and substantial technical knowledge is needed to assemble, wire and program a Campbell Scientific data logger-modem station. On the other hand, in recent years a great variety of low-cost micro-controllers, data loggers, modems and other "Internet of Things" technologies have become available. One does not need a sophisticated research-grade data logger to count the pulse output and correctly log the volumes recorded by a flowmeter.

DESCRIPTION

To offer growers an affordable alternative to Campbell Scientific data loggers and obtain access to CropManage, we developed a low-cost data logger with cellular modem communication based on Arduino microcontrollers (https://www.arduino.cc/) with the following features: a) Low cost per unit (<$300); b) Low power requirement; c) Capability to count pulses from the flowmeter cable output; d) Generating a comma-separated file with two-minute entries in the same format as Campbell Scientific data logger and thus directly importable by CropManage; e) Ready availability of components and ease of construction; f) Capability to transfer files with the FTP protocol through a cellular modem; g) Possibility to scale-up a large number of devices (up to 30 with the current software); h) Capability to run on 12V batteries and solar panels; i) Ability to monitor battery voltage; j) Possibility to monitor soil sensors in addition to a flowmeter. This project aims at creating a simple "plug-and-play" solution that any grower, consultant or Farm Advisor could adopt with minimal technical skills required.

OBJECTIVES

1. Identify a flowmeter capable of pulse output that can be interfaced with low-cost Arduino data loggers and field test the loggers for use with CropManage.
2. Improve the current Arduino prototype data logger software for cellular communication.
3. Increase adoption of CropManage and implementation of recommendations among growers and irrigators.
4. Assess effectiveness and impact of CropManage adoption among growers and irrigators

RESULTS

After testing several flowmeters from different brands (Figure 1), we recommend Netafim WMR 2-inch flowmeter with reed switch register (~$600), the Netafim WST 3-inch flowmeter with electronic ER register (~$1000), and the Seametrics AG3000 6-inch flowmeter (~$1700). These flowmeters can be programmed to give a 10 gallons per pulse output that can be recorded by the Arduino data loggers.

We built 8 data loggers based on 2G cellular technology and three were deployed in spring 2020. T-Mobile announced that their 2G network is being progressively decommissioned in order to free up other spectrum for a newer technology. As a result, as of spring 2020, 2G devices communicate data only if we install directional antennas. Nevertheless, two 2G stations successfully communicated data from the flowmeters to the FTP server and from there to CropManage in season 2020 (Error! Reference source not found.).

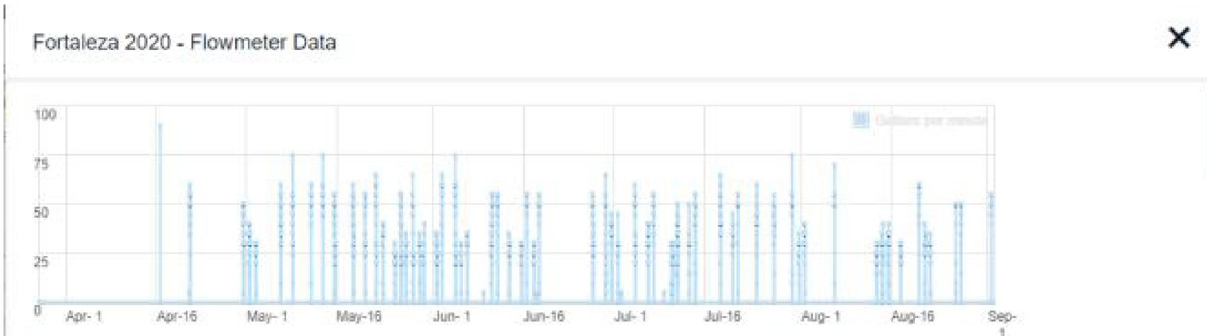
To address the issue of 2G decommissioning, we built 4 dataloggers based on the microcontroller Arduino MKR 1500 NB that comes with a built-in 4G cellular network modem (Figure 3). The new devices are being tested in the field for power requirements and will be deployed to monitor flowmeters in spring 2021 (Figure 4). We programmed the devices to transfer datafiles using the File Transfer Protocol (FTP). We identified a simple freeware software that can be used to set up an FTP server on a Window machine (https://filezilla-project.org/). This software allows the creation of different users with their unique password so any grower or farm advisor can create their own username to send datafiles to the server. The Arduino logger is then configured to send the flowmeter datafiles to the FTP server with the user's credentials. From there, the user can set up CropManage to fetch the flowmeter datafile for any particular planting. One FTP server was set up at the UCCE office in Salinas and one at the RCD office in Capitola.

Figure 1. Testing the output of various flowmeters with Arduino dataloggers

When the devices are powered up, a boot-up signal is sent to the FTP server in a log file that includes date and time of boot-up, device ID and network strength. After boot-up, the devices collect water volume data from the flowmeter and store them in a 2-minute datafile. A few minutes past midnight, the microcontroller powers up the modem and sends the daily datafile to the FTP server. Files on the FTP server are easily accessible from any smartphone to facilitate maintenance and troubleshooting from the field. Future developments may include configuring the 4G devices to send data directly to the CropManage API, skipping the intermediate step of the FTP server.

ACCOMPLISHMENTS

1. Identified flowmeters capable of interfacing with Arduino loggers
2. Developed 2G device with software and developed FTP server infrastructure
3. Work in progress on 4G device software and power supply/management



Start	End	Average Flow Rate (gpm)	Gallons	Time	Applied Flowmeter Water (in.)	Application Rate (in/hr)	Flowmeter Area (acres)
04/16/2020 15:58	04/16/2020 16:02	45	180	0.07	0.02	0.24	0.41
04/21/2020 10:14	04/21/2020 10:18	3	10	0.07	0.00	0.01	0.41
04/21/2020 13:20	04/21/2020 16:02	50	8,120	2.70	0.74	0.27	0.41
04/30/2020 09:32	04/30/2020 12:22	36	6,190	2.83	0.56	0.20	0.41
05/01/2020 09:48	05/01/2020 11:22	34	3,160	1.57	0.29	0.18	0.41
05/01/2020 12:46	05/01/2020 13:36	29	1,450	0.83	0.13	0.16	0.41

Figure 2. Flowmeter data from a 2G device visualized on CropManage

Figure 3. Building the loggers

Figure 4. Installing 2G and 4G devices in the field

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 (N) 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" an Irrigation and N Management Plan (INMP) to track N fertilizer applications. For land in areas within High Vulnerability Groundwater Areas, Irrigation and N Management Plans must be certified by an N management plan specialist. Growers may certify their own N management plans only after they successfully participate in a CDFA N and Irrigation Management Training class. To date, this program has qualified 3,800 growers in a joint effort with CDFA, CURES and UC. Upon successful completion of the course, a grower is able to certify their INMP for lands that they farm. After the initial grower self-certification, additional hours of Continuing Education (CE) 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 CE requirement of the INMP certification process. Requests for CE credits are submitted online and contain basic contact information, as well as course details. 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 CE 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. In response to Covid-19 restrictions, all in-person meetings were cancelled and online CE courses were made available to growers who need to obtain CE Units (CEUs) to maintain their certification. CURES, FREP and UC collaborated and created criteria for approval and online applications. Course sponsors can now submit applications for live meetings and online courses. All courses are posted on the CURES website and growers have the option to complete online or "Self-Study" courses at their leisure.

OBJECTIVES

1. Develop a process to review the content of CE sessions in order for qualified growers to fulfill this condition of the INMP certification program; also develop criteria for evaluating a session proposal (CURES, PI and CDFA staff).
2. Review and approve requests from meeting organizers for CE 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 INMP certification process.

DESCRIPTION

1. 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 CEUs 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.
2. 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 INMP page on the CURES website. If an application meets the requirements, it is approved and implemented. Upon completion of a course, a grower will receive a Certificate of Completion. The grower is responsible for filing and maintaining records of attending CE events. CURES staff regularly notifies INMP 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

Figure 1. Irrigation and Nitrogen Management Plans webpage on the CURES website. This page contains the CEU Request Application for course sponsors, as well as a schedule of CEU courses for growers.

course is added, an email notification is 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 CE sessions in collaboration with agriculture organizations in the Central Valley for growers who have been certified to complete their own N Management Plans. Since the start of the program, CURES has received 144 applications for live and online CE sessions using criteria developed in conjunction with CDFA and UC. Out of the 144 applications, 135 were approved to issue CEUs to course participants. Table 1 below shows the number of applications received since the program's start in 2017.

In response to Covid-19 restrictions, eight in-person meetings were cancelled and online CE courses were made available to growers who need to obtain CEUs to maintain their certification. CURES, FREP and UC collaborated and created criteria for approval and online applications. To date, 12 online self-study courses were approved and are posted for growers to take at their leisure. Courses are posted on the CURES website at

www.curesworks.org/cecourses/.

Table 1. The number of INMP Continuing Education applications received from October 2017 to September 2020. 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 – Dec 2019	30	1	31
Jan – Sept 2020	42	2	44
TOTALS	**135**	**9**	**144**

ACCOMPLISHMENTS

The system and criteria that was developed by CURES staff, CDFA, and UC has been integral in implementing educational workshops to increase agricultural N 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 CE 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 CE outreach sessions and online courses. The organizations and the growers they teach advance the knowledge of proper N 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 N 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 N and irrigation management.

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 criteria. Recognition is also deserving for the water quality coalitions and agriculture organizations that hold CE courses for growers throughout the Central Valley to obtain CEUs in N and irrigation management.

Next Generation Nitrogen Management Training for Certified Crop Advisors

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INTRODUCTION

The enactment of the Irrigated Lands Regulatory Program (ILRP) now mandates grower reporting of nitrogen (N) use efficiency (applied N from all sources/N removed in the harvested crop) and legislates a reduction in nitrate leaching to groundwater. This represents a challenge to farming communities as implementation of these rules will require an increase in the efficiency of applied N. Current regulations require growers to develop an annual N management plan in consultation with a certified crop advisor (CCA) at the beginning of the growing season, followed by reporting actual N use the following year. As the mandate of the ILRP widens, our reliance on an educated and informed CCA workforce becomes more important. Our current CCA N management program resulted in 11 workshops and multiple UC ANR publications. However, these efforts have yet to translate into a long-term sustainable solution for training the next generation of CCAs to be proficient in N management. The overall goal of this program is to facilitate the understanding of best N management practices and increase the ability of CCAs to make informed recommendations to growers, thereby improving both environmental quality and crop productivity.

OBJECTIVES

1. Deliver one in-person CCA workshop
2. Organize key information sources into a study curriculum
3. Curate study materials into online video course
4. Develop exam questions in collaboration with our partners
5. 5Analyze exam responses and update study and exam materials accordingly

DESCRIPTION

Our project will consist of distinct phases – 1) CCA workshop; 2) curriculum building; 3) exam questions and video development; and 4) test deployment and feedback. In March 2020, we conducted one CCA N training workshop following the 2-day agenda developed by our project team. In early 2020, we began to build the study curriculum including 1) consolidation of training modules and study materials already developed by our team; 2) drafting of exam question categories and outlining levels of difficulty and; 3) organization of workshop slides to be developed into video content. In mid-to-late 2020, we will finalize exam questions for review by our project partners into a standardized specialty exam to be hosted by American Society of Agronomy (ASA).

