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FREP WPH

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Proceedings

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Thirtieth Annual Nutrient Management Conference

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INTRODUCTION

Fertilizer Research and Education Program

Welcome to the Fertilizer Research and Education Program (FREP) and Western Plant Health (WPH) Annual Nutrient Management Conference. Over the last 30 years, this conference has provided a venue where FREP grant recipients report findings of their projects and industry representatives share valuable irrigation and nutrient management information with an audience of crop advisors, students, growers, researchers, and agricultural professionals. Since 1991, FREP has supported farming operations and California communities by funding research, demonstration, and education projects to increase efficiency and adoption of irrigation and nutrient best management practices.

30th Annual FREP/WPH Conference

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

Dr. Daniel Geisseler, University of California, Davis (UCD) will share key findings of his research on determining the relationship between nitrogen (N) applied and N removed from fields, a key metric of the Irrigated Lands Regulatory Program (ILRP). Nitrogen removed is calculated by multiplying the yield with the N concentration in the harvested plant parts (commonly called crop N removal coefficient). Over the last several years, Dr. Geisseler's team has analyzed hundreds of samples from different crops for which, no robust coefficients were available.

Dr. Mark Lundy, UCD, and his team have been demonstrating the use of tools to optimize N management in wheat and other small grains on commercial farms across California. The tools include an interactive website that provides customized, site-specific N fertilizer recommendations. Dr. Lundy will explain how these tools have increased crop productivity and farmer net income by optimizing N fertilizer applications across diverse environments and management systems. The N Fertilizer Management Tool for California Wheat uses crop monitoring information to produce a targeted in-season N fertilizer recommendation. Case studies detailing site-specific management practices and outcomes can be found on the project website:

https://smallgrains.ucanr.edu/Nutrient_Management/N-rich_reference_zones/

Dr. Jairo Diaz, UC Cooperative Extension (UCCE) will share results of a 3-year project that evaluated the effects of irrigation management and N fertilization rates on yield and quality of fresh market onion bulb production in Imperial County for which the Colorado River has been the sole water source for over 100 years. California has the largest water appropriation of the Colorado River Basin and over two decades of persistent drought has brought the need to adapt to future shortages of water, especially in Imperial County. Thus, Dr. Diaz has been conducting these field assessments at the UC Desert Research and Extension Center in Holtville, CA to improve irrigation and nutrient use efficiency.

Dr. Aparna Gazula, UCCE, will share results of her ongoing project on irrigation and N management in Asian leafy vegetables in Fresno and Santa Clara counties. With proposed regulations under the ILRP to control N application, it is important to understand N uptake in crops that have significant acreage but do not have commodity board support. The overall goal of her project is to provide detailed measurements of total N uptake/pattern of bok choy, on choy, garlic chives, daikon and lemongrass. The information collected will provide the basic information necessary for growers to better manage N inputs and protect water quality. Dr. Gazula will report on the research results in bok choy, its crop canopy development, and nutrient uptake patterns under greenhouse production systems.

Dr. Patrick Brown, UCD, will share recent results of his ongoing project demonstrating how managing N in cherry orchards is a balancing act of supply and demand and why growers need to consider the supply of N provided by fertilizers, organic matter, and irrigation water, as well as the demand for N due to tree growth and fruit production needs. According to Dr. Brown, with proper management, optimal productivity and minimized N loss can be achieved simultaneously and to maintain productivity and avoid losses, N must be replaced efficiently.

Dr. Joji Muramoto, UCCE, will share results of his project on integrating a simple N mineralization model with CropManage to provide fertilizer recommendations for organic vegetable production. Dr. Muramoto will report a two-pool simulation model developed for typical organic fertilizers based on 113 N mineralization datasets from replicated incubation trials published in peer-review papers. He will also discuss N mineralization from crop residues and the significance and implications of crop residue-derived N.

Sacha Lozano and Dan Hermstad, Santa Cruz County Resource Conservation District, will discuss how irrigation and N management is a crucial and often challenging component of specialty crop production on the California Central Coast. Some growers apply both irrigation water and N fertilizer following a pre-defined schedule for each crop, based on their experience, but regardless of site-specific conditions. This can result in under or over application, which in turn can affect yields, aggravate aquifer overdraft and/or impair water quality and expose growers to strict water regulations. In this presentation, Sacha Lozano and Dan Hermstad will also share their experience working with Spanish speaking growers and irrigators to remove adoption barriers and facilitate use of CropManage, a decision-support tool that can help them improve irrigation and N management.

Dr. Sat Darshan Khalsa, UCD, and a team of UCANR and UCD advisors and researchers have developed an asynchronous online course focused on N management in California. This course has been open to all interested parties and has successfully educated over 150+ students in two years and prepared over 50 CCAs to earn the California N specialty. According to Dr. Khalsa, the output of this project provides a much-needed boost to the availability of trained individuals who can sign off on N management plans for our grower communities. Dr. Khalsa will share more details on their ongoing project results in his presentation.

Past Research

Since 1991, FREP has committed over 28 million dollars in over 260 projects focused on irrigation and nutrient management research, outreach, and the development of decision support tools. These projects address management challenges and opportunities in several commodity areas and growing regions across California (Figures 1).

The Crop Fertilization Guidelines website (cdfa.ca.gov/go/FREPguide) is an important resource resulting partly from FREP-funded projects. The guidelines provide insight to nutrient management for the most wide¬spread 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.

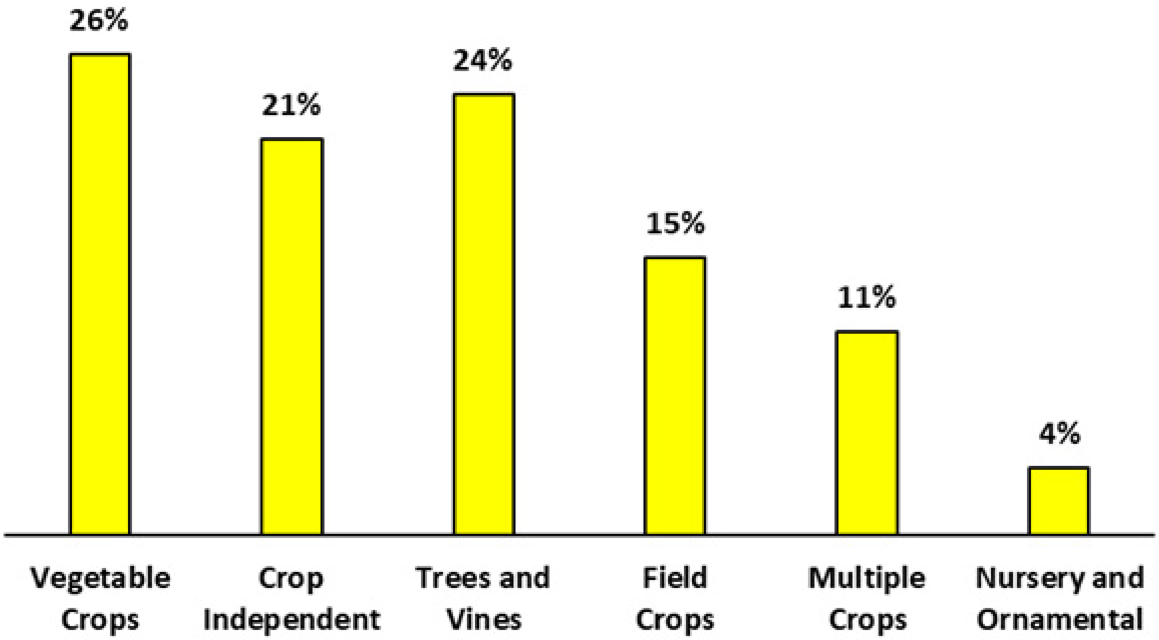

Figure 1. Distribution of commodities (%) represented in FREP-funded projects

Current Projects

FREP is currently funding 31 innovative projects to promote 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. Some of the ongoing FREP-funded projects across the state are highlighted below:

In the Central Valley, Dr. Daniel Geisseler (UCD) is developing site-specific N fertilization recommendations for annual crops through estimates of the contribution of N mineralization to the plant-available N pool and incorporating them into user-friendly online N fertilization calculators. Dr. Anthony O'Geen (UCD) is evaluating techniques to minimize nitrate loss from the root zone during managed aquifer recharge (MAR) and to encourage wider adoption of Flood-MAR among growers by identifying best management strategies. Charlette Gallock (Kings River Conservation District) leads a group in assessing harvested and sequestered N content to improve N management in crops. Parry Klassen (Coalition for Urban and Rural Environmental Stewardship) and his team are developing "Crop Nutrient Minute" a video series in Spanish and English using irrigation and N management information compiled for the seven major acreage crops in the Central Valley and Central Coast. Dr. Bob Hutmacher (UCCE) is assessing N response of industrial hemp cultivars grown for cannabidiol and essential oils. In this project, he evaluates the impacts of N application rates and variety/growth habit/plant type on plant N uptake, harvest removal, and yield response for two biotypes of industrial hemp. Dr. Timothy Bowles (UC Berkeley) is quantifying, and modeling overlooked pathways of N loss (dissolved organic N) from organic inputs across contrasting soil types.