RESULTS AND DISCUSSION

Our CCA workshop was hosted in Fresno, CA during March 3rd and 4th 2020. The number of participants to gain the California N specialty was 65 CCAs. Transition to an internet-based training exam began in April 2020 with the following performance objectives (POs) outlined as educational goals for the new CCA exam:

Competency Area 1. Environmental Impacts of Nitrogen Loss

- **A** Identify the impact of nonpoint source N pollution on human health
- **B** Recognize sources of surface runoff and describe the effect on water quality
- **C** Describe how N leaching influences groundwater and drinking water quality
- **D** Understand the role of certified crop advisors in promoting efficient N use

Competency Area 2. Nitrogen Cycling - Soil Transformations

- **A** Describe mineralization including N sources and products types of microbes, and how moisture, temperature, and C:N ratios affect rates
- **B** Describe immobilization including N sources, energy requirements, types of products and impact of C:N ratios
- **C** Explain nitrification including the necessary reactants, products and how rates are impacted by temperature
- **D** Explain denitrification including reactants, intermediary steps and products, and how soil moisture and soil texture affect rates
- **E** Define volatilization and the role of soil pH plays along with what practices create significant losses

Competency Area 3. Nitrogen Uptake - Plant Utilization

- **A** Compare the differences in root N uptake of ammonium and nitrate profile and the consequences of choice of N source on soil pH
- **B** Understand the process of assimilation of inorganic N into organic N compounds in plants
- **C** Identify important times in the growing season for N uptake and understand the patterns of N allocation and utilization for annual and permanent crops

Competency Area 4. Nitrogen Sources

- **A** Outline the contribution of various N sources to soil by different forms of fertilizers (organic/synthetic/foliar/controlled release/inhibitors)
- **B** Identify organic matter amendments and crop residues and how their availability is impacted by C:N ratios
- **C** Identify and calculate the availability of nitrate in irrigation water
- **D** Describe the residual soil nitrate as a N source during crop rotations
- **E** Recognize the contribution of soil organic matter as a source of N via mineralization

Competency Area 5. Nitrogen Budgeting

- **A** Define different terminologies of N requirement, N uptake and N removal
- **B** Understand how to account for N credits from irrigation water, residual nitrate and organic matter amendments

- **C** Calculate the N sink and source terms to develop a balanced N budget
- **D** Express the N removed over input ratio to determine crop N use efficiency using the partial nutrient balance method

Competency Area 6. Irrigation and Nitrogen Management

- **A** Understand how irrigation practices can lead to N leaching below the root zone due to nitrate mobility in soils
- **B** Identify efficient fertigation methods by surface and pressurized irrigation systems like split applications
- **C** Identify the role of evapotranspiration in irrigation scheduling and how timing irrigation scheduling relative to fertigation can influence nitrate leaching
- **D** Understand how the practice of leaching excess salt under saline or sodic conditions may increase the risk of N leaching below the root zone
- **E** Determine how distribution uniformity by irrigation systems influences N use efficiency

Competency Area 7. California Cropping systems

- **A** Describe how to minimize N losses during annual crop rotations and what factors to consider like residual soil nitrate, crop residues and rooting depth
- **B** Discuss storage and remobilization of stored N in woody biomass of permanent crops and what role N storage plays in early season N demand

UC Nitrogen Management Online Course at http://ucanr.edu/NitrogenCourse is available with associated Nutrient Management (NM) and Soil and Water Management (SW) CCA CEU units for individual Modules and

Discussion sections:

Module 1: Environmental Impacts of Nitrogen Loss

Release date: 11/9/2020 | CEUs: 0.5 SW unit

Module 2: Nitrogen Cycling Soil Transformations

Release date: 11/16/2020 | CEUs: 1.0 SW unit

Module 3: Nitrogen Cycling Plant Utilization

Release date: 11/23/2020 | CEUs: 1.0 NM unit

Module 4: Nitrogen Sources

Release date: 11/30/2020 | CEUs: 1.0 NM unit

Module 5: Nitrogen Budgeting

Release date: 12/7/2020 | CEUs: 1.0 NM unit

Module 6: Irrigation and Nitrogen Management

Release date: 12/14/2020 | CEUs: SW 1.5 unit

Module 7: California Cropping Systems

Release date: 12/21/2020 | CEUs: 2.0 NM unit

Discussion 1: Nutrient Management Topic TBD

Week of 1/4/2020 | CEUs: 1.0 NM unit

Discussion 2: Soil & Water Management Topic TBD

Week of 1/11/2020 | CEUs: 1.0 SW unit

Discussion 3: Nutrient Management Topic TBD

Week of 1/18/2020 | CEUs: 1.0 NM unit

Discussion 4 Soil & Water Management Topic TBD

Week of 1/25/2020 | CEUs: 1.0 SW unit

TAKE-HOME MESSAGE

Preliminary work shows demand for the California CCA N Management Specialty will continue in the years to come with internet-based methods for teaching and testing playing a vital role. The performance objectives were reviewed by twenty professionals and vetted for importance, relevance and frequency of use. We will launch our online video course in on November 9th 2020 by registering at:

http://ucanr.edu/NitrogenCourse with the first exam available in February 2021. Find more information on the California N Management Specialty exam visit: http://www.certifiedcropadviser.org/exams/

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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 six to seven 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 Nitrogen (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. 1 Evaluate N uptake, N availability, canopy development and water application of Bok choy, water spinach, garlic chives, moringa, and lemongrass.
2. 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

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

2 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.

3 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).

4 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

1 We installed flow meters in the above-mentioned fields.

2 Using an infra-red camera, we took canopy photos of the crop every two weeks.

3 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

2 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 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 were 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 three 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 (Figure 3). The plant samples, soil moisture data, and crop canopy data from the first year of bok choy in Santa Clara county were analyzed. Work began on year one of water spinach and garlic chives in January of 2020.

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

Tensiometers and dataloggers were recalibrated and all sensors and dataloggers were installed in two grower fields of water spinach and two grower fields of garlic chives on February 13th and 14th. Data collection was set to begin around March 15th. However, due to strict shelter-in-place guidelines and restrictions on travel in Santa Clara County (one of county's' most affected by Covid19 early in the pandemic) that were in effect through end of May we were unable to collects weekly crop canopy data and regular soil and biomass samples. As such the trials for water spinach and garlic chives had to be abandoned for the 2020 calendar year. In Fresno, similarly due to Covid-19 challenges Year one of Lemongrass and Moringa could not be implemented in Spring 2020. Our offices continue to operate under work-from-home guidelines and due to restrictions on indoor gatherings and outdoor gatherings of more than ten people, all in-person outreach activities are currently cancelled. We are currently evaluating outreach methods that would work best for limited resource socially disadvantaged farmers.

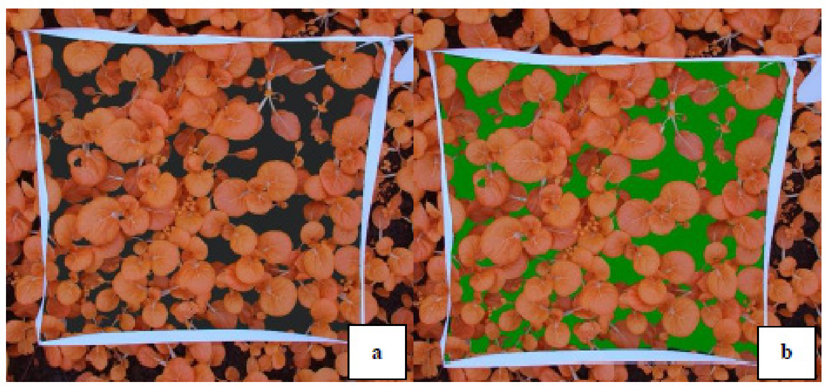

Figure 2a. Crop canopy cover image with soil and weeds greyed out prior to canopy analysis with Tetracam Pixelwrench2 software. 2b. Crop canopy cover image after canopy coverage has been quantified, 75.61% in this instance.

Project work in Fresno was delayed due to budget constraints for 1) purchasing equipment and 2) additional proved. The Fresno staff have purchased the supplies needed for the tensiometers and the dataloggers.

In Santa Clara, we plan to complete year two labor and equipment required to

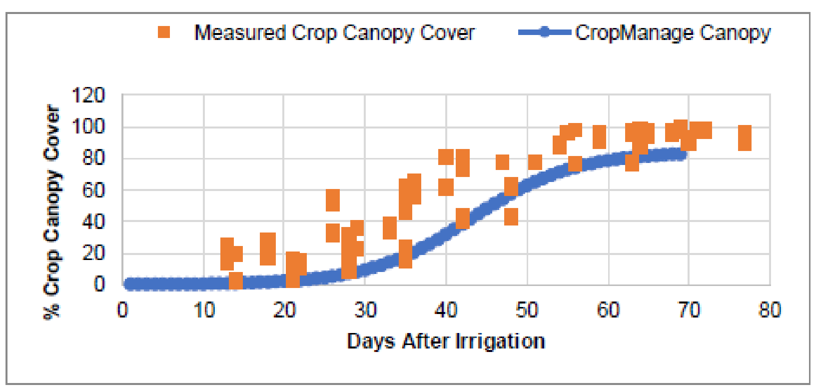

Figure 3. Bok choy crop canopy development as measured in greenhouse production system in Santa Clara County.

monitor over long growing seasons for lemongrass and moringa. The project in Fresno requested a cost extension and an extended timeline for data collection which was approved. The Fresno staff have purchased the supplies needed for the tensiometers and the dataloggers.

In Santa Clara, we plan to complete year two of Bok Choy in Fall 2020, and in Fresno year 1 of Bok Choy will commence in Fall, 2020. Year one of water spinach and garlic chives trial in Santa Clara, will be reimplemented in the field in February 2021, and in Fresno Year 1 of Lemongrass and Moringa will also be implemented in Spring 2021.

RESULTS AND DISCUSSION

Based on information from grower interviews of their nutrient management practices, the nitrogen application for Bok Choy ranged between 93.2-132 lb/acre. Nitrogen uptake was slow during the first month after planting but then accelerated considerably until harvest after about ten weeks (Figure 4). 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 field with the residue.

ACCOMPLISHEMNTS

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 results were also presented at the 2019 Western Nutrient Management Conference that is attended by professionals working in the plant nutrient management field including.

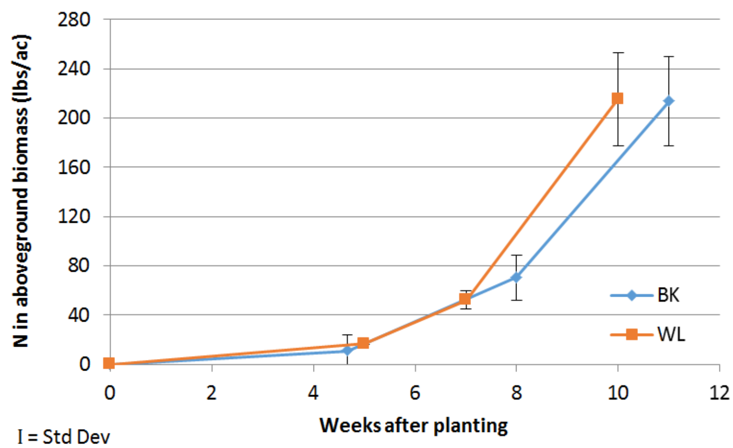

Figure 4. Nitrogen in the aboveground biomass of bok choy. BK and WL refer to two different fields.

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 irrigation and nitrogen management plans (INMP) by growers within the Central Valley Basin. The INMP consists of documenting annual nitrogen (N) inputs and outputs to calculate potential N available for leaching into groundwater. Inputs consist of existing N in soil and N applied as fertilizer, organic amendments, and irrigation water. N output is based on the yield and N content of harvested products. 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 INMP worksheet. The whole product, including the shoots, roots, and substrate, is "harvested" and shipped from the nursery grounds to 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 and leaching can be significant (Cabrera 2003, Narvaez et al. 2012, Narvaez et al. 2013). Leaching losses could contaminate ground and surface waters and denitrification can contribute to atmospheric N pollution as nitrous oxide (N2O).

To help growers fulfill the INMP requirement, it is necessary to identify the losses of applied N during crop production. Additionally, mitigating environmentally harmful discharges of N will help the nursery industry meet environmental regulations and achieve sustainability goals. 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 could 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 and identify environmentally harmful N discharges. Impervious (lined) and pervious (unlined) growing beds were installed at a nursery from May 4 to July 24, 2018 to quantify N inputs and outputs and allow for estimating soil N infiltration. To test potential BMPs, a greenhouse experiment was conducted to determine the effect of three rates of surface-applied urea formaldehyde fertilizer on N2O-N emissions from controlled-release fertilizer (CRF) incorporated soilless growing media. The three fertilizer rates were 0, 5, and 35 g of urea-formaldehyde. Another greenhouse experiment was conducted to determine cause of high inorganic N concentrations in the soilless growing substrate solution fertilized with incorporated CRF. The soilless substrate had CRF incorporated either mechanically or by hand at the same rate and plants were planted in the substrate. All leachate was collected, and samples were analyzed for inorganic N.

RESULTS

The mean number of plants, total N at planting, total N at harvest, and emitted N2O-N were not significantly different ($p>0.05$) between the two bed styles (Table 1). Runoff N from lined beds was greater than from unlined ones and unaccounted N from unlined beds was significantly greater than from lined beds (Table 1).

Table 1. The amount of nitrogen applied as fertilizer, sold (in growing substrate and plant), emitted as N2O-N, in runoff, and unaccounted from polyethylene sheet-lined and unlined experimental beds.

		Nitrogen (lb. per bed)				
Bed type	**Plant #**	**Total at planting**	**Total at harvest**	**N_2O-N**	**Runoff**	**Unaccounted**
Lined	153.00	13.92	8.41	0.20	1.48	3.92
Unlined	150.75	13.74	8.30	0.19	0.92	4.41
P-value	0.77	0.94	0.94	0.94	0.004	0.016

The greenhouse treatments with three different rates of surface-applied urea formaldehyde and the N balance experiment showed a rapid increase in cumulative N2O-N emissions early on in the experiment. After about day 35, the magnitude of N2O- N emissions decreased. The 5 g treatment flux was significantly less ($p<0.05$) than that from the 35 g treatment. Surprisingly, the flux from the 0 g treatment was not significantly different from any of the other treatments. There was not a significant difference ($p>0.05$) in plant growth between any surface-applied urea formaldehyde treatments.