On the Central Coast, Richard Smith (UCCE) is assessing N content of the harvested portion of several specialty crops to estimate crop N removal coefficients and improve N management. Dr. Charles Burt (Cal Poly San Luis Obispo) is developing a Certification and Distance Learning program for Fertigation for English and Spanish field workers and irrigators. Dr. Lorence Oki (UCD) is developing fertilizer and plant nutrition workshops for greenhouse and nursery growers across the state. In another project, he is investigating techniques to optimize N fertilizer concentrations in vegetable transplant production. Jodi Switzer (Ventura County Farm Bureau) is developing a Ventura County N management training program to provide growers with the information and credentials needed to develop site-specific N management plans for their farms in Southern California. In an outreach and education project, Deborah Nares and Tom Stein (American Farmland Trust) are conducting nutrient management and irrigation efficiency outreach and education for Latino and Southeast Asian Farmers in the Central Coast and Central Valley regions.

In the low desert of the Imperial Valley, Dr. Ali Montazar (UCCE) is studying strategies to enhance N and water use efficiency in California carrot production through management tools and practices. Dr. Oli Bachie, (UCCE) will develop N fertilizer and irrigation best management practices for low desert sudangrass production by conducting research trials in Imperial County.

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

Future FREP Projects

In 2022, FREP has committed to funding three new grant projects focused on irrigation and nutrient management in Central Valley, Central Cost, and Desert regions.

In the Central Valley, Drs. Patrick Brown and Stavros Vougioukas will develop a yield monitoring system integrated into a modern off ground harvester to achieve single tree yield measurements and tree identification while operating at full commercial harvest speed. This project addresses three main issues: i) Efficient N and K management ii) Optimizing orchard productivity, and iii) Improving the utility of in-field sensors and remote sensing.

On the Central Coast, Dr. Charlotte Decock (Cal Poly San Luis Obispo) and Dr. Michael Cahn (UCCE) aim to support growers to reduce N inputs and losses by quantifying the N credit from irrigation water in broccoli production under contrasting irrigation management and soil characteristics in on-farm trials; assess barriers to pump and fertilizer practice through questionnaires and workshops; and demonstrate and promote potential gains in N and water use efficiency associated with implementing pump and fertilize through outreach and education.

Dr. Ali Montazar (UCCE) will undertake a study to improve and promote management practices that optimize N and irrigation water use efficiency in the California's low desert lettuce production systems. In his study, Dr. Montazar will quantify and elucidate lettuce production challenges under current regional management practices. He will look at different N and water application rates and timing, create N uptake curves, describe crop N removal, crop water use, crop yield and quality, N and water use efficiency, and he will a conduct a viability assessment of drip versus furrow irrigation.

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: Dr. Jerome Pier (Chair), Dr. Tom Bottoms, Dr. Ben Faber, Daniel Rodrigues, Dr. Jan Hopmans, Dr. Lisa Hunt, Dr. Sebastian Saa, Dr. Robert Mikkelsen, Dr. Jairo Diaz, Edgar Macias Flores, and David McEuen.

In addition, we thank the members of the Fertilizer Inspection Advisory Board for their continued support of the FREP program: Melissa McQueen (Chair), Gary Silveria (Vice Chair), Jake Evans, David McEuen, Greg Cunningham, William Oglesby, Timothy Howard, and Gus Olson.

We thank WPH as a continued valued partner in the conference. Since 2005, FREP has teamed up with WPH 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.

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

Special recognition goes to the leadership at the CDFA including Secretary Karen Ross; Inspection Services Division Director Natalie Krout-Greenberg; and Dr. Amadou Ba, Environmental Program Manager II.

We also thank Maria Tenorio Alfred (Research Data Specialist III) from the Feed, Fertilizer, and Livestock Drugs Regulatory Services Branch and 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); Jennifer Harmon, Associate Government Program Analyst; Nicole Nunes, Environmental Scientist; and Dr. Emad Jahanzad, Senior Environmental Scientist (Specialist).

Conference Program

30th Annual FREP/WPH Nutrient Management Conference

Wednesday October 26, 2022

Facilitator: *Dr. Rob Mikkelsen, Director of Agronomic Services, Yara International*

9:00-9:30 **Welcome**
Renee Pinel, President/CEO (WPH); Karen Ross, Secretary, California Department of Food and Agriculture

9:30-10:00 **Crop Nitrogen Removal Coefficients**
Daniel Geisseler, Specialist in Nutrient Management, University of California Cooperative Extension

10:00-10:30 **Achieving Efficient Nitrogen Fertilizer Management in California Wheat**
Mark Lundy, Assistant Specialist, University of California Cooperative Extension

10:30-10:50 **Break**

10:50-11:20 **Assessing Drip Irrigation and Nitrogen Management of Fresh Onions Produced in the Low Desert**
Jairo Diaz, Desert Research and Extension Center Director, University of California Cooperative Extension

11:20-11:50 **Evaluation of Nitrogen Uptake and Applied Irrigation Water in Asian Vegetables**
Aparna Gazula, Small Farm Advisor, University of California Cooperative Extension

11:50-1:10 **Lunch**

1:10-2:25 **Panel: Impact of High Input Costs on Nitrogen Management**
Moderator: Tom Bottoms, Operations Manager, Timothy and Viguie Farming

Panelists:
Gary Silveria, Vice President of Sales and Marketing, Tremont Lyman
Mark Mason, Ag Manager, Huntington Farms
Justin Diener, Co-Owner, Red Rock Ranch

2:25-2:45 **Break**

2:45-4:15 **Breakout Sessions**

Groundwater Protection Targets
Kenneth Miller, Soil Scientist, Formation Environmental

Irrigation Management in Nursery Production
Loren Oki, Specialist, University of California Cooperative Extension

4:30-6:30 **Poster Reception and Social Hour**

Thursday October 27, 2022

Facilitator: *Andy Low, Helena Agri-Enterprises*

8:15-8:30 **Welcome and Recap**

8:30-9:00 **Development of Nutrient Budget and Nutrient Demand Model for Nitrogen Management in Cherry**
Patrick Brown, Professor of Plant Sciences, University of California, Davis

9:00-9:30 **Research Updates on Nitrogen Management in Walnuts**
Katherine Jarvis-Shean, Orchard Systems Advisor, University of California Cooperative Extension

9:30-10:00 **Using Biosolids-based Fertilizers as a Nitrogen Source in California Grains**
Konrad Mathesius, Farm Advisor, University of California Cooperative Extension

10:00-10:20 **Break**

10:20-10:50 **Developing a Nitrogen Mineralization Model for Organically Managed Vegetable Farms on the Central Coast**
Joji Muramoto, Organic Production Specialist, University of California Cooperative Extension

10:50-11:20 **Promoting the Adoption of CropManage to Optimize Nitrogen and Irrigation Use through Technical Assistance with Data Loggers and Cellular Modems for Spanish Speaking Growers in Santa Cruz and Monterey Counties**
Sacha Lozano, Program Manager, Santa Cruz County Resource Conservation District
Dan Hermstad, Program Technical specialist, Santa Cruz County Resource Conservation District

11:20-11:50 **Next Generation Nitrogen Management Training for Certified Crop Advisors**
Sat Darshan Khalsa, Assistant Professional Researcher, University of California, Davis

11:50-12:00 **Closing Remarks**

SUMMARIES OF PRESENTED FREP PROJECTS

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 that varies dramatically across the state. These conditions make efficient N fertilizer management difficult because the right rate varies from field-to-field and year-to-year. With increasing regulatory, market and social demands for sustainable N management, 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 and related winter cereals.

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 related winter cereals. Demonstration sites are located on diverse California farms and implemented across three growing seasons.
2. Measure crop yield and N uptake resulting from N fertilization management decisions in response to site-specific, real-time information. Compare results in 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, final grain yield and N uptake as well as provide an agronomic interpretation of the results.
4. Develop 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 and management recommendations based on site- and time-specific farm management variables, environmental conditions and California-specific models of wheat growth and development.

DESCRIPTION

Sixteen field-scale demonstrations were completed between the 2019-21 and 2021-22 seasons. Demonstration sites included 8 fields in the Sacramento Valley, 3 fields in the San Joaquin Valley, 3 fields in the Intermountain region of Northern California, and 2 in the Delta region. Fields included highly productive, irrigated locations with grain yields as high as 9000 lb/ac. They also included low productivity, rainfed locations with yields as low as 1500 lb/ac. 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. N 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 measured canopy reflectance (i.e. NDVI/NDRE) both within N-rich reference zone(s) and in the broader field and also measured soil nitrate-N in the top foot of soil using quick tests. Measurements were made prior to participating growers' 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 via a customized web-tool. When no deficiency was detected, monitoring continued until either deficiency was detected or the grower decided to apply N fertilizer in-season.

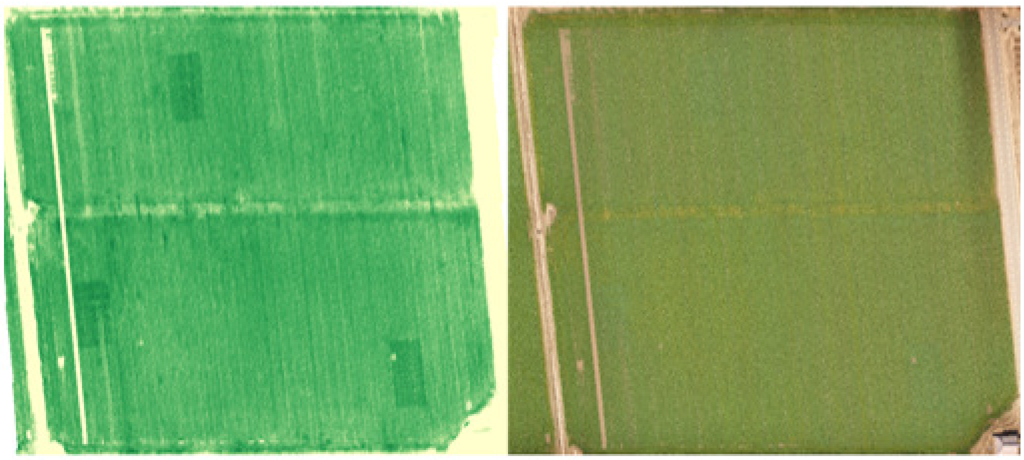

Figure 1. Demonstration site showing crop N deficiency signal. The three N-rich reference zones appear in the NDRE measurement (on the left) but are not visible to the nake eye (RGB image on the right).

When 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 10 of the 16 locations. When the crops reached maturity, yields and crop N uptake were measured within the main field, the N-rich reference zones, and the alternative management zones (when applicable).

RESULTS AND DISCUSSION

In-season monitoring of the plant and soil resulted in a wide range of measurements, N fertilizer recommendations, and outcomes (Table 1). Based on site-specific, real-time measurements, The Nitrogen Management Tool for California Wheat produced a targeted recommendation. When in-season N fertilizer applications were recommended, they resulted in an average yield increase of 28% (~1500 lb/ac) compared to an in-field control. When monitoring indicated that crop response to N fertilization was unlikely and no fertilizer application was recommended, yields in the grower field were equal to the control. In addition, these growers saved an average of 50 lb/ac N compared to their typical N fertilizer rates, which translated to savings of ~$40/ac in fertilizer costs. Overall, crops at the demonstration sites removed 27 lb/ac more N than was applied as fertilizer for an average applied/removed ratio of 80%. These outcomes, measured over three seasons and across a wide range of California small grain agroecosystems, illustrate that efficient N fertilizer manage-

Table 1. Indicates whether in-season N fertilizer was recommended, the rate of N fertilizer applied, and the resulted changes in yield at sites where alternative management plots permitted comparision (“-” indicates that the effect was not measured).

Location	In-season N recommended	In-season N applied (lb/ac)	Yield change (compared to control, lb/ac)	Total N Applied (lb/ac)	Total N Uptake (lb/ac)
Solano 2019-20	N	0	no change	0	97
Yolo 2019-20	Y	50	-	76	30
Siskiyou 2019-20	Y	200	+ 3672 (75%)	200	181
Colusa 2019-20	Y	46	+844 (15%)	106	156
Kings 2019-20	Y	61	-	209	161
Sacramento 2019-20	N	0	-	60	148
Yolo 2020-21 (irrigated)	Y	50	+1119 (26%)	50	115
Yolo 2020-21 (rainfed)	N	0	no change	74	58
Colusa 2020-21	N	0	-	60	146
Kings 2020-21	Y	140	+ 1088 (14%)	140	177
Sacramento 2020-21	N	0	no change	60	163
Yolo 2021-22 (rainfed)	N	60	no change	110	41
Yolo 2021-22 (irrigated)	Y	30	-	139	130
Kings 2021-22	Y	80	-	210	221
Lassen 2021-22 (forage)	Y	92	+ 3548 (29%)	98	129
Lassen 2022 (barley)	Y	40	+ 604 (15%)	46	127

ment can be achieved by combining plant and soil monitoring with site and time specific decision support information.

ACCOMPLISHMENTS

In addition to the agronomic measurements recorded at the demonstration sites, this project produced a diverse set of outreach materials and educational outcomes. These include a devoted University of California webpage containing information about the project and links to related resources. Among these resources are case studies that provide a full-season agronomic overview for each demonstration site, blog posts and articles that describe important considerations for implementing and measuring N-rich reference zones, and videos illustrating and discussing demonstration outcomes. In addition, multiple interactive web-tools were developed during the course of this project along with how-to videos describing how to use these web-tools. These websites provide customized, site-specific fertilizer recommendations, real-time information about seasonal weather, and a tool to convert measurements from an in-field soil nitrate quick test to a N fertilizer equivalent based on soil type. At five of these events, surveys were used to evaluate efficacy of the educational content. Based on ratings from a subset of attendees (n=42), knowledge of the project concepts and associated tools increased and attendees were more likely to use N rich reference zones and associated UC webtools as a result of the information presented at these events. In addition, case studies were an effective method for learning about the tools and methods being demonstrated by this project.

TAKE-HOME MESSAGE

Shifting N fertilizer applications from preplant to in-season increases fertilizer recovery in small grains. Using site-specific measurements to refine in-season N application rates and timing further increases fertilizer use efficiency. This project has demonstrated how to implement N-rich reference zones in production fields and developed new tools to interpret real-time plant and soil measurements and determine whether and how much N fertilizer to apply in-season.

ACKNOWLEDGEMENTS

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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

Horizon Farms

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 4 rows on 40-inch beds. Sixty-four plots are established (16 treatments and 4 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 for the region. Soil water tension meters are installed at 6-, 12-, and 24-in. Four in-season nitrogen treatments are assessed: 0, 75, 150, and 225 lbs N per acre. Soil samples are collected (pre-planting, in-season, and post-harvesting) at different depths (from 0 to 36 in depth) and analyzed for NH_4 and NO3. Furthermore, bulbs and leaves are analyzed for their N concentration during the growing season to determine N uptake and removal in the different treatments. Onion yield, size, and quality are assessed at harvest.

RESULTS AND DISCUSSION

This summary shows results from the October 2021 to May 2022 growing season.

Twenty-two sprinkler irrigations were scheduled for all treatments from 10/29/2021 to 12/27/2021 with a total water applied of 9.55 in. Irrigation treatments were converted to drip in January 2022. Total applied irrigation water (sprinkler and drip systems) for the growing season ranged from 14.65 in (40% ETc) to 26.14 in (130% ETc). Total rain during the growing season was 0.18 in.

Average hourly soil water tension (SWT) records during germination and establishment periods (10/29/2021 – 1/31/2022) were near field capacity in the top one foot. During the irrigation treatments (2/1/2022-4/21/2022), the 100% and 130% ETc treatments were in the range of plant optimal growth (Table 1). Average records at 6- and 12- in depths from 40% and 70% ETc treatments indicated dryness.

Table 1. Average hourly soil water tension (cb) from 2/1/2022 to 4/21/2022.

Depth (in)	130% ETc	100% ETc	70% ETc	40% ETc
6	-31	-45	-49	-106
12	-23	-31	-67	-128
24	-13	-18	-24	-24

In general, N in biomass increased as irrigation and N fertilization increased (Table 2). Final residual N in soil tended to increase as N fertilization increased. We believe that nitrogen mineralization during the growing was around 60 lb/ac, which contributed to our observation that N output exceeded N input in all treatments.

Table 2. Nitrogen balance by irrigation and nitrogen treatments.