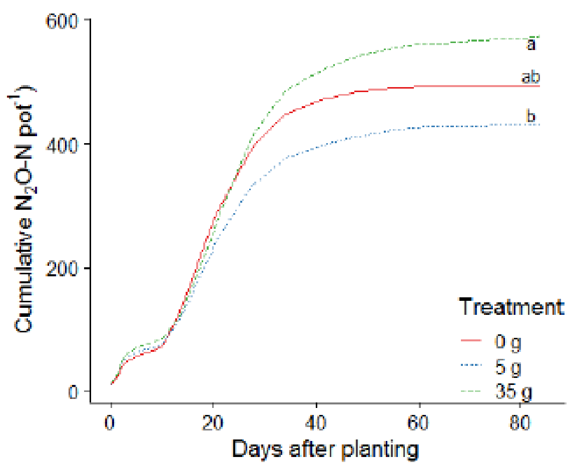

Figure 1. Mean cumulative nitrous oxide (N_2O-N) flux from fir bark-based soilless growing substrate in a greenhouse experiment treated with 0, 5, or 35 g of surface-applied urea-formaldehyde fertilizer. Different letters next to cumulative N_2O-N lines indicate significant differences ($p<0.05$) in cumulative N_2O-N on day 84 after planting. The majority of N_2O-N was emitted in the first five weeks.

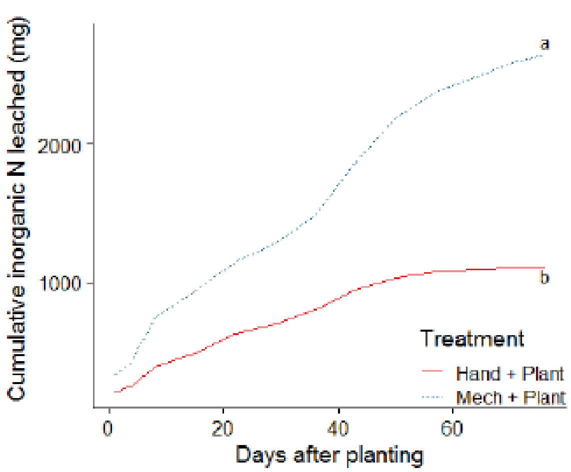

Figure 2. Cumulative inorganic nitrogen leached from soilless substrate with mechanically- (Mech) or hand-incorporated (Hand) controlled release fertilizer. Different letters next to cumulative inorganic nitrogen leached lines indicate significant differences ($p<0.05$) in total inorganic N leached on day 76 after planting. The hand-incorporated CRF leached almost 2.5-times less inorganic N than the mechanically-incorporated CRF over a 76-day experiment.

DISCUSSION

A large portion of the planted N (60%) was either taken up by the plant or remained in the substrate when the plant was shipped from the nursery (Table 2). A fertilizer reserve in the growing substrate ensures the plant will maintain aesthetic appeal while waiting for sale to the final consumer. Unaccounted N was mostly lost as dinitrogen (N2) gas resulting from denitrification (Table 2). The small fraction of planted N emitted as either N2 or N2O gas from the saturated bed soil surface (Table 2) indicates that little denitrification occurred in the saturated growing bed soil. The 10.6% of planted N in bed runoff and infiltration (Table 2) indicates nurseries should capture and recycle irrigation runoff water to reuse the N. Adding impervious growing bed surfaces will help to recover more of that N.

A large proportion of emitted N2O occurred in the first five weeks of production (Figure 1) and further opportunities to improve N use efficiency exist by reducing the amount of inorganic N in the substrate solution. Using gentler CRF-incorporation methods have the potential to reduce N leaching from the growing substrate by 2.5-times (Figure 2). Growers should incorporate CRF at the last possible location in the substrate mixing line and minimize mechanical handling once incorporated with CRF. The N balance 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, at a nursery that uses liquid feed fertilization and an irrigation system with poor application efficiency. 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 (i.e. sandy) that have higher infiltration rates, more N may infiltrate the soil. If plants were placed “can-tight” instead of on two-foot centers, with minimal space between them, all N values per acre would change because there would be more plants, substrate, and N fertilizer applied per acre.

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.

	At planting	At harvest	Substrate N_2O-N	Bed runoff	Bed infiltration	Bed (N_2 + N_2O)-N	Unaccounted
Nitrogen (lb ac^{-1})	884.30	534.10	12.40	58.66	35.56	0.29	243.29
Percent of planted	100.0%	60.4%	1.4%	6.6%	4.0%	0.0%	27.5%

LITERATURE CITED

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

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Supporters

Imperial Valley Vegetable Growers Association, Coastline Family Farms and Imperial Valley College.

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. 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

A field assessment is performed at the University of California Desert Research and Extension Center - UCDREC, Holtville, CA. The assessment is carried out with four replicates in a split-plot design with drip irrigation treatments in the main plot and four N-fertilization rates at the subplot level. Research plots are 50 ft long and comprise four rows on 40-inch beds. Sixty-four plots are established (16 treatments and four replicates). Sprinklers are used for germination and establishment in all treatments. Four irrigation levels are established: 40, 70, 100, and 130% of crop evapotranspiration (ETc). Irrigation scheduling is based on weather data from the UCDREC's CIMIS station and stage-specific crop coefficients developed by Montazar (2019) for the region (emergence: 0.40, 2-3 leaves to bulb development: 0.84, and bulb fully developed to dry leaf stage: 0.62). Soil water tension meters are installed at 6-, 12-, and 24-in. Four in-season nitrogen treatments are 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. 56.3 lbs N per acre were applied with pre-plant fertilizer in all treatments. Soil samples are collected (pre-planting, in-season, and post-harvesting) at different depths (from 0 to 36 in depth) and analyzed for NH4 and NO3. Irrometer soil solution access tubes are installed at 6, 12, and 24 inches depth. Water samples are analyzed for pH, electrical conductivity and nitrate. Furthermore, bulbs and leaves are analyzed for their N concentration during the growing season to determine N uptake and removal in the different treatments. Water and biomass data are collected five or six 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

This document shows results from the October 2019 to May 2020 growing season. Fourteen sprinkler irrigations were performed for all treatments from planting to 3-4 true leaves (10/24/2019 to 12/17/2019) with a total water applied of 8.86 in. Irrigation was converted to drip in January 2020. Total applied irrigation water (sprinkler and drip systems) for the growing season ranged from 10.74 in (40% ETc) to 18.90 in (130% ETc). Total rain during the growing season was 4.67 in. Average hourly soil water tension (SWT) records in the top one foot from the 100% and 130% ETc irrigation treatments were in the range of plant optimal growth (Table 1). At 70% ETc, an increase in SWT was observed at 6- and 12-in depth compared to 130% and 100% ETc treatments. Average SWT values recorded in the 40% ETc treatment show lack of available water for optimal crop production.

Table 1. Average hourly soil water tension (cb) from 1/28/2020 to 4/28/2020.

Depth (in)	130% ETc	100% ETc	70% ETc	40% ETc
6	-44.83	-45.57	-49.68	-120.61
12	-29.98	-26.88	-41.88	-90.63
24	-17.37	-17.68	-18.04	-18.27

A comparison between the amount of mineral N present in the soil profile pre-plant and the mineral N left in the profile after the harvest of the onions shows that mineral N accumulated at the lowest irrigation rate (40% ETc) during the season, except in the zero-N treatment (Figure 1).

With an irrigation rate corresponding to 70% ETc, only the highest two N application rates resulted in an accumulation of mineral N in the soil profile. The soil mineral N pool was depleted at all N fertilization levels with the two highest irrigation treatments.

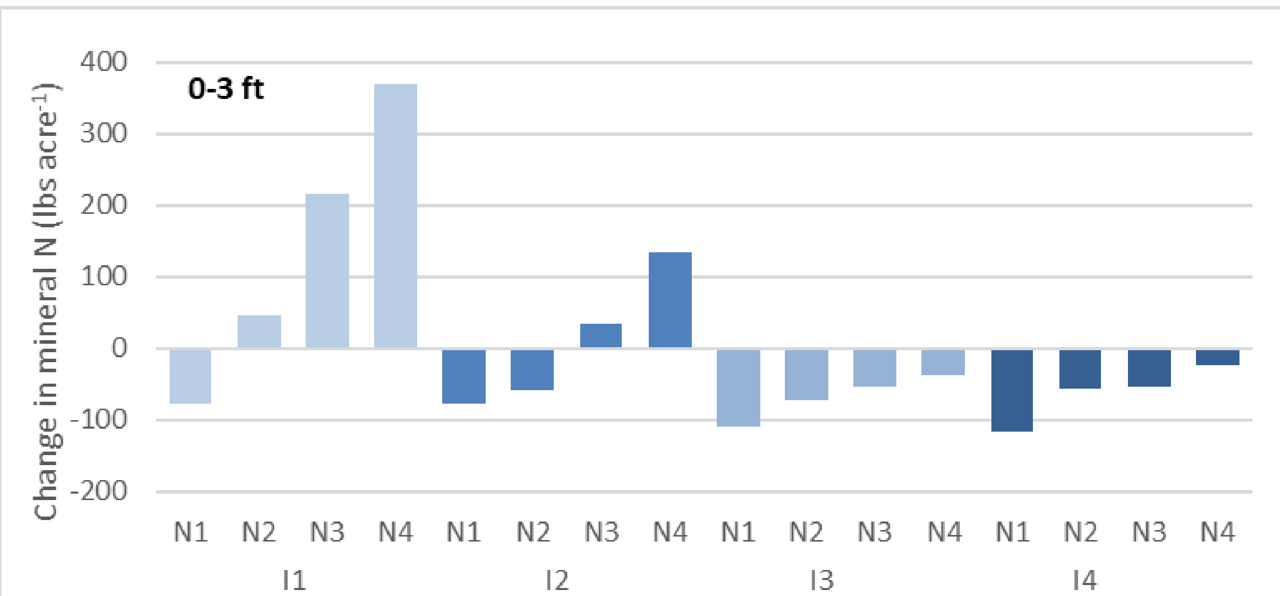

Figure 1. Change in the mineral N content in the soil profile between the pre-plant and post-harvest sampling dates for the different irrigation and N fertilization treatments. Irrigation treatments I1 to I4 correspond to water applications of 40, 70, 100, and 130% of ETc, while N treatments N1 to N4 correspond to in-season N application rates of 0, 75, 150, and 225 lbs per acre.

There were no significant irrigation rate x nitrogen rate interactions ($P \leq 0.05$) for bulb size distribution and total yield (Table 2). Onion size distribution and total yield did not respond to N rates, suggesting that the pre-plant application of 56.3 lbs N per acre and the pre-plant mineral N (69 lbs N per acre in the top foot and 59 lbs N per acre in the second foot of the profile) were enough to achieve maximum yields. Reduction in irrigation rates significantly impacted onion size distribution and total yield.

The total yield reductions by 40%, 70%, and 100% ETc compared to 130% ETc were 34%, 22%, and 3%, respectively. Higher yields of mediums and lower yields of jumbo, colossal and super colossal were obtained with the lowest irrigation rate (40% ETc). The two highest irrigation rates (100% and 130% ETc) yielded the highest jumbo (average 31.8 ton/acre), colossal (average 11.2 ton/acre), and super colossal (average 2.6 ton/acre) yields.

Table 2. Effect of irrigation and nitrogen rates on fresh market onion size distribution and total yield.

Treatments	Prepack	Medium	Jumbo	Colossal	Super Colossal	Total
	ton/acre					
Irrigation rate (I)						
130% ETc	0.6 c[y]	4.8 c	31.2 a	12.6 a	3.1 a	52.4 a
100% ETc	0.6 c	5.8 bc	32.4 a	9.7 ab	2.0 ab	50.6 a
70% ETc	1.2 b	9.0 b	26.2 ab	4.0 bc	0.3 b	40.7 b
40% ETc	1.6 a	13.7 a	17.6 b	1.3 c	0.2 b	34.4 c
P	0.000	0.000	0.000	0.000	0.000	0.000
Nitrogen rate (N)						
PN + 225 lb/ac	1.2 a	8.9 a	25.6 a	7.2 a	0.9 a	43.8 a
PN +150 lb/ac	0.9 a	9.3 a	26.3 a	6.1 a	1.9 a	44.3 a
PN + 75 lb/ac	1.1 a	7.3 a	27.9 a	7.4 a	1.2 a	44.9 a
PN + 0 lb/ac	0.9 a	7.9 a	27.7 a	6.9 a	1.7 a	45.0 a
P	0.090	0.065	0.287	0.718	0.425	0.755
Interaction (IxN)						
P	0.227	0.610	0.484	0.386	0.221	0.624

[x]Onion bulbs were categorized as prepack (less than $2^{1/2}$ in), medium ($2^{1/2}$-$3^{1/4}$ in), jumbo ($3^{1/4}$-4 in), colossal (4-$4^{1/4}$ in), and super colossal (greater than $4^{1/4}$ in) based on bulb diameter.