Treatment[1]	Initial residual N (lb/ac in 3 ft)	N fertilization (lb/ac)	Total input (lb/ac)	N in biomass (lb/ac)	Final residual N (lb/ac in 3 ft)	Total output (lb/ac)	Output – Input[2] (lb/ac)
I1-N1	140	0	140	110	132	241	101
I1-N2	140	75	215	127	419	545	330
I1-N3	140	150	290	115	639	754	463
I1-N4	140	225	365	130	933	1063	698
I2-N1	140	0	140	99	64	164	23
I2-N2	140	75	215	148	218	366	151
I2-N3	140	150	290	160	301	461	171
I2-N4	140	225	365	165	560	725	360
I3-N1	140	0	140	86	64	150	10
I3-N2	140	75	215	144	64	208	-7
I3-N3	140	150	290	186	126	312	22
I3-N4	140	225	365	158	173	331	-34
I4-N1	140	0	140	106	54	160	19
I4-N2	140	75	215	140	78	218	3
I4-N3	140	150	290	161	134	295	5
I4-N4	140	225	365	202	105	307	-58

[1]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; [2]positive values mean that there was some input not included in this budget, negative values indicate that N was lost.

Onion yields and bulb size distribution responded to irrigation and nitrogen rates (Table 3). The total yield reductions by 40%, 70%, and 100% ETc compared to 130% ETc were 56%, 38%, and 16%, respectively. High value sizes (jumbo, colossal, and super colossal) were highly affected by irrigation rates counting only 20% of the total yield in 40% ETc treatment and up to 70% of the total yield in 130% ETc irrigation treatment. The second largest N treatment (150 lbs per ac) reached the highest yield. In the two lowest N treatments (0 and 75 lbs per acre), most of the bulbs had a medium size.

Jumbo sizes were used for onion quality analysis. Onion bulb firmness and total soluble concentration (brix) ranged from 10.1 to 12.5 lbs and 7.2 to 7.9 %, respectively. Firmness and brix values responded to irrigation and nitrogen rates. Firmness and brix results increased with increasing irrigation. Firmness values decreased as N rates increased. The second largest N treatment (150 lbs per ac) yielded the highest brix result, but there were no differences in brix among the other N treatments.

Table 3. Effect of irrigation and nitrogen rates on fresh market onion size distributionx and total yield.

Treatments	Prepack	Medium	Jumbo	Colossal	Super Colossal	Total
	ton/acre					
Irrigation rate (I)						
130% ETc	2.4c[y]	7.8b	14.6a	5.7a	4.1a	34.6a
100% ETc	2.9bc	9.0ab	13.0a	3.5a	0.6b	29.0b
70% ETc	3.9ab	10.5a	6.7b	0.4b	0.0b	21.6c
40% ETc	4.8a	7.4b	3.0c	0.0b	0.0b	15.3d
P	0.000	0.000	0.000	0.000	0.000	0.000
Nitrogen rate (N)						
PN + 225 lb/ac	3.0b	8.6ab	10.9a	2.4ab	1.1b	26.1ab
PN +150 lb/ac	3.2b	8.7ab	10.6ab	3.1a	2.5a	28.0a
PN + 75 lb/ac	3.5b	9.6a	8.6bc	2.6ab	0.9b	25.2b
PN + 0 lb/ac	4.3a	7.9b	7.2c	1.5b	0.3b	21.2c
P	0.000	0.131	0.002	0.101	0.000	0.000
Interaction (IxN)						
P	0.400	0.484	0.007	0.183	0.000	0.002

[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 Duncan's multiple range test. ETc = crop evapotranspiration. PN = pre-plant nitrogen.

ACCOMPLISHMENTS

An undergraduate student from Universidad Autonoma de Baja California, Mexicali was trained in tasks related to this project. The student mentioned that she will continue to pursue career opportunities in Agronomy as result of the internship experience. Results from this project were presented during two virtual meetings and one in-person conference.

RECOMMENDATIONS

Adjust nitrogen applications based on mineral N measures in the top 1 foot. Proper irrigation management following information from soil water tension sensors installed in the top 1 foot will help to maximize yields and quality of onion production.

TAKE-HOME MESSAGE

Proper irrigation and nitrogen management (amount, timing, and system) will maximize yields, large size distribution, and quality of onion production in CA low desert region. Growers can take a conservative approach while managing irrigation and nitrogen fertilization of onions using drip irrigation systems.

ACKNOWLEDGEMENTS

We thank you CDFA FREP for providing funds for this project. We are grateful to the support of DREC staff and local growers (Mr. Larry Cox and Mr. John Hawk).

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

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INTRODUCTION

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

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

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

OBJECTIVES

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

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

DESCRIPTION

Work Plan Year 2 – Bok Choy, Water Spinach, Garlic Chives, and Lemongrass

Task 1: N and irrigation evaluations for water spinach, garlic chives (Santa Clara), and lemongrass (Fresno) were installed in the field in Spring 2022 and data collection is currently ongoing.

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

- Two high yielding fields of water spinach and garlic chives were selected in Santa Clara.

For lemongrass in Fresno, a replicated study was established at the Kearney Agricultural Research and Extension Center (KARE) comparing two levels of fertilizer treatment and an unfertilized control.

For year 2 bok choy field trials in Fresno, a replicated field study comparing different fertilizers treatments will be established at KARE in the fall season of 2022. Bok choy field trials are completed for Santa Clara region.

- During the current growing season, data collection is underway for above ground biomass, biomass N and soil nitrate evaluations 7 times for water spinach and lemongrass to generate N uptake curve. Each water spinach and garlic chives field were divided into three blocks (replicates). Separate samples are being taken from each block. For water spinach and garlic chives, the crops lack separation of biomass into marketable and unmarketable portions as all harvested biomass is marketable.
- At harvest, samples will be 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 portion of the crops (expressed in lbs/ton fresh weight).
- At key stages of crop development, diagnostic sampling of leaves will be done for analysis of total N.

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

- We installed flow meters in the above-mentioned fields.
- Using an infra-red camera, we are currently taking canopy photos of the crop every two weeks.
- We installed and are maintaining 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

In Santa Clara County work began on year 2 of water spinach and garlic chives in January of 2022. 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. Each field was divided into three blocks. Separate samples are being collected from each block. Currently we are collecting samples for conducting above ground biomass, biomass N and soil nitrate evaluations 7 times for water spinach and 12 times for garlic chives to generate N uptake curve. We are also collecting soil moisture data, and crop canopy data (Figure 1a and b).

We plan to present the initial findings of the bok choy trials at the 2022 FREP/WPH Nutrient Management Conference to held in Visalia that will be attended by over 150 people (UCCE Advisors and Specialists, Certified Crop Advisors, and agricultural production consulting personnel).

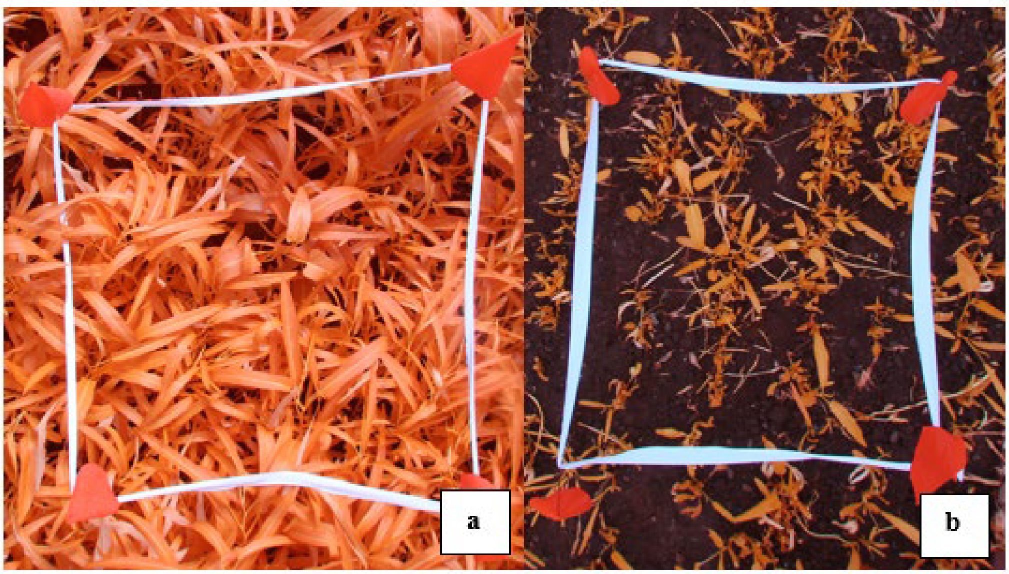

Figure 1a. Infrared crop canopy cover image of water spinach at 3 weeks after a harvest. 1b. Infra-red crop canopy cover image of water spinach 1-week after a harvest, the crop is harvested 7-10 times during the growing season.

In Fresno County, work began on year 1 of lemongrass in May 2022. Dataloggers were set up with network service, and dataloggers, tensiometers, and flow meters were installed in both plots. Three rows of lemongrass were planted, with four replications of each treatment: a) standard application of NPK fertilizer; b) reduced rate of NPK fertilizer; and c) unfertilized control. We are currently collecting samples for aboveground biomass, biomass N, and soil nitrate, and collecting soil moisture and crop canopy data.

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.

Project Title

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 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.