[y]Means in a column followed by the same letter are not significantly different at $P \leq 0.05$ according to the Tukey's Studentized range test.

ETc = crop evapotranspiration. PN = pre-plant nitrogen.

ACCOMPLISHMENTS

Two undergraduate students and one PhD student from UABC, Mexico were trained in field and laboratory methods used in this project.

RECOMMENDATIONS

Pre-plant mineral N (PMN) in the top 1 foot can be a significant source of N. Adjust N applications based on PMN.

TAKE-HOME MESSAGE

Onion growers in the CA low desert region could manage drip irrigation systems in 40-in beds using 100% ETc rates for optimum irrigation water use, yields, and large size classes.

LITERATURE CITED

Montazar, A., 2019. Preliminary estimation of dehydrator onion crop water needs in the Imperial Valley. Agricultural Briefs 22(7):131-135. University of California Cooperative Extension – Imperial County.

ACKNOWLEDGEMENTS

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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). 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

1. Evaluate various N management practices for mixed baby leaf conventional and organic production systems
2. Calibrate "CropManage" for desert production

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. In fall 2019 through spring 2020 we expanded into Tasks 2, 3 ,4, and 5, which included evaluations in conventional and organic baby spinach and conventional spring mix production systems. We will expand into organic spring mix systems in 2020-2021 as well as add additional sites for other systems and enhance "Crop Manage" evaluation.

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/m2), 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. Nitrogen 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.

These experiment-demonstrations were and continue to be conducted in grower fields to hasten technology transfer.

Figure 1. Typical Eddy covariance set up in all fields. This example is from JV 714.

RESULTS AND DISCUSION

In January 2019, we initiated a three-year project aimed at better water management for Baby Green vegetables in the desert. Through the spring 2020 we had completed data collection on six sites. In 2019 we focused on collecting background information to calibrate "Crop Manage" for desert production systems. In 2020 we continued this effort but also began testing "Crop manage" (Table 1). Measured ET on four sites in 2020 are shown in Figure 2. Water application efficiencies are high, often exceeding 90%, and is consistent with data we reported last year. This is verified by salinity monitoring where surface soil salinity generally increases during the growing period, indicating the leaching fraction observed is less than required leaching for salt balance (Figure 3).

Nitrogen recoveries are generally less than 50%, and further improvements will be sought out by optimizing timing. Satellite measured NDVI for all field sites in spring 2020 are shown in Figure 4. These data show that satellite imagery tracks growth well and will be a basis for adjusting crop coefficients in-season.

Table 1. Field sites completed in winter-spring 2020.

Farm	Crop	System	Wet date	Harvest Date
JV 25	Spring Mix	Organic	Feb. 28	March 30
JV 710	Spring Mix	Conventional	Feb. 20	March 30
JV 713	Spinach	Conventional	Jan 9.	Feb. 22
JV 714	Spinach	Conventional	Jan. 6	Feb. 13

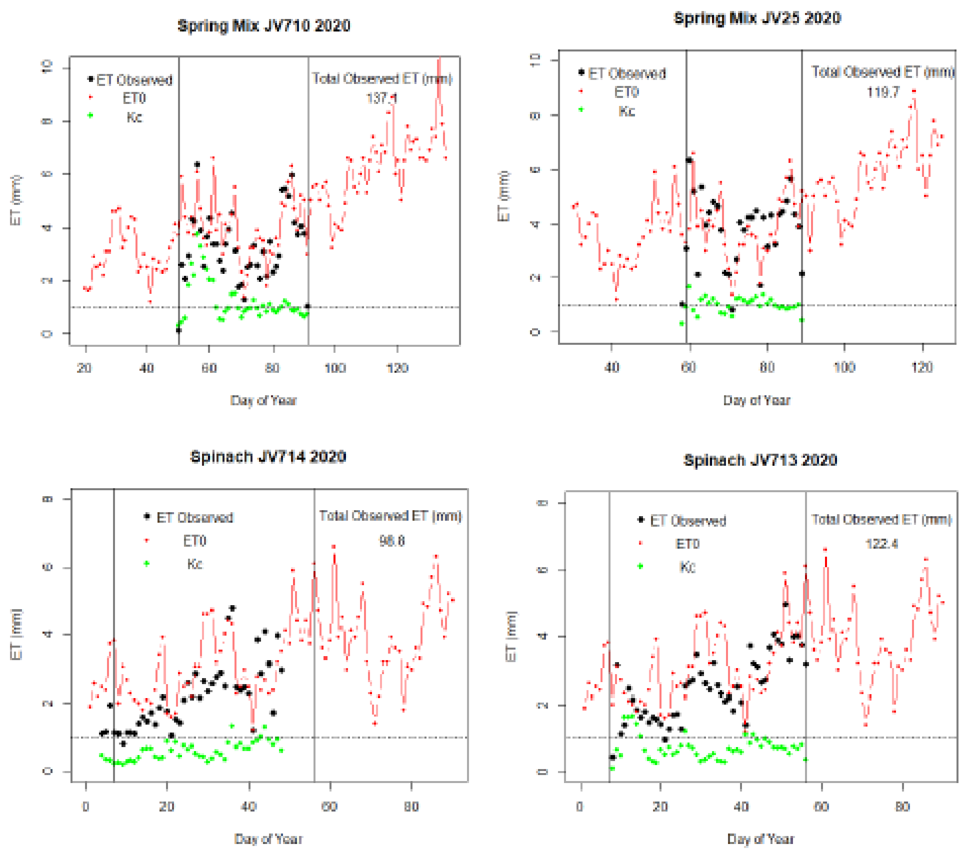

Figure 2. Measured ET at all field sites in spring 2020.

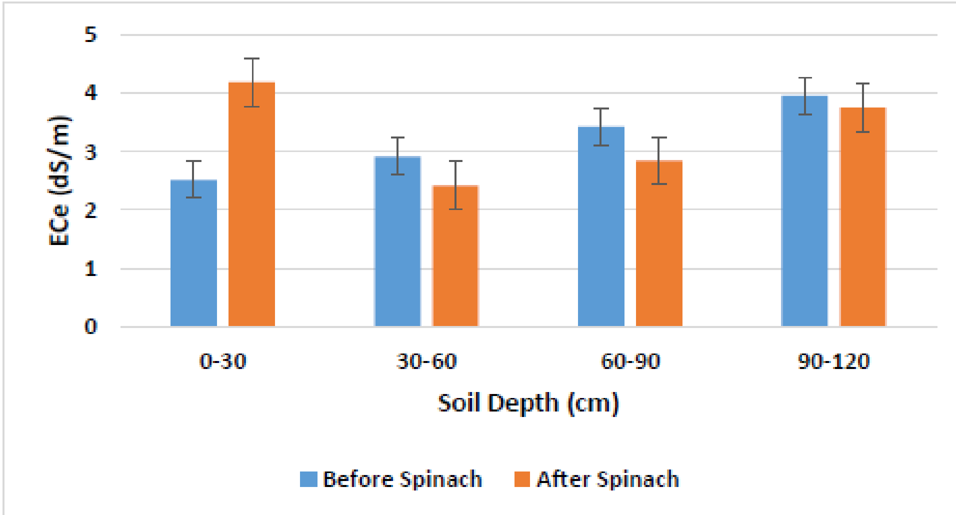

Figure 3. Salinity parameters in soil before and after spinach for one site. Bars are standard error.

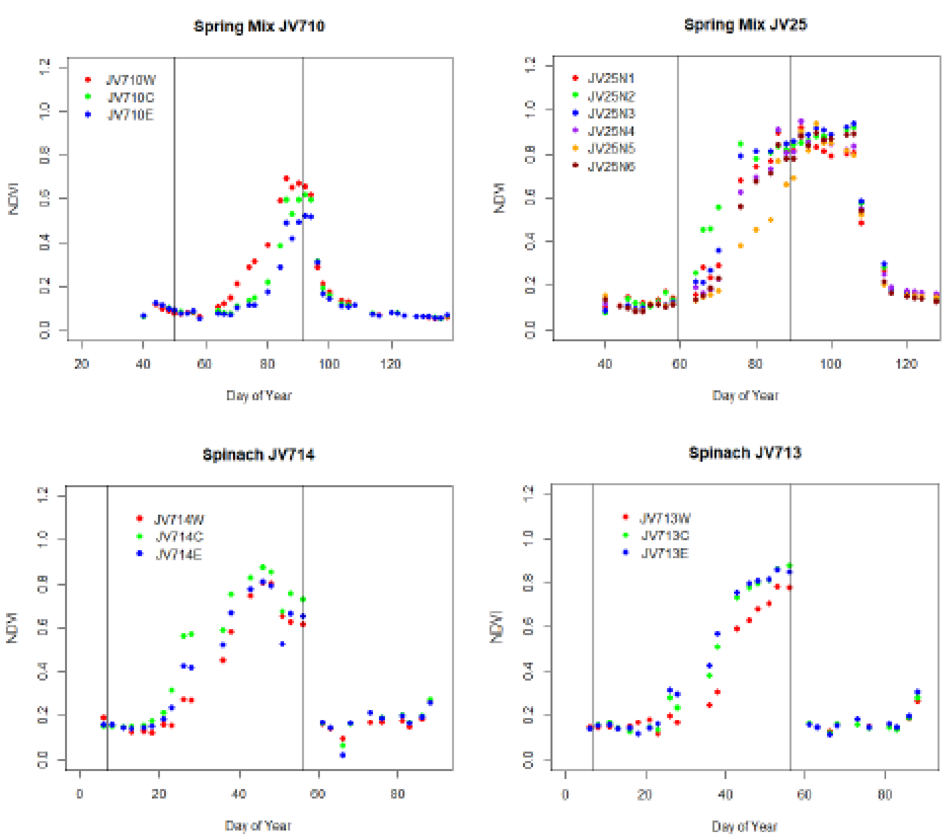

Figure 4. Satellite measured NDVI for all field sites in spring 2020. Different colors reflect in-field variation.

ACCOMPLISHMENTS

We completed field work on six production field sites and completed subtasks associated with tasks one through five. Water balance is complete for these six sites. Salinity and N laboratory analysis, and computational work related to the calibration of "CropManage" is on-going.

RECOMMENDATIONS

Because these crops are irrigated by sprinklers, season long and ET replacement is easily achieved, and current water application efficiencies are often high. The exception is when rainfall is high. Thus, further improvements in N utilization efficiency will be largely be based on achieving better timing of N fertilization. The use of "CropManage" may help in this regard.

LITERATURE CITED

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

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Developing a Nitrogen Mineralization Model for Organically Managed Vegetable Farms on the Central Coast

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INTRODUCTION

Organic vegetable production on the Central Coast (Monterey, Santa Cruz, and San Benito Counties) was valued at $390 million in 2017. Organic production continues to expand given the optimal climatic conditions and increasing consumer demand. Science-based information for managing nitrogen (N) is rarely applied to organic fertilizer programs; current fertility practices vary widely among growers, which have both economic and environmental ramifications. Further, growers are now required to estimate mineralization rates to complete the mandatory N management plans submitted to the Regional Water Quality Control Board, but there is insufficient information on N mineralization of organic fertilizers and amendments under local conditions for this to be done in an informed way.

CropManage (CM) is an online irrigation and N management decision support tool that was originally developed under FREP funding in 2011 and now has more than 1700 registered users. In recent years, the online advisory service has provided more than 1000 recommendations per month during the production season to vegetable and berry growers mainly farming in the coastal valleys of California. Though originally developed for lettuce, continued research efforts and funding have expanded CM to include other leafy greens (spinach, mizuna, leaf lettuce), cole crops (broccoli, cabbage, and cauliflower), celery, pepper, raspberry, and strawberry. However, currently, CM cannot simulate N mineralization from organic fertilizers and amendments.

This three-year project aims to integrate a simple N mineralization model with CM so that it can provide fertilizer recommendations for organic vegetable production. Here we describe the outline of the entire project and report the progress made in the first year by August 2020.

OBJECTIVES

1. Create an N mineralization database for organic fertilizers and amendments, crop residues, and soil organic matter (SOM).
2. Develop a simple N mineralization model using the existing data.
3. Evaluate and improve the simple model by field trials and incubation studies.
4. Integrate the model into CropManage (CM).
5. Conduct outreach and a demonstration field demonstration.

DESCRIPTION

1. Creating N mineralization database. We compiled existing data on N mineralization of organic fertilizers and amendments, crop residues, and soil organic matter from literature and past studies. N-mineralization data of replicated incubation trials conducted under a controlled environment were gathered. Incubation trials will be conducted to fill any gaps in database that need to be addressed experimentally.
2. Developing a simple N mineralization model. We will select simple models that can fit well with CM. A one-pool model will be fit to the data from the incubations by non-linear regression. The response of N mineralization to temperature and soil moisture will also be expressed with mathematical functions. These equations will then be used to calculate net N mineralization rates in daily time steps for each pool (soil, organic amendments, and residues) separately. The model will assume that net N mineralization rates from these pools are additive and that there are no priming effects, e.g., the addition of residues or organic amendments will not change the N mineralization rates of SOM.
3. Evaluate and validate the model in field trials. To evaluate the model, N mineralization rates of selected dry organic fertilizers and amendments and crop residues will be determined under field conditions on organic farms in Coastal California.
4. Integrate the model into CropManage (CM). The model developed under Objective 2 and evaluated under Objective 3 shall be incorporated into CM.
5. Conduct outreach and a demonstration field demonstration. We will report results at the annual Salinas Valley Irrigation and Nutrient Management Meeting, as well as in UCCE newsletters, blogs, and trade publications (CAPCA News, AgAlert, Vegetables West, etc.).

RESULTS AND DISCUSSION

We reviewed 24 relevant publications and found 16 publications from which we collected N-mineralization data. Some unpublished data were also gathered. Replicated N mineralization data of 172 organic fertilizers, composts, and manures, 64 cover crops and crop residues, and 12 soil organic matter were entered into the database. As an example, Table 1 shows the summary of organic fertilizer data (excluding manure data). N mineralization data conducted at 20 to 25 °C with near field capacity moisture using different soils are summarized. Using these data, we will identify gaps in available data, conduct incubation trials to supplement these data, and develop one-pool models for estimating N-mineralization of varying organic materials and soil organic matter.

Table 1. Summary of N mineralization characteristics of varying organic fertilizers

Type	Total N % d.w.*	CN ratio	Mineralized N % of Total N Day 0	Mineralized N % of Total N Day 28
Granular/pelleted organic fertilizer				
N below 3%	2.2 (1, n/a)**	10.9 (1, n/a)	n/a	5.8 (1, n/a)
N 3-5.9%	4.3 (5, 0.7)	6.0 (5, 0.8)	16.3 (3, 3.9)	34.4 (8, 2.2)
N 6-8.9%	7.9 (4, 0.5)	5.0 (4, 0.1)	3.7 (1, n/a)	46.8 (5, 2.8)
N 9% or higher	10.4 (7, 1.7)	4.3 (7, 0.1)	1.0 (2, 0.2)	56.9 (7, 2.2)
Other solid organic fertilizer				
Blood meal	14.5 (3, 0.6)	3.4 (3, 0.3)	0.5 (2, 0.1)	63.2 (5, 2.1)
Feather meal	11.6 (5, 2.2)	4.6 (5, 1.2)	3.4 (4, 3.7)	59.1 (7, 2.5)
Fish powder	11.6 (3, 1.4)	3.6 (3, 0.2)	1.5 (1, n/a)	60.6 (4, 1.5)
Kelp meal	1.0 (1, n/a)	26.0 (1, n/a)	n/a	-6.0 (1, n/a)
Plant-based meal***	6.4 (4, 1.7)	8.7 (4, 2.8)	0.2 (1, n/a)	45.8 (4, 16)
Seabird guano	12.1 (2, 0.4)	2.2 (2, 1.1)	30.9 (2, 24)	70.2 (4, 8.5)
Compost				
Chicken manure compost	4.0 (9, 0.3)	7.6 (9, 0.3)	18.2 (8, 1.5)	33.1 (12, 2)
Dairy solid compost	2.0 (6, 0.1)	19.4 (6, 2.0)	4.2 (6, 0.6)	4.9 (6, 1.9)
Rabbit manure compost	1.8 (1, n/a)	10.0 (1, n/a)	8.3 (1, n/a)	16.0 (1, n/a)
Vermicompost	2.6 (1, n/a)	13.2 (1, n/a)	17.8 (1, n/a)	15.4 (1, n/a)
Yard trimming compost	1.5 (17, 0.1)	16.4 (17, 0.9)	2.9 (13, 1.5)	2.5 (19, 1.3)
Yard trimming/chicken manure compost blend	2.6 (1, n/a)	12.1 (1, n/a)	9.9 (1, n/a)	12.7 (2, 0.8)
Other				
Liquid organic fertilizer	3.5 (5, 0.7)	4.2 (5, 0.8)	18.3 (5, 3.4)	70.7 (10, 5)
Anaerobically digested dairy solid	1.9 (1, n/a)	19.6 (1, n/a)	13.0 (1, n/a)	14.0 (1, n/a)

* d.w. dry weight basis except for liquid organic fertilizer (as is basis).
** Mean (n, standard error of mean). n/a: data not available.
*** Alfalfa meal, canola meal (x 2), and soybean meal.
Sources: Gale et al., 2006; Harts and Johnstone 2006; Hartz et al., 2010; Hartz, unpublished; Lazicki et al., 2020; Sullivan et al., 2019.

LITERATURE CITED

Gale, E.S., D.M. Sullivan, C.G. Cogger, A.I. Bary, D.D. Hemphill and E.A. Myhre. 2006. Estimating plant-available nitrogen release from manures, composts, and specialty products. Journal of Environmental Quality 35, 2321-2332.

Hartz, T.K. and P.R. Johnstone. 2006. Nitrogen availability from high-nitrogen- containing organic fertilizers. HortTechnology 16, 39-42.

Hartz, T.K., R. Smith and M. Gaskell. 2010. Nitrogen availability from liquid organic fertilizers. HortTechnology 20, 169-172.

Lazicki, P., D. Geisseler and M. Lloyd. 2020. Nitrogen mineralization from organic amendments is variable but predictable. Journal of Environmental Quality, DOI: 10.1002/jeq1002.20030, available at https://acsess.onlinelibrary.wiley.com/doi/full/20010.21002/jeq20032.20030 .

Sullivan, D.M., N. Andrews, C.A. Sullivan and L.J. Brewer. 2019. OSU Organic Fertilizer & Cover Crop Calculator: Predicting Plant-available Nitrogen. Oregon state university extension service EM 9235.

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Pima Cotton Nitrogen Management, Uptake, Removal - Impacts of Varieties, Subsurface Drip and Furrow Irrigation

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INTRODUCTION

Over the past three decades, California cotton production has shifted from nearly all acreage being planted to specialized Upland cotton varieties to more than 75 percent of acreage now planted to Pima cotton. There are some reasons to believe that cotton nitrogen (N) uptake and management responses may differ from Upland varieties, since Pima cotton cultivars typically require a two to three week longer growing season than most Upland varieties, and there are known differences in sensitivity to insect pests, impacts of plant water stress on fruiting, very different recommended petiole nitrate values by growth stage, and in plant responses to management practices such as use of growth regulators. Since cotton produces high protein content seed, prior studies in Upland cotton have shown that close to harvest timing, bolls typically contain 50-60% or more of total above-ground late-season plant N (Hutmacher et al, 2004). Under CA conditions where we leave essentially all leaf and stem materials in the field at harvest, most harvest N removal should be in the seed. With the exception of some older Arizona studies (Unruh and Silvertooth, 1996), and a few small N uptake measurements made as part of irrigation studies conducted by the project team running this current project, we are not aware of arid or semi-arid zone research done specifically to identify whether or not N management recommendations and guidelines developed for Upland cotton are applicable to Pima cultivars. Average N removal with harvest shown on the FREP N management website for Upland cotton is 43.7 lbs N per ton of lint and seed harvested when averaged across a range of studies that include older Upland varieties. That same site references some limited work on Pima cotton (seven observations total) for Pima types of cotton (Fritschi, et al, 2004) that indicated an average value of N removal of 33.1 lbs N/ton of lint plus seed, suggesting that removal in Pima is much lower than the average value of 43.7 lbs N/ton of lint plus seed that represents Acala and non-Acala Upland types of cotton.

The Pima studies referred to, which were also conducted at the West Side REC, were relatively limited in number, and represented lower yield situations than those now achieved by commercial Pima growers in California. The limited uptake data from small plot irrigation studies on Pima cotton (unpublished to date) conducted at the UC West Side REC in recent years were determined using small area harvests in field research plots, with plants partitioned in different components, weighed, and then subsampled to determine N content. In those studies, the average values for N removal with harvest for Pima types of cotton were actually quite similar to those in some more limited studies we have done using Upland varieties and have not shown lower values for Pima cotton. This current study is being conducted to provide N uptake and removal data from Pima cotton grown under a range of field conditions.

OBJECTIVES

1. Evaluate at West Side REC site the impacts of N application amount, variety and irrigation method (subsurface drip versus furrow irrigation) on total plant N uptake and harvest removal in Pima cotton plants.
2. Determine total above-ground plant N uptake at early open-boll timing of multiple Pima varieties at three Pima cotton farm sites with moderate to high yield potential at early open-boll timing, and N removal with harvest (measured as N content of seed, lint, gin trash, measured separately) to better understand Pima N requirements and harvest removal.
3. Provide information to grower groups, consultants and industry to give opportunities for feedback and to refine concepts of workable changes in pima cotton N management approaches.

DESCRIPTION

Two types of field studies were conducted in 2019 and 2020 as part of this three year study, including: (1) University of CA West Side REC - small plot studies on N uptake as a function of N application amount and variety under subsurface and drip irrigation, including multiple Pima varieties versus an Upland variety for comparison; and

(2) Grower field site studies in three San Joaquin Valley counties (Merced, Kern and Fresno or Kings) which focus on determining total plant N uptake and N removal with seed and gin trash as affected by Pima varieties. Grower sites were in soils described as clay loams or loams in terms of texture, and were furrow or level-basin irrigated. At grower and REC sites, yields were determined using spindle-type pickers, with sub-sampling for ginning used to separate seed from trash and lint as part of the protocol.

At the West Side REC site, 5 N application levels were established, representing 0, 50, 75, 100 and 125% of estimated N requirements, adjusted for soil residual nitrate N in the upper two feet of the soil profile at planting timing. Estimated N fertilizer needs were adjusted for early season residual soil nitrate, with the target amount based on a realistic yield goal for the site. The timing of N applications for the subsurface drip treatments started at the seven to eight leaf growth stage, with proportional application rates stepped up as plants grow (based on prior West Side REC studies with drip), with the goal of completing N applications (applied as water-injected liquid urea) by close to peak bloom growth stage (late July or first week of August). Furrow irrigated plots received N applications in two injections of knifed-in liquid UAN about 8-10 inches away from seed row and 4 to 6 inches deep, with applications split between one made about 3 weeks post-planting and another at lay-by. At initiation of the projects at West

Side REC, soil samples were collected to a depth of eight feet below grade to identify initial residual soil nitrate, while planting time sampling at the grower sites was to a depth of four feet. These data will be used to develop crop N fertilization values (applied N plus estimate of residual soil nitrate-N).

RESULTS AND DISCUSSION

Pre-plant residual NO3-N averages in the upper two feet of soil profile at each site are shown in Table 1. It is important to note that the N rate and irrigation method comparison study was only done at the West Side REC site, while at grower sites we measured yield components (seed, lint, trash) and sampled plants for peak N uptake and harvest removal. Pre-plant residual NO3-N values (Table 1) were relatively low to moderate in our experience considering a mix of prior crop field rotations with agronomic and vegetable crops. Harvest timing soil samples were collected to a depth of four feet at grower sites and to eight feet at West Side REC site to evaluate changes in soil nitrate-N during the crop cycle, but the samples have not been analyzed to date.

Study Site / Treatment	Pre-plant residual soil NO3-N (upper two feet)	
	2019	2020
West Side – subsurface drip	38 (7)	29 (6)
West Side – furrow	42 (8)	35 (7)
Merced County site	55 (10)	37 (13)
Kings County site	31 (11)	40 (7)
Fresno County site	51 (12)	60 (9)

Table 1. Average Pre-Plant Residual Soil NO3-N in upper two feet of profile at study sites in 2019 and 2020 as a function of location (all sites) and irrigation method (at West Side REC only). Mean values (and standard deviations in parentheses) are shown.