DESCRIPTION

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.

We are currently monitoring three replicated blocks of trees (3 trees per block, totaling 9 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.

A new nutrient BMP will be developed by integrating the findings from whole tree nutrient curves and early season tissue analysis. The combination of nutrient budget, seasonal changes in tree N content and in-season prediction of tissue nutrient status will help is developing a robust new fertilizer management tools for cherry growers of California.

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 six trees excavated in 2020-2021 for each cultivar. Canopy branches and large roots accounted for the majority of the biomass (~40-60%) in all orchards. Canopy branches and large roots also included a notable fraction of nutrients present in below- and aboveground tissues as shown in Figure 1.

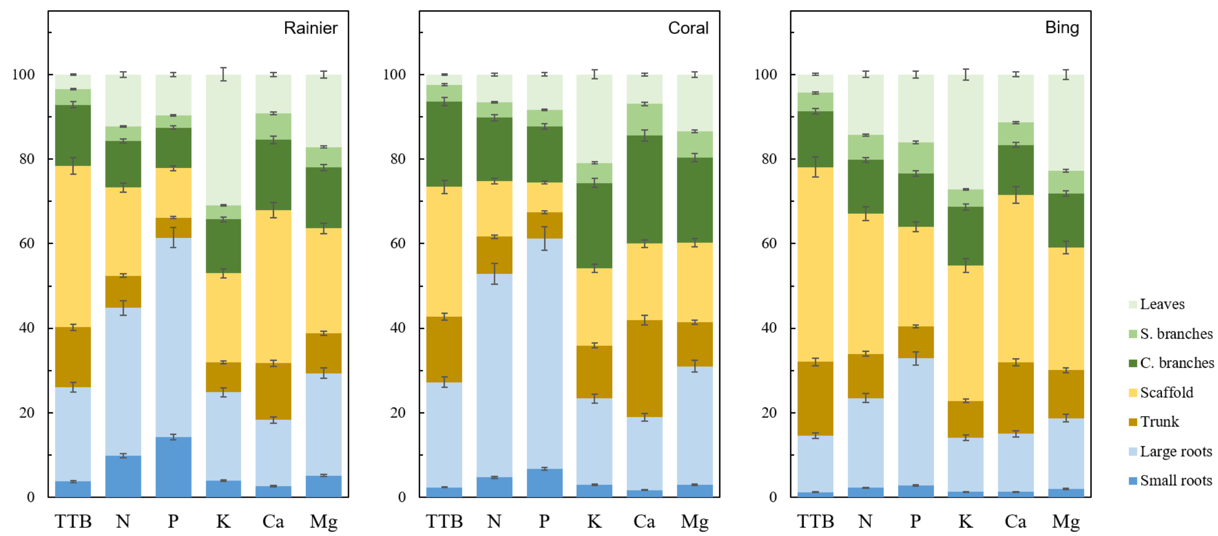

Figure 1. Tree partitioning (% of total) of total tree biomass (TTB) and macronutrients (N, P, K, Ca, and Mg) content. Data refer to cherry cultivars "Rainier", "Coral", and "Bing". Bars represent standard errors.

Dynamics of Nitrogen uptake during the season

Seasonal N content in perennial organs (trunk, scaffold, canopy branches and roots), and leaves of cherry trees are shown in Figure 2. Data refer to the average of 9 trees per orchard for each species.

The seasonal demand of N in cherry is high early in the season from March through September. 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 cherry trees from March to October. In contrast, from November to February, no net increase in nutrient was observed during this period.

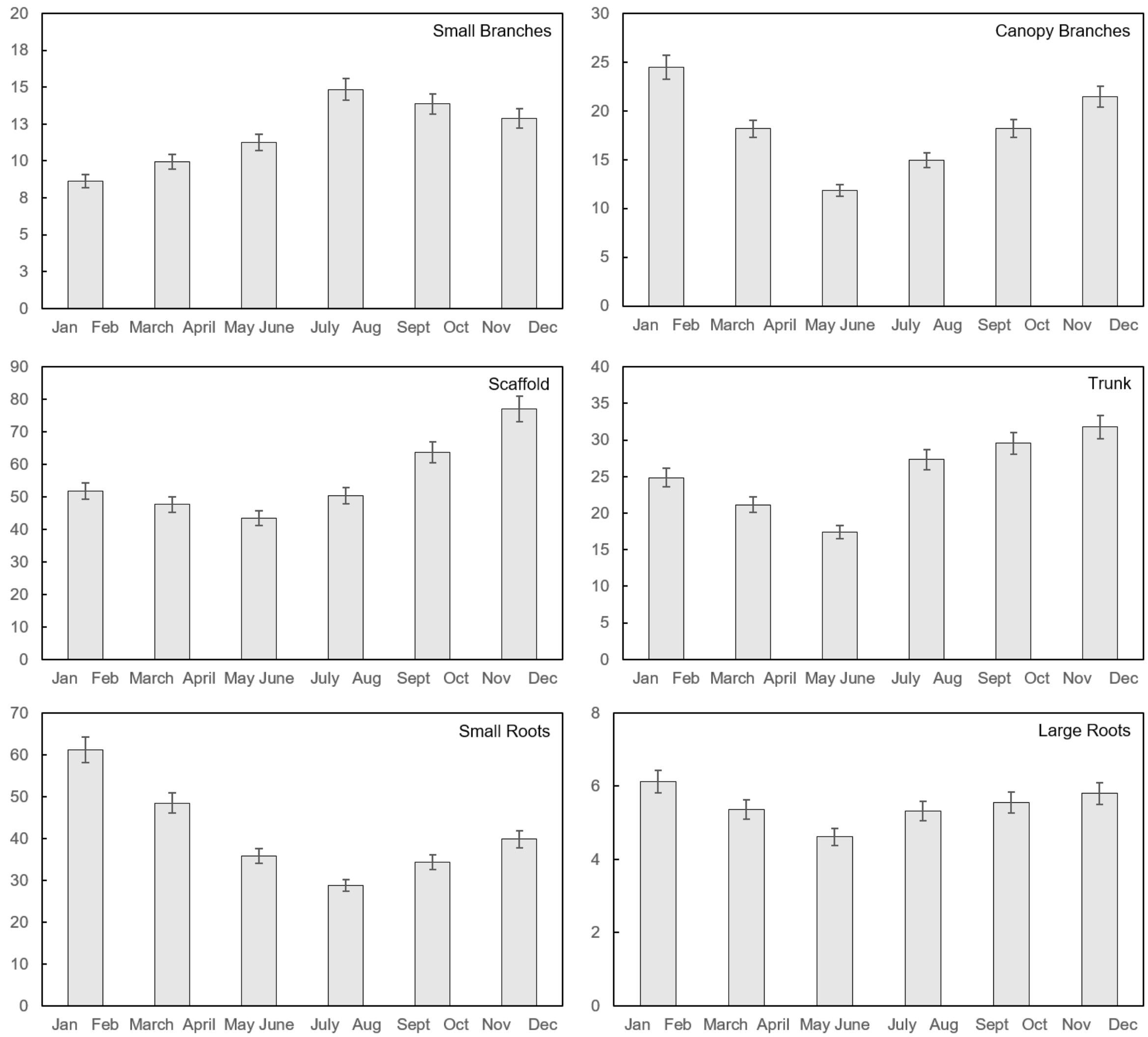

Figure 2. Seasonal trends in Nitrogen partitioning in fruits, leaves, and perennial organs (trunk, scaffold, canopy branches and roots) of mature cherry trees. The overall average is weighted for the number of observations in all trials (n = 27). Bars represent standard errors.

Nitrogen removal during the season

On average, preliminary data suggests that cherry offtake of N was estimated to be 2.52 lb. per 1000 lbs. of fresh fruit. In addition, N requirement for tree development (biomass accumulation) was estimated to be 28.3 lbs. acre (Table 1). Nitrogen use efficiency can be optimized by adjusting fertilization rate based on realistic, orchard specific yield, accounting for all N inputs and adjusting fertilization in response to spring nutrient status and yield estimates.

Table 1. Nitrogen removal in cherry cultivars. The overall average is weighted for the number of observations in each trial (*n* = 9).

Variety	*Removal at harvest (lbs N/1000 lbs of fruits)*
Rainier	2.74
Coral	2.73
Bing	2.32
Weighted Average	**2.59**

	Tree development (lbs N/acre)*
Rainier	28.99
Coral	28.41
Bing	27.51
Weighted Average	**28.30**

*Planting density of 120 trees per acre.

It is important to note that the data shown in this report is a **preliminary data** from year 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 (2020-2023) in cherry trees to develop a nutrient prediction model for cherry cultivars "Rainier", "Coral", and "Bing" to guide fertilizer application based on crop phenology for the State of California.