Lint cotton yields (lbs/acre) of Pima versus Upland varieties included in the N rate by irrigation method study in 2019 at the University of CA West Side REC site are shown under subsurface drip (SDI) Irrigation and furrow irrigation (Table 2). The 2019 and 2020 years have both been fairly high lygus bug pressure years at the West Side REC site and the Kern County grower sites, which tends to reduce yield potential more in the Pima varieties than in Upland varieties most years, and this difference in yield levels in cotton types was observed in the 2019 data (Table 2). Grower site yield averages ranged from a low of 1115 to over 2211 lbs lint/acre in 2019 so represent a wide range of yield levels where we will determine plant N uptake and harvest N removal. Targeted plant sampling dates were met for total uptake and removal sampling at all sites in 2019. yield data was collected at each location (West Side REC and grower sites) in the study. The 2020 plant sampling and lint harvests will be conducted in September/October, 2020. In 2019 SDI and furrow irrigated N studies at the West Side REC, we did achieve significant yield differences across plots associated with 0 and 50% estimated N requirement treatments, and these should be useful in demonstrating whether or not the amount of N taken up and removed is tightly correlated with yield levels attained, or if there are differences in uptake and removal rates when yields are lower. N deficiency symptoms in plants are even more apparent in low applied N SDI and furrow treatments at West Side in 2020. Most 2019 plant tissue samples have been prepared for analysis, but not analyzed yet due to personnel and lab availability issues associated with COVID-19. We expect to have access to more complete soil and plant tissue N data later in the year and early next year from both 2019 and 2020 seasons.

Table 2. Mean cotton lint yields for Pima varieties (average of two varieties) and mean cotton lint yields for Upland varieties (average of two varieties) as a function of N application treatment under furrow irrigation at the UC West Side REC in 2019. LSD (least significant difference) values shown indicate difference between yields required to be significantly different at the five percent level, P (probability) values shown.

Type of Cotton	N Treatment (% of estimated N needed for high yields – adjusted for residual NO3-N top two feet)	Subsurface Drip Cotton lint yields (lbs/acre)	Furrow Irrigated Cotton lint yields (lbs/acre)
Pima	0	1467	1361
	50	1784	1352
	75	1906	1683
	100	1828	1904
	125	1911	1881
		LSD(0.05)=199	LSD(0.05)=200
		P=0.001	P=0.000
Upland	0	1819	1771
	50	2094	2097
	75	2794	2494
	100	2582	2463
	125	2639	2544
		LSD(0.05)=113	LSD(0.05)=176
		P=0.000	P=0.000

LITERATURE CITED

Hutmacher, R.B., et al. 2004. Response of Acala Cotton Varieties in Variable Nitrogen

Rates in the San Joaquin Valley of California. Agron. J. 96:48-62.

Unruh, B.L. and J.C. Silvertooth. 1996. Comparisons between an upland and a pima cotton cultivar: II. Nutrient uptake and partitioning. Agron. J. 88:589-595.

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Achieving Efficient Nitrogen Fertilizer Management in California Wheat

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INTRODUCTION

Wheat and other small grains are grown in diverse agricultural environments throughout California. Approximately 90% of the wheat, triticale and barley in California are fall-sown and rely on precipitation patterns that vary dramatically across the state. These conditions result in a wide range of fertilizer use efficiency, which makes it difficult to make robust N fertilizer rate recommendations across seasons and among farms. With increasing regulatory attention related to N management in the state of California, growers and crop consultants need improved N fertilizer management strategies and innovative tools that enable adaptive management and responsive farming. Therefore, the goal of this project is to demonstrate and enable new ways of achieving best N management practices in California wheat.

OBJECTIVES

1. Demonstrate how to use N-rich reference zones and site-specific measurements of the soil and plant N status on a field-scale to guide real-time N management decisions in wheat and triticale. Demonstration sites are located in diverse California farms and implemented across three growing seasons.
2. Measure crop yield and N uptake resulting from N fertilization management actions taken/not taken in response to site-specific, real-time information. Compare results in the alternative management scenarios within and across demonstration sites.
3. Produce case-studies for each demonstration site that document agronomic conditions, in-season measurements, management responses, and final grain yield and N uptake as well as provide an agronomic interpretation of the results.
4. Develop generalized summaries and guidelines for implementing N-rich reference zones, taking site-specific measurements, interpreting results, and making responsive farming decisions.
5. Develop, beta-test, and extend dynamic, web-based decision support tools that provide customized information based on site- and time-specific environmental conditions and California-specific models of wheat growth and development.

DESCRIPTION

Six field-scale demonstrations were completed during 2020, which was the first year of a three-year project. Demonstration sites included five fall-planted locations in the Sacramento Valley (3), Delta Region (1), and San Joaquin Valley (1) and one spring-planted location in the Intermountain Region. Each site had one to four 90-ft by 180-ft N-rich reference zones that were established in representative areas of the field at or near the time of planting. Nitrogen fertilizer rates in these zones were 2-3 times the amount of expected crop N uptake from planting until the start of in-season plant and soil monitoring. From the tillering stage of growth to the heading stage of growth, project leaders recorded measurements of canopy reflectance (i.e. NDVI/NDRE) and soil nitrate-N (via quick tests) in the top foot of soil both within N-rich reference zone(s) and in the broader field. Measurements were made prior to participating growers' in-season fertilizer management decisions. When crop N deficiency was detected by real-time plant and soil measurements, N fertilizer recommendations were produced using a combination of the site-specific measurements and the expected crop N demand remaining for the field. When no deficiency was detected, monitoring continued until either deficiency was detected or the grower decided whether or not to apply N fertilizer in-season. Where possible, the alternative to the cooperating grower's management action (either applying N fertilizer when the grower applied none or excluding fertilizer when the grower decided to apply) was enacted to measure the effect of the management decision and the accuracy of the modeled, in-season fertilizer recommendation. Alternative N management scenarios were successfully implemented at three of the six locations during 2020. When the crop reached maturity, yields and grain N uptake were measured within the main field, the N-rich reference zones, and the alternative management zones (where applicable).

RESULTS AND DISCUSSION

In-season monitoring of the plant and soil resulted in a range of measurements, in-season N applications, and grain yield (Table 1). At three locations (Solano, Yolo, Siskiyou), crop N deficiency was detected early in the season. Two of these sites (Solano and Yolo) were fall-planted, rainfed locations, and received no rainfall between 1/27/20 and 3/14/20. Despite the early-season detection of N deficiency, as a result of the drought period there was not an opportunity to apply in-season N fertilizer until the late-vegetative growth stages, reducing the efficiency of in-season N fertilization at

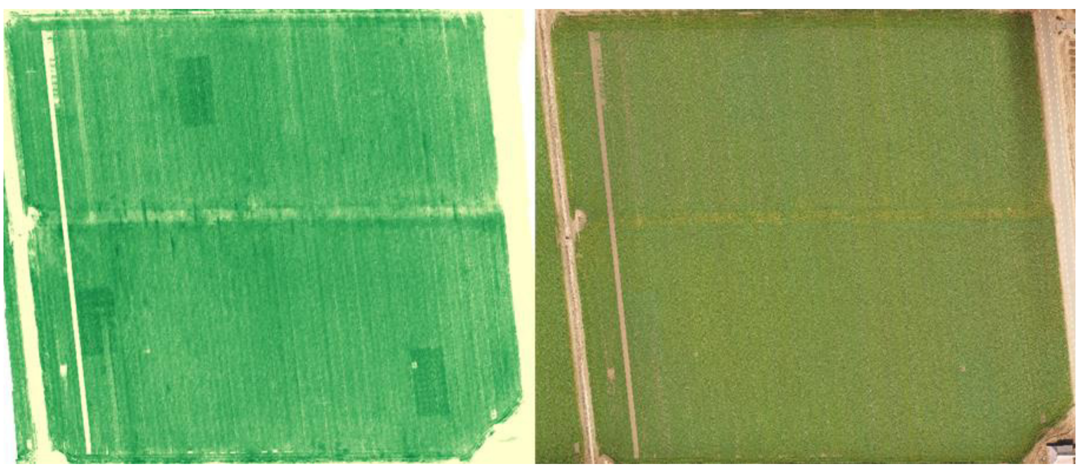

Figure 1. Demonstration site in Solano County on 2/20/20 showing crop N deficiency signal. The three N-rich reference zones appear in the NDRE measurement (on the left) but are not visible to the naked eye (RGB image on the right).

these sites (Table 1). In contrast, the Siskiyou location was an irrigated, spring-planted site. Here, the early detection of N deficiency led to a large early-season N application that resulted in an 80% increase in yield (Table 1). Colusa was a fall-planted location where two of the three N-rich reference zones detected N deficiency at early stages of crop growth but a third zone indicated crop N sufficiency. Irrigation accompanied an in-season N application at this location, and the N application increased yields by an average of 16% (Table 1). Of note is that in the two field areas where N-rich reference zones had indicated crop N deficiency, yields were higher in the N-rich zones than in alternative management zones (where no in-season N application occurred). At the Kings location, crop deficiency wasn't detected until relatively late in the season (heading) and only in one of four N-rich reference zones. The grower had already applied in-season N earlier in the season. Because the deficiency signal appeared late in development and was isolated to one of four reference zones, no additional N application was made at the field. At the location in the Delta region of Sacramento County, multiple plant and soil monitoring events resulted in no detection of N deficiency, and the grower chose not to apply in-season N. The varied in-season measurements, in-season N fertilizer applications, and grain yield from the 2020 sites.

Table 1. Indicates whether and at what growth stage in-season N deficiency was detected via in-season plant and soil monitoring of wheat and triticale crops at 2020 demonstration sites. Also indicated are the rate and timing of N fertilizer applied post-detection of N deficiency, and the resulting changes in yield (at sites where alternative management plots permitted comparison).

Location (county)	In-season N deficiency detected?	Crop stage when deficiency detected	In-season N applied post-detection	Crop stage of post-detection N application	Yield change resulting from post-detection N application
Solano	Y	tillering	60 lb/ac	flag leaf	+8% ($p = 0.25$)
Yolo	Y	tillering	50 lb/ac	flag leaf	not measured
Siskiyou	Y	tillering	200 lb/ac	early tillering	+80% ($p < 0.01$)
Colusa	Y (2 of 3 zones)	tillering	46 lb/ac	late tillering	+16% ($p = 0.06$)
Kings	Y (1 of 4 zones)	heading	0	-	not measured
Sacramento	N	none detected	0	-	not measured

ACCOMPLISHMENTS

In addition to the grain yield and N uptake being measured from the demonstration sites, several outreach products were produced during 2020. Among these was a newly developed web page with resources to help users understand and implement a soil nitrate quick test. These resources were introduced via a UC Small Grains blog post on 5/13/20 and include step-by-step instructions in both written and video formats as well as an interactive web-tool that simplifies the process of interpreting the results of the quick test. This is one component of a larger set of N management decision support tools being created as part of this project. Other outreach products developed in 2020 were blog posts outlining the important considerations for implementing and measuring N-rich reference zones in a production field. These were published on the UC Small Grains Blog on 5/27/20 and 6/30/20 and will inform forthcoming print and web-based documents on similar topics. An additional blog post provided an in-season update on the demonstration site in the Delta region. Finally, case studies that provide a full-season agronomic overview of the 2020 demonstration sites will be available prior to the start of the 2020-2021 season.

TAKE-HOME MESSAGE

Shifting N fertilizer applications from preplant to in-season increases N fertilizer recovery in small grains. Using site-specific measurements to refine in-season N application rate and timing further increases fertilizer use efficiency. This project is demonstrating how to implement N-rich reference zones in production fields and interpret real-time measurements made with simple tools to determine whether and how much N fertilizer to apply in-season.

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Development of Nutrient Budget and Nutrient Demand Model for Nitrogen Management in Cherry

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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 cherries 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 yield and vegetative growth estimated crop demand coupled with an understanding of seasonal nutrient demand dynamics. This approach has not been developed for cherry cultivars in California and hence cherry growers do not have improved fertilizer management decision tools to apply the right rate of fertilizer at right time, to optimize productivity and avoid environmental losses. Current approaches to nutrient management in cherries rely heavily on leaf sampling collected during late summer which is too late to respond to deficiencies or adjust fertilizer regimes. The concept of demand driven nitrogen management is not widely practiced but is essential to meet ILRP guidelines and achieve a high efficiency of N use. Critical data on N export rates, seasonality of N demand and differences between cultivars and practices in N dynamics, is not currently available from California cherry production.

OBJECTIVES

Our goal is to develop knowledge of the pattern of nutrient uptake and allocation of nutrients in cherry and to provide insight into nutrient allocation patterns, the storage of nutrients in perennial tissue and the role of nutrient remobilization in supplying early season nutrient demand and direct application for the management of nutrients in commercial orchards.

The specific objectives of the project are:

1. Develop nutrient demand curves to guide the quantity and time of fertilizer application in cherry. Repeat for most representative cultivars and production systems.
2. Develop and extend nutrient Best Management Practices (BMP) for cherry cultivars.