TAKE-HOME MESSAGE

As a best management practice, fertilizer application in a cherry orchard should be based on expected yield estimated at flowering and fruit set followed by analysis of leaves to diagnose any deficiency. The combination of nutrient budget determination, nutrient response information, improved sampling and monitoring strategies, and yield determination provide a theoretically sound and flexible approach to ensure high productivity and good environmental stewardship.

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

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INTRODUCTION

Organic production on the Central Coast (Monterey, Santa Cruz, and San Benito Counties) was valued at $919 million in 2020. 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 by August 2022.

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

- 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 are in progress to fill any gaps in database that need to be addressed experimentally. N mineralization from strawberries and Brussels sprout residues were examined and from artichoke residues and some liquid and solid organic fertilizers are to be examined.
- Developing a simple N mineralization model. We selected a simple model to calculate net N mineralization rates for soil organic matter and organic amendments. In the next step, the model will be calibrated to simulate N mineralization from crop residues including cover crops. The response of N mineralization to temperature was also expressed with a mathematical function. These equations will be used to calculate net N mineralization rates in daily time steps for each pool (SOM, organic fertilizers and amendments, and crop 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 would not change the N mineralization rates of SOM.
- 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. One trial completed and another one is in progress.
- Integrate the model into CropManage (CM). The model developed under Objective 2 is incorporated into CM. This process is ongoing.
- Conduct outreach and a demonstration field demonstration. We reported results at the Annual Salinas Valley Irrigation and Nutrient Management Meetings (2/23/2021, 2/23/2022. Virtual), and the Practical Training on Nitrogen Management in Organic Production of Vegetables and Strawberries (3/2/2021. Virtual).

RESULTS AND DISCUSSION

N mineralization of 4 different strawberry cultivar residues (Table 1) showed a similar pattern regardless of different C:N ratios ranging from 26 to 34. They immobilized soil inorganic N for the first 4 weeks, and then mineralized gradually, with 31 to 33% of the total N being mineralized at 24 weeks. After 24 weeks, N mineralization almost reached a plateau (Figure 1). This means that about 30-40 lb-N/A is mineralized from strawberry residues in typical commercial fields (Table 1).

Table 1. Biomass N in strawberry residues collected for the incubation trial.

#	Cultivar	Org /Conv	Planting month	Marketable yield lb/A	Plant density #/A	Dry biomass T/A	C:N ratio	Total N lb-N/A	Mineralizable N in 24 weeks lb-N/A
1	Albion	Organic	Nov. 2020	46,072	21,541	3.53	29	110	34.7
2	Proprietary 1	Conv.	Nov. 2020	89,280	14,191	4.56	30	131	43.6
3	Proprietary 2	Conv.	Nov. 2020	108,224	14,191	3.99	34	106	33.8
4	Monterey	Conv.	Oct. 2020	64,000	13,403	3.63	26	103	33.4

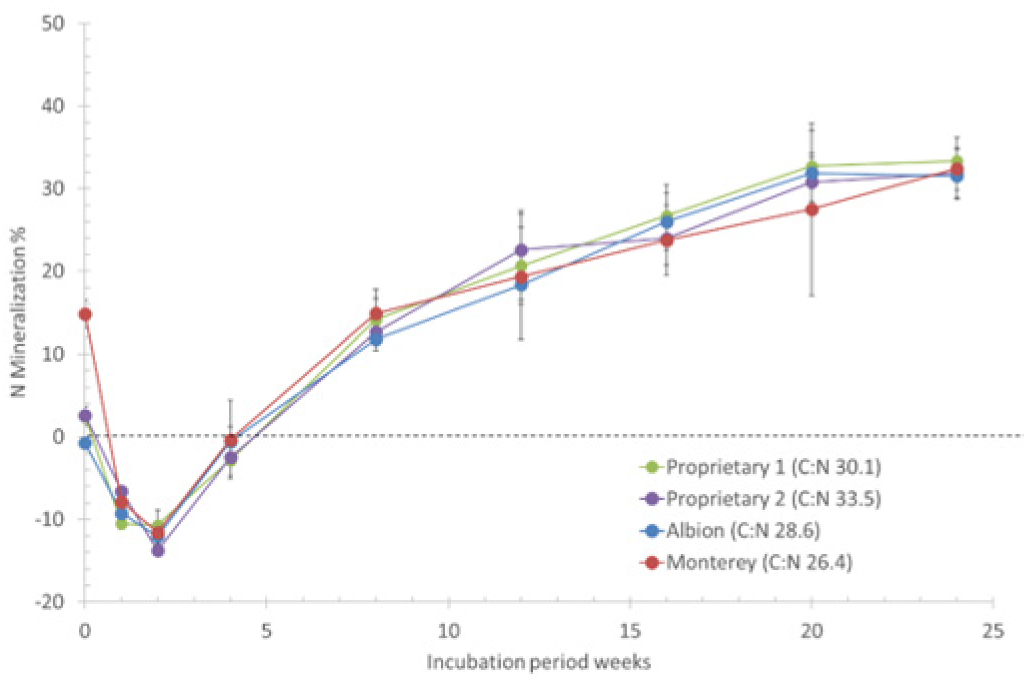

Figure 1. N mineralization patterns of strawberry residues.

Three Brussels sprout residues showed different N mineralization patterns depending on their C:N ratio (Table 2). Residues of the Gigantus variety with a C:N ratio of 15.9 mineralized fastest and reached 41% at 12 weeks, followed by two types of residues of the Gradius variety, one with a C:N ratio of 18.9 (29% at week 12), and the other with a C:N ratio of 24.4, which had the lowest mineralization rate of 17% at week 12. This pattern followed a known general trend of "the higher the C:N ratio, the lower the mineralization rate". However, the relationship between C:N ratios and N mineralization rates among Brussels sprout residues differed from the one among organic fertilizers (Lazicki et al., 2020), suggesting a different mineralization model is necessary for crop residues (and cover crops) containing more labile C than organic fertilizers.

Table 2. Biomass N in Brussels sprout residues collected for the incubation trial.

#	Variety	Org /Conv	Planting month	Marketable yield T/A	Plant density #/A	Dry biomass T/A	CN ratio	Total N lb-N/A	Mineralizable N in 20 weeks lb-N/A
1	Gigantus	Conv.	May 2021	14	14,520	4.32	16	210	85.2
2	Gradius	Conv.	July 2021	11	11,616	3.74	19	152	43.8
3	Gradius	Conv.	June 2021	11	13,403	3.34	24	109	19.1

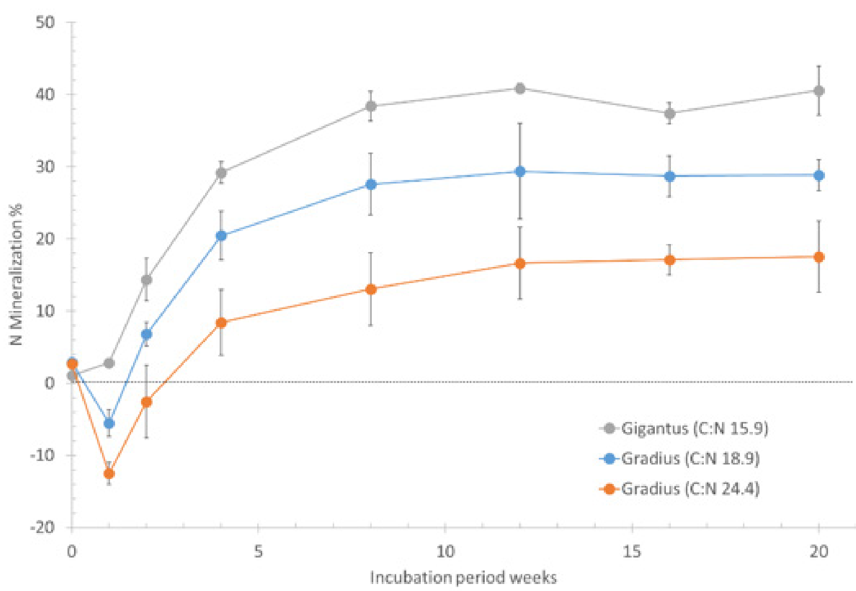

Figure 2. N mineralization patterns of Brussels sprout residues.