DESCRIPTION

Activities 1. Develop nutrient demand curves that guide the quantity and time of fertilizer application in cherries (Years one and two). Activity 1 will be achieved by intensive monitoring of highly productive groves of cherries in California Central Valley. Three replicated blocks of three different cultivars or production systems that are representative of broad acreage, will be selected for sampling. Replicate trees of each cultivar will be monitored for changes in nutrient concentrations in different plant organs (roots, trunk, scaffold, canopy branches, small branches, fruits and leaves) six times during the season for two seasons. This will be achieved by root digging, tissue coring and organ sampling. Three trees of each cultivar will also be excavated at the beginning and end of each season to determine total biomass accumulation during the growing seasons and also nutrient concentrations in tree organs. The samples will be analyzed for N, P, K, S, Ca, Mg, Zn, B, Fe, Mn and Cu. The changes in biomass of different organs will be examined during two seasons and yield data will be collected at harvest to develop seasonal demand curves for N and other nutrient elements based on yield and whole tree nutrient demand.

Activity 2. Develop and extend nutrient Best Management Practices for cherries (Year three). 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 cherries growers of California. The finding from the research will help in development of the ‘Right Rate’ and ‘Right Time’ to guide N applications. A computer-based model will be developed that will be available for the grower to estimate their crop fertilizer needs based on phenology, plant age, environment, crop load and yield. Extensive outreach events will be conducted, and online tools will be developed. This activity will define the required N removal values for cherry production and guide growers on methods to attain high Nutrient Use Efficiency (NUE).

Evaluation. Project success will be evaluated by the development of demand curves in cherries; availability of online information system for cherry growers which will guide the quantity and time of fertilizer application and in-season monitoring, and extension of result findings and improvements in nutrient use efficiency.

RESULTS

The first year (2020) of this project was assigned to establish the experiment and to collect samples, thus no data have been analyzed.

The study is being conducted in three high yielding commercial cherry cultivars “Bing”, “Coral”, and “Rainier” orchards in the California Central Valley. All varieties were grafted on Mazzard rootstock with an approximate planting density of 202 trees per acre.

Samples of soils from all locations are being collected at every 6-month periods. The samples will be analyzed for Organic Matter (OM), soluble and mineralizable N pools and other critical parameters.

We have been monitoring three replicated blocks of trees (4 trees per block, totaling 12 trees per orchard) for each cherry cultivar (“Bing”, “Coral”, and “Rainier”) for changes in nutrient concentrations 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. Samples collected are being processed for analysis.

Figure 1. Highly productive groves of cherry cultivars (Bing, Coral, and Rainier) were selected in the California Central Valley.

LITERATURE CITED

Muhammad et al. 2015. Seasonal changes in nutrient content and concentrations in a mature deciduous tree species: Studies in almond (Prunus dulcis (Mill.) D. A. Webb). Europ. J. Agronomy 65 (2015) 52–68.

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.

Weinbaum et al. 2001. Necessity for whole tree excavations in determining patterns and magnitude of macronutrient uptake by mature deciduous fruit trees. In Proc. IV IS on Mineral Nutrition in Fruit. pp. 41–49. Acta Hort. (ISHS) 564.

ACKNOWLEDGEMENTS

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Immobilization of Nitrate in Winter-Fallow Vegetable Production Beds to Reduce Nitrate Leaching

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INTRODUCTION

In the fall, at the end of the cool-season vegetable production season on the Central Coast of California, crop residues are incorporated into the soil as the soil is tilled and listed into fallow beds for the winter. Cool season vegetable crop residues contain significant quantities of nitrogen (N) which allows rapid decomposition of the tissue. For instance, cole crop residues contain more than 2.5% N, and 60 to 80% of the tissue decomposes in four to eight weeks following incorporation into moist soil (Hartz, 2020). The resulting pool of residual soil nitrate-N is vulnerable to leaching by rains during the winter fallow (Smith et al, 2016). Winter-grown cover crops can take up a large portion of this nitrate and maintain it in their biomass and thereby reduce nitrate leaching over the winter. However, cover crops are little used on the coast due to economic constraints such as high land rents and the risk they pose to winter/early spring planting schedules. As an alternative to the use of cover crops, we are examining the use of high carbon: nitrogen (C:N) ratio composts (e.g. > 40) to immobilize residual soil nitrate. The use of fall applications of compost is a common practice in this region and the goal of this project is to test whether substituting a high C:N soil amendments could successfully immobilize a portion of soil nitrate in winter beds and thereby reduce nitrate leaching during this critical time of the year. In recent studies, we observed that 5 – 10 tons/acre of almond shells ground to pass through a two mm screen and glycerol at 2.5 tons/acre reduced the load of nitrate in the top three feet of soil by 34 to 51% over the untreated control (Smith et al 2019). Although effective, ground almond shells and glycerol are currently cost prohibitive. This project is evaluating lower cost, locally-sourced high C:N ratio green waste compost to sequester residual soil nitrate. If successful, the use of this material would be a practical and economical practice that growers could readily adopt as a best management practice (BMP) to reduce nitrate leaching during the winter fallow period and improve water quality.

OBJECTIVES

1. Identify and select locally-sourced high C:N ratio green waste materials and conduct laboratory incubations of them at different particle sizes to determine the levels of N immobilization that they provide of cole crop residues.
2. Conduct large scale field trials with cooperating growers in commercial vegetable production fields evaluating the impact of materials identified in objective 1 on nitrate leaching during the winter fallow
3. Evaluate the magnitude and longevity of the impact of the high C:N materials on subsequent crop production, and determine if there is a negative effect of these materials on the yield and N fertilizer requirement of the subsequent vegetable crops
4. Develop algorithms for CropManage that can provide estimates of immobilization based on C:N ratio of the amendment and the quantity added to the soil
5. Conduct economic analysis of the cost of the use of high C:N amendments
6. Conduct grower outreach through blogs, trade journal articles and grower meetings

DESCRIPTION

1. Identify and select locally sourced high C:N ratio green waste materials. We worked with a local composting company to identify an affordable high C material that could be used to immobilize residual soil nitrate. A material called "forest mulch" compost which is made from trunks and branches of trees was identified. It is triple screened and contains a good percentage of small fines that can rapidly stimulate soil bacteria to immobilize nitrate-N in a timely fashion. It has a C:N ratio of 186 and costs $25/ton which is equivalent to yard waste compost that is commonly used in vegetable production fields. Further laboratory incubation evaluations of high C composts will be conducted to better understand the efficacy and longevity of the immobilization process.
2. Conduct large scale field trials with cooperating growers in commercial vegetable production fields. Field trials will be conducted in the winter of 20-21 and 21-22. A greenhouse evaluation was conducted in which the equivalent of 35 tons/acre of broccoli residue (90% moisture) was placed in six inch in diameter PVC cylinders six inches deep filled with screened Chualar loam soil. Residue pots were treated with the following amendments: forest mulch compost at 2.5, 5.0 and 10.0 tons/acre, ground almond hulls at 5.0 tons/acre, glycerol at 2.5 tons/acre and no

amendment. Soil samples were collected each week and analyzed for mineral nitrogen.

3 Evaluate the magnitude and longevity of the impact of the high C:N materials on subsequent crop production. A trial was conducted in a commercial head lettuce field in which 5, 10 and 15 tons/acre of forest mulch compost was applied to 40 inch beds and mulched into the top 3 inches of soil with a bed shaper. After seeding the starter fertilizer 6-15-0 was applied to the bed tops at three rates: 7.8, 15.5 and 23.2 lbs N/acre. Stand counts, phytotoxicity ratings and yield evaluations were conducted to determine detrimental effects of the compost on the lettuce crop.

4 Develop algorithms for CropManage that can provide estimates of immobilization based on C:N ratio. Algorithms developed and refined in Objective 1 will be incorporated into CropManage.

5 Conduct economic analysis of the cost of the use of high C:N amendments. Cash costs for the use of high C compost in Objective 2 will be calculated.

6 Conduct grower outreach through blogs, trade journal articles and grower meetings. Results of this project will be presented at the annual Salinas Valley Irrigation and Nutrient Management Meeting, in the UCCE Salinas Valley Agriculture Blog and in trade publications.

RESULTS AND DISCUSSION

We identified an affordable high carbon compost made from local materials called "forest mulch". It is triple screened and is composed of a mix of fines and coarser material. The cost is comparable to yard waste compost that is commonly used in the Salinas Valley. In a pot test conducted in a greenhouse, it immobilized nitrate

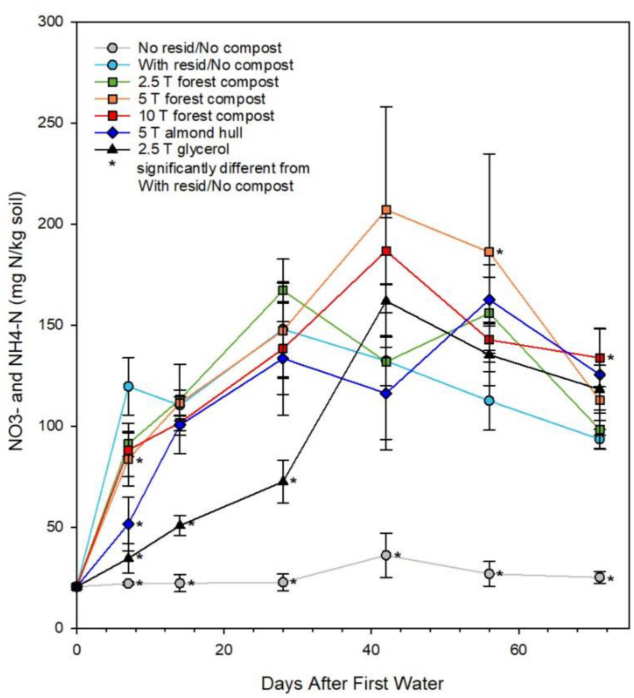

Figure 1. Mineral nitrogen in soil of high carbon amended treatments

mineralized from broccoli residue for the first week after incorporation, but not thereafter (Figure 1). It is possible that this material does not contain sufficient fines and that higher rates may need to be applied to supply sufficient fines to immobilize nitrate for a longer period of time. This material was evaluated for its impact on the yield of the subsequent lettuce crop. There is a trend that indicates lower lettuce yield at higher application rates of forest mulch compost. However, this trend can be reversed by applying a greater amount of starter fertilizer to overcome the effect of immobilization (Table 1).

Table 1. Soil mineral nitrogen and lettuce crop evaluations in compost treatments (including all fertilizer treatments) and fertilizer treatments (including all compost treatments).

Compost Tons/A[1]	Starter fertilizer[2] Lbs N/A	Soil 13-Mar		26-Mar		8-May
		NH_4-N ppm	NO_3-N ppm	Lettuce stand plants/A	Phyto-toxicity[3]	Mean head lbs
0	---	1.2	35.3	32,516	0.0	1.6
5	---	1.2	22.7	32,026	0.3	1.6
10	---	1.5	24.1	31,863	0.3	1.5
15	---	1.8	26.2	32,189	0.5	1.4
---	0.0	1.5	23.9	31,862	0.8	1.5
---	7.8	1.2	26.3	32,516	0.0	1.5
---	15.5	1.6	28.1	32,352	0.3	1.5
---	23.2	1.3	30.0	31,862	0.0	1.6

1 – Compost 36.7% moisture (net solids applied: 5 tons/A = 3.2, 10 = 6.3; 15 = 9.5); compost C:N ratio = 215:1
2 – Fertilizer applied post planting 6-16-0 (7.8 lbs N/A = 15 gallons/A; 15.5 = 30 gallons; 23.2 = 45 gallons)
3 – Scale: 0 = no crop damage to 10 crop dead

LITERATURE CITED

Hartz, TK. 2020. Efficient nutrient management in California Vegetable Production. University of California Agriculture and Natural Resources. Publication 3555.

Smith, R.F., M.D. Cahn, T.K. Hartz, P. Love and B. Farrara. 2016. Nitrogen dynamics of cole crop production: implications for fertility management and environmental protection. HortScience 51(12): 1586-1591.

Smith, R.F., J. Muramoto, L.J. Tourte, A. Haffa, F. Melton and P. Love. 2019. Immobilization of nitrate in fallow winter vegetable production beds. UCCE Blog, Jan. 3.

(https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=29071).

Irrigation and Nitrogen Management, Monitoring, and Assessment to Improve Nut Production While Minimizing Nitrate Leaching to Groundwater

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INTRODUCTION

Groundwater provides one-third and - in dry years - over 50% of the California's urban and agricultural water supply and nearly 100% of rural drinking water supplies. Agriculture has been shown to be the major source of groundwater nitrate (1). In some of California's most productive agricultural counties, over 40% of tested domestic wells exceed the drinking water limit for nitrate (2). In the Central Valley (CV) and Central Coast regions, the Irrigated Lands Regulatory Program (ILRP) and Agricultural Order, respectively, were developed by Regional Water Boards (RWBs). Growers and their agricultural coalitions are charged with assessing, controlling, and regulating nitrate leaching from irrigated crops. For compliance, growers implement nitrogen (N) management plans and report their N mass balance, improve nitrogen use efficiency (NUE), and reduce N leaching to groundwater. Under the ILRP, agricultural coalitions – on behalf of their growers - develop and demonstrate practices that are protective of groundwater. Among those practices, our research is showing that high frequency low concentration (HFLC) fertigation can improve production through higher NUE, potentially reducing impacts to groundwater (3). However, commercial orchard scale implementation of HFLC with direct measurements of resulting groundwater quality improvements immediately underneath the orchard is lacking.

OBJECTIVES

1. Fine-tune the HFLC approach and demonstrate, in a commercial scale almond orchard, that HFLC fertigation practices increase NUE while successfully producing high yields and reducing groundwater quality impacts.
2. Perform, compare, and assess three independent monitoring approaches to estimate groundwater nitrate contribution from an orchard to guide growers, agricultural coalitions, and regulatory agencies on the compliance process.

DESCRIPTION

General Approach: A commercial 56 hectare almond orchard west of Modesto, overlying the CV unconfined aquifer system, was equipped for HFLC (10 – 15 fertigation events with nitrogen added during the middle third of the irrigation cycle), and a comprehensive, high-resolution nitrogen monitoring system was installed in 2016/2017. Orchard water and nitrogen management is adaptive using monitoring data [soil moisture, ET (evapotranspiration), plant tissue, harvest]. The monitoring system estimates nitrate leaching to groundwater. It consists of three separate elements and has sufficient replication of monitoring sites to allow for detailed assessment and comparison of the three methods:

1. Monitoring equipment to measure water and nitrogen application rates, ET, and harvest N removal (orchard water and N mass balance as employed by the ILRP)
2. Seven replicate multi-level, vadose zone monitoring sites (water, nitrate, and ammonium fluxes and storage at 0 -3 m depth).
3. 20 groundwater monitoring wells (screened at 7-17 m below ground surface, in first encountered groundwater), a regulatory "gold standard" for monitoring pollution.

RESULTS AND DISCUSSION

Water and nitrogen mass balance. Annual water mass balance for the four years prior to this project (starting in 2017) yields a negative water balance. Reported irrigation was less than the difference between ETa and P (precipitation). Monthly water mass balances shows that only during the rainy season there was a surplus of precipitation and irrigation, therefore recharge was likely restricted to that period. Because estimated recharge is very small relative to other water fluxes, uncertainty can be several times the estimated value (4); (a) ETa introduces an average error of 15% (5). (b) Irrigation during the historic mass balance is estimated at 10% error per block. (c) Change in storage is assumed to be zero on a yearly basis (4,6), but a dry year may significantly deplete soil moisture adding to the uncertainty. The average nitrogen use efficiency (NUE) in the orchard was 67% under advanced grower practice (AGP), this is consistent with results elsewhere (7). The first HFLC growing season (2018) achieved a high NUE of 87% due to excellent climate conditions during the season resulting in high yields. However, the second year (2019) saw significantly lower yields due to rain during the pollination period resulting in an NUE of 66%, similar to 2013-2017, indicating opportunities for further adjusting N fertigation in response to early season climate impacts on yields. Estimated nitrogen losses to groundwater in 2012 – 2017, prior to utilizing HFLC, ranged from 36 to 92 lb/acre. These amounts of excess combined with the little amounts of water leached may have caused significant accumulation of high concentration of nitrogen in the unsaturated zone profile.

Root zone monitoring. The monitoring sites show great variability in daily water flux (Figure 1). On average, across all sites, water flux out of the root zone increases with rain events, but variability across sites also increases during the rainy season. While

vadose zone monitoring of both water and nitrate fluxes indicate large variability, especially during rain events, the average water and nitrogen flux (representative of the orchard as a whole) show trends that are consistent with cumulative flux dynamics obtained from the mass balance approach: leaching and, hence, nitrogen movement out of the root zone occurs only during the precipitation season. The study shows a close relation between the mass balance of water and nitrogen and the observed nitrate losses out the root zone: both indicate losses on the order of 50 kg/ha-N in 2019. Significant correlations have been established between the two in other studies (8,9). Yet, the source of variability between the two methods is different: While the variability in mass balance approach comes from uncertainties in the irrigation amount, ETa values and storage between individual orchard blocks, the root zone monitoring uncertainties originate from highly variable distribution, at the 1 – 10 m scale, of fertilizer, soil properties and flux calibration constants.

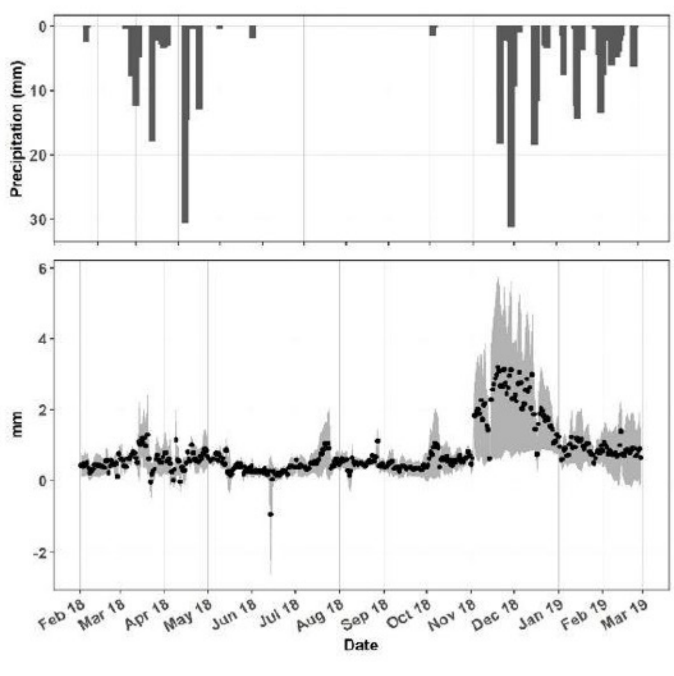

Figure 1. Daily (top) precipitation events during 2018 growing season and mean daily fluxes out of the root zone (black dots) of the 7 monitoring sites with standard deviation among 7 sites (gray).

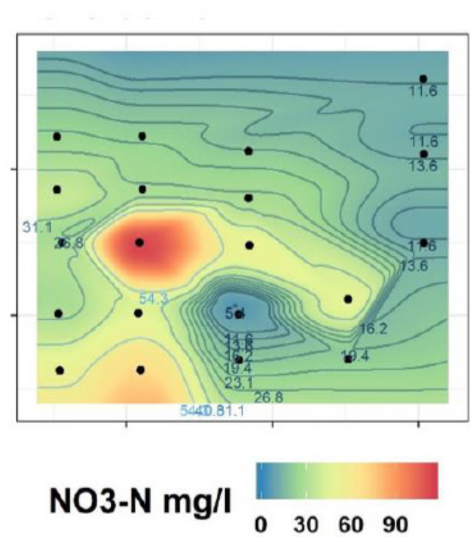

Figure 2. Spatial concentraion of ntirate in the 20 monitoring wells using Kriging interpolation.

Groundwater monitoring. Spatial variability of nitrate concentrations was high. Between wells, concentrations ranged between 10 and 60 mg/L NO3-N, with wells at 60 mg/L NO3-N only 200m away from wells with 20 mg/L NO3-N (Figure 2). Most of the wells show concentrations around 20 mg/L NO3-N. There was an increase in groundwater nitrate concentration following implementation of HFLC. This is evidence of the lag in nitrate travel time through the vadose zone, and from the water table to the monitoring well screen. This increase is likely a result of previous practices. Our results demonstrate the importance of measurement scale in space and time. Water and nitrate mass balance, vadose zone observations, and groundwater quality can be shown to be in good agreement with each other, after accounting for temporal delays. Each method is associated with its specific scale in space and time in the orchard: The annual mass balance approach, operates at the kilometer scale, spatially, and annual scale, temporally, averaging data per block in the orchard. Root zone monitoring observes a single tree at a scale representing a few decimeters laterally and a few centimeters vertically in space (6) and represents hours to days in time. Groundwater monitoring in monitoring wells screened about 5m from the water table and deeper represent a mixed sample from a narrow (several meters) recharge source area that may be from a few tens of meters to hundreds of meters long, and representing a temporal mixture of recharge that occurred over one to several years (10). Comparison between methods must take differences in these scales into account.

TAKE-HOME MESSAGE

There are two aspects to look at for future work- the effectiveness of HFLC as a management practice and changes in groundwater concentrations due to improved management practice. HFLC management was promising during its first year with better yield and NUE compared to AGP. The second year under the same practice had a much lower yield, but due to HFLC was able to reach an NUE similar to normal years with AGP practices. This will need further observation and refinement as trees may take time to accommodate the HFLC practice and tune it to the amounts needed to get both better yield and reduction in nitrate leaching. Better understanding of the impact of HFLC on groundwater, relations between the different scales of measurements, and groundwater variability will be addressed over the next three years through monitoring to better characterize spatio-temporal variability. A groundwater sample, represents an average of approximately the past five years of practice of the orchard. It will likely take until 2023 or longer before monitoring wells capture the full effect of the HFLC practice. This is the main reason for designing this project as long-term.

LITERATURE CITED

1. Harter T, Dzurella K, Kourakos G, Bell A, King A, Hollander A. Nitrogen Fertilizer Loading to Groundwater in the Central Valley. Final Report to the Fertilizer Research Education Program, Projects 11-0301 and 15-0454. 2017;(August 2017):333.

2. Lockhart KM, King AM, Harter T. Identifying sources of groundwater nitrate contamination in a large alluvial groundwater basin with highly diversified intensive agricultural production. J Contam Hydrol [Internet]. 2013;151(3):140–54. Available from: http://dx.doi.org/10.1016/j.jconhyd.2013.05.008

3. Baram S, Couvreur V, Harter T, Read M, Brown PH, Hopmans JW, et al. Assessment of orchard N losses to groundwater with a vadose zone monitoring network. Agric Water Manag [Internet]. 2016;172(3):83–95. Available from: http://dx.doi.org/10.1016/j.agwat.2016.04.012

4. Healy R, Scanlon B. Estimating Groundwater Recharge. Cambridge: Cambridge University Press; 2010.

5. Allen RG, Pereira LS, Howell TA, Jensen ME. Evapotranspiration information reporting: I. Factors governing measurement accuracy. Agric Water Manag [Internet]. 2011;98(6):899–920. Available from: http://dx.doi.org/10.1016/j.agwat.2010.12.015

6. Onsoy YS, Harter T, Ginn TR, Horwath WR. Spatial Variability and Transport of Nitrate in a Deep Alluvial Vadose Zone. Vadose Zo J. 2005;4(3):41–54.

7. Saa Silva S, Muhammad S, Sanden B, Laca E, Brown P. Almond Early-Season Sampling and In-Season Nitrogen Application Maximizes Productivity, Minimizes Loss. Almond Board Calif. 2013;1–9.

8. Botros FE, Onsoy YS, Ginn TR, Harter T. Richards Equation – Based Modeling to Estimate Flow and Nitrate Transport in a Deep Alluvial Vadose Zone. Vadose Zo J. 2012;

9. Baram S, Couvreur V, Harter T, Read M, Brown PH, Kandelous M, et al. Estimating Nitrate Leaching to Groundwater from Orchards: Comparing Crop Nitrogen Excess, Deep Vadose Zone Data-Driven Estimates, and HYDRUS Modeling. Vadose Zo J. 2016;15(11).

10. van der Schans ML, Harter T, Leijnse A, Mathews MC, Meyer RD. Characterizing sources of nitrate leaching from an irrigated dairy farm in Merced County, California. J Contam Hydrol [Internet]. 2009;110(1–2):9–21. Available from: http://dx.doi.org/10.1016/j.jconhyd.2009.06.002

11. Brown P, Muhammad S, Sebastian S, Bruce L, Richard P, Richard, C. R, et al. Development of a Nutrient Budget Approach to Fertilizer Management in Almond. 2008.

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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.

University of California Nursery and Floriculture Alliance Fertilizers and Plant Nutrition Education Program • *Lorence Oki*, 16-0678

Develop Nutrient Budget and Early Spring Nutrient Prediction Model for Nutrient Management in Citrus • *Patrick Brown*, 16-0707

Online Decision Support Tools for Irrigation and Nitrogen Management of Central Valley Crops • *Michael Cahn,* 16-0710

Demonstration of a combined new leaf sampling technique for nitrogen analysis and nitrogen applications approach in almonds • *Patrick Brown*, 16-0708

Understanding Influences on Grower Decision-Making and Adoption of Improved Nitrogen Management Practices • *Mark Lubell*, 16-0620

N and P management in organic leafy greens • *Richard Smith*, 15-0522

Developing a decision support tool for processing tomato irrigation and fertilization in the Central Valley based on CropManage • *Daniel Geisseler,* 15-0410

New Fertigation Book • *Charles Burt,* 15-0393

Evaluation of the Multiple Benefits of Nitrogen Management Practices in Walnuts • *Parry Klassen*, 15-0360

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

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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