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Promoting the Adoption of CropManage to Optimize Nitrogen and Irrigation Use through Technical Assistance with Data Loggers and Cellular Modems for Spanish-speaking Growers in Santa Cruz and Monterey Counties

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INTRODUCTION

Irrigation and nitrogen management are challenging issues in berry and vegetable production on the California central coast. Many growers irrigate based on a fixed schedule throughout the irrigation season, generally resulting in over-application at the beginning of the crop cycle, and under-irrigations at the end of the cycle. Few growers keep track of the total irrigation water applied per crop cycle or per irrigation season. Under-irrigation results in lowered yields, while over-irrigation results in nitrate leaching, water quality impairment and aquifer overdraft, all of which expose growers to increasingly stringent water resource regulations. Similarly, growers often manage nitrogen application based on a schedule or on previous year's management. Some use pre-plant soil nitrogen testing and/or in-season soil testing, but there are uncertainties among growers on how to interpret the test results to inform fertilizer applications. CropManage is an online decision-support tool developed by the UC Cooperative Extension (https://cropmanage.ucanr.edu/) that assists growers with water and nitrogen management and record keeping (Cahn et al 2011 and 2015). The software has built-in crop water and nitrogen uptake models for various specialty crops (based on years of local research), and it uses customer-defined data inputs including evapotranspiration (ET) data from local weather stations, ranch settings, soil nitrogen tests and water use (flowmeter data), to generate recommendations based on crop demand at any given time. The adoption of CropManage has great potential for improving water and nitrogen application efficiency, particularly in vegetable and berry production, by reducing over-irrigation and thus leaching of nitrogen to the groundwater and by producing nitrogen application recommendations based on soil sampling.

OBJECTIVES

1. Increase understanding and trust in weather-based irrigation scheduling decision support tools among Spanish-speaking growers and irrigators.
2. Increase adoption of CropManage and implementation of recommendations among Spanish-speaking growers and irrigators.
3. Assess effectiveness and impact of CropManage adoption among participating growers and irrigators.

DESCRIPTION

The project approach is to promote and facilitate adoption of CropManage among Spanish-speaking berry and vegetable growers. While the CropManage software allows for manual data entry, the most efficient and practical way to optimize its value for irrigation water use tracking and recommendations in real-time is using flowmeters with telemetry (dataloggers and cellular communication) to automate data input. Through this project, RCD staff works with growers to install, manage, and troubleshoot equipment for data collection to be used in CropManage. Commercially available and relatively affordable flowmeters and dataloggers are installed at the fields of participating growers as part of a loaner program allowing them to try this technology and learn how to interpret and use the data it provides. Direct and sustained individual assistance in Spanish facilitates adoption and fosters trust in new management ideas and tools to adapt and improve existing cultural practices. Growers and irrigators are trained on how to install irrigation monitoring equipment in the field, how to collect and interpret a soil nitrate quick test, and how to setup an account, ranches and plantings on CropManage to access real-time recommendations for water and nitrogen management through computers or mobile devices. Each participating grower (and/or irrigator) is visited once or twice a month and receives a bi-weekly report comparing their current irrigation management (water use) with weather-based recommendations from CropManage. The irrigation reports include potential savings in water and money throughout the crop cycle. Upon request, growers and irrigators are also trained on how to conduct a soil nitrate quick test and enter the results into CropManage to obtain nitrogen application recommendations.

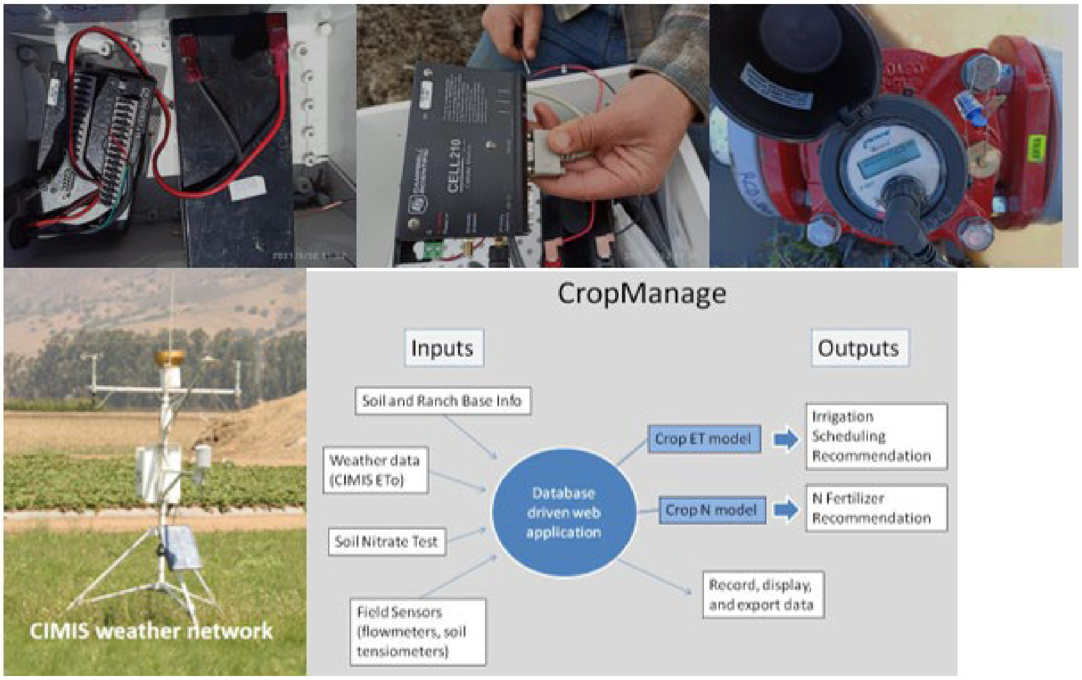

Figure 1. Irrigation monitoring equipment, weather station and CropManage flowchart.

RESULTS AND ACCOMPLISHMENTS

Direct individual assistance to growers:

Results for each task:

1. Sixteen Spanish speaking growers and/or irrigators (6 new, and 10 returning from last year) were identified and enrolled to receive technical assistance, monitoring, and one-on-one training on weather-based irrigation scheduling and use of CropManage as a decision support tool during the 2022 season.
2. Baseline practices and decision-making tools and process regarding irrigation scheduling were discussed with six new participants. These six growers have considerable experience, and they mostly rely on direct observations of plant vigor and soil moisture, as well as their practical experience to inform their irrigation scheduling. None of them had used CropManage before.
3. Irrigation monitoring equipment was installed on sixteen (16) different fields/plantings, and thirteen (13) growers and irrigators were introduced to basic concepts and tools related to weather-based irrigation scheduling and soil moisture management. Four growers/irrigators were introduced to CropManage for the first time, while the other nine continued to engage in one-on-one training and guided practice (continuing from last year). The project team's approach has helped to build confidence among growers to either adopt and independently use these tools or follow recommendations from them.
4. Participating growers received monthly or bimonthly visits to review monitoring data and CropManage recommendations to improve their irrigation scheduling. Three (3) participants are now actively using the CropManage

software to generate and follow recommendations to guide their irrigation scheduling. Others are only checking (and understanding) the periodic reports provided by the team and adjusting their schedules accordingly. But in most cases the combined use of field monitoring equipment (flowmeters, soil tensiometers and telemetry), CropManage recommendations, and guided technical assistance is resulting in a close match between applied and recommended water use among participating ranches. Growers who received assistance with nitrogen management and soil nitrate testing are gradually improving their understanding and confidence to calculate how much fertilizer N they need to apply based on current soil N levels and crop growth stage; however, most of them still require considerable handholding and revision of tools and concepts.

5 Periodic meetings with participating growers have demonstrated increasing confidence and ability to use weather-based irrigation scheduling monitoring tools and concepts; this is especially true among returning growers from last year, and it shows the importance of continued hand-holding and one-on-one assistance. Participating growers are paying attention to CropManage's retrospective feedback (on their past water management) and adjusting irrigation practices; accordingly, some of them have taken the next step to actively use the software to generate and interpret recommendations for future irrigation events.

Figure 2. Individual assistance to growers to monitor and inform irrigation scheduling and nitrogen management.

Education and Outreach:

1. UCANR and RCD co-hosted an in-person "CropManage Hands-on Training" for growers and irrigators - RCD staff provided simultaneous Spanish interpretation. The training had 15 attendees (mostly growers with some PCA's/CCA's and large ag company attendees).
2. RCDSCC, EcoFarm conference and Wild Farm Alliance co-hosted an in-person discussion at Live Earth Farm titled "Flyways, Wildways & Waterways Field Day". The talk was about Irrigation systems that reduce greenhouse gases and save water on the farm – as part of this presentation, RCD staff discussed assistance to Spanish speaking growers to facilitate adoption of weather-based irrigation scheduling tools and practices. There were 62 attendees (mostly growers, CCAs, educators, farm business advisors and agriculture students).

TAKE-HOME MESSAGE

CropManage is a powerful and relatively easy-to-use decision-support tool that can help growers improve their irrigation and nitrogen management. However, for it to be effective, irrigators and ranch managers must invest time to familiarize with and develop trust for the new tool. They require sustained individual assistance in a linguistically and culturally appropriate manner to ensure adequate data inputs, and to track, interpret and apply management recommendations from the software. This season's efforts have shown that sustained and consistent experience with the program, especially with appropriate support, builds improved on-farm management practices in relation to on-farm irrigation.

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ACKNOWLEDGEMENTS

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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 this transition by equipping CCAs with knowledge of best N management practices and increasing 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. Analyze exam responses and update study and exam materials accordingly
6. Deliver online course on a bi-annual basis to the general public

DESCRIPTION

Our project consisted 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 completed 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 finalized exam questions for review by our project partners into a standardized specialty exam to be hosted by American Society of Agronomy (ASA) and launched an online course. In February 2021, the first California Nitrogen Specialty exam was carried out by ASA followed by coordinated offerings of the course and exam in August 2021 and February and August 2022. To date the course recruited 146 students including both CCAs and other professional designations, and the 66 CCAs passed the exam as of February 2022.

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

Starting in November 2020 and through July 2022 on a bi-annual basis the UC Nitrogen Management Online Course was available to the public at http://ucanr.edu/NitrogenCourse and offers associated Nutrient Management (NM) and Soil and Water Management (SW) CCA CEU units for individual Modules and Discussion sections. In 2021 and 2022 we expanded the course to include a new Module on Barriers to Adoption based on the findings from FREP projects 16-0621-SA and 18-0596:

Module 1: Environmental Impacts of Nitrogen Loss - CEUs: 0.5 SW unit

Module 2: Nitrogen Cycling Soil Transformations - CEUs: 1.0 SW unit

Module 3: Nitrogen Cycling Plant Utilization - CEUs: 1.0 NM unit

Module 4: Nitrogen Sources - CEUs: 1.0 NM unit

Module 5: Nitrogen Budgeting - CEUs: 1.0 NM unit

Module 6: Irrigation and Nitrogen Management - CEUs: SW 1.5 unit

Module 7: California Cropping Systems - CEUs: 2.0 NM unit

Module 8: Barriers to Adoption - CEUs: 2.0 NM unit

Discussion 1: Nutrient Management I - CEUs: 1.0 NM unit

Discussion 2: Soil & Water Management I - CEUs: 1.0 SW unit

TAKE-HOME MESSAGE

Our 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 launched our online course in 2020, and offered it in 2021, 2022 and will again in 2023. Future registration can be found at http://ucanr.edu/NitrogenCourse. Four exam sessions were made available to the public in February and August 2021 and 2022, and will continue into 2023. To find more information on the California N Specialty visit http://www.certifiedcropadviser.org/exams/

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SUMMARIES OF CURRENT FREP PROJECTS

Development of Site-Specific Nitrogen Fertilization Recommendations for Annual Crops

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INTRODUCTION

To minimize nitrate leaching to groundwater while maintaining high yields, growers need reliable tools to determine optimal rates and timing of N applications. These tools should be based on field-specific information, including availability of N from non-fertilizer sources, such as residual soil nitrate, nitrate in the irrigation water and N mineralization from soil organic matter (SOM).

In a recent project, we found that combining measures of soil texture as well as SOM content and quality can provide accurate site-specific N mineralization estimates. Particulate organic matter and fluorescein diacetate (FDA) hydrolysis, a measure for microbial activity, were good measures for SOM quality. However, these lab-based estimates for N mineralization have not yet been validated in field trials. Furthermore, these SOM quality methods require several steps and may not be attractive to commercial soil test labs, where growers and consultants routinely send their samples. Another method, Fourier transform infrared spectroscopy (FTIR), has been shown to be useful to identify labile SOM fractions that are related to N mineralization. Infrared spectroscopy is a rapid and cost-effective method that is already commonly used to characterize feed and forage samples. Therefore, the personnel of many analytical labs are already familiar with the principles of infrared spectroscopy, which can greatly facilitate adoption by commercial labs. We hypothesize that FTIR can be used to assess soil quality measures such as particulate organic matter and FDA hydrolysis. The results can then be used to generate site-specific recommendations for calculating N mineralization from SOM, improving the precision of N management planning budgets for annual crop.

OBJECTIVES

The goal of the proposed project is to develop robust site-specific estimates of the contribution of N mineralization to the plant-available N pool for different regions in California and incorporate them into user-friendly online N fertilization calculators. Specific objectives are:

1. 1 Validate N mineralization estimates in field trials in the Central Valley, including the Delta, as well as in the Tulelake basin.
2. 2 Characterize the chemical composition of SOM using FTIR and correlate it to soil organic matter quality and N mineralization.
3. 3 Develop user-friendly and site-specific online N fertilization calculators for different crops.

DESCRIPTION

Field trials were conducted in commercial fields in the Central Valley, including the Delta, as well as in the Tulelake basin in 2021 and 2022. Two treatments were included: (i) no N fertilizer applications in plots within the field and (ii) grower's standard N management. Soil samples were collected pre-plant from the top four feet of the profile in one-foot increments and analyzed for soil properties, including residual mineral N content and N mineralization potential. Post-harvest soil samples were collected from the same depths and analyzed for residual mineral N content. The aboveground biomass of crops from fertilized areas within the fields was harvested in 3-week intervals to determine dry matter biomass and its N concentration. This information was used to develop seasonal N uptake curves and N uptake per unit yield. Irrigation water samples were analyzed to determine the input of N with the irrigation water. At harvest, the aboveground biomass and its N concentration were also determined in the unfertilized plots. With data collected from the unfertilized plots, the capacity of the soil to provide plant-available N through mineralization was calculated.

The FTIR-based method to assess soil organic matter quality will be conducted through fall 2022 and winter 2023. Air-dried samples collected from more than 70 fields across northern and central California in previous and ongoing projects will be used. Multivariate regression analysis will be used to estimate N mineralization based on soil texture, SOM content and FTIR-based measurements of SOM composition. The estimates will then be validated with the results of the field trials.

The online N calculators will be developed with site-specific features based on the results of this study.

RESULTS AND DISCUSSION

Field trials were conducted in 12 fields in 2021 and another 11 fields in 2022. Plant analyses for the 2021 sites have been completed. Nitrogen uptake for all crops followed an S-shaped pattern, with low uptake during the first 3-4 weeks, followed by rapid uptake during the vegetative growth phase and low uptake during the last third of the season (Figure 1). During vegetative growth, the increase in aboveground biomass N reached 3.7, 4.1, 5.2 and 6.4 lb ac-1 day-1 for sunflower, cotton, corn and spring wheat, respectively.

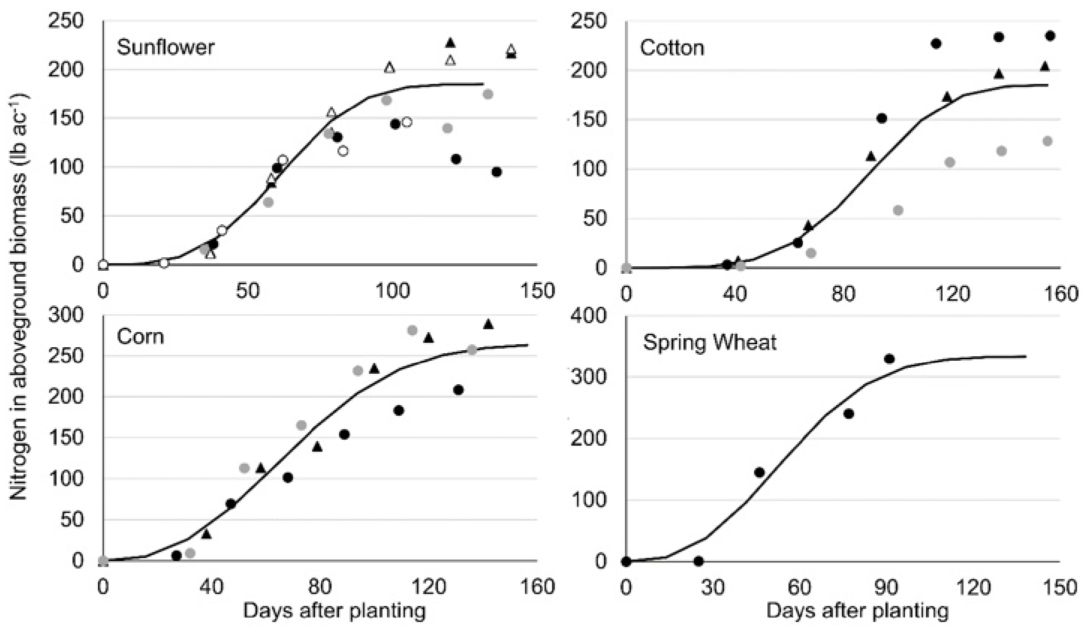

Figure 1: Increase in total nitrogen in the aboveground biomass of sunflower, cotton, corn, and spring wheat grown in fields in Northern and Central California in 2021. Different symbols represent different fields.

Total N in the aboveground biomass averaged 208, 185, 260, and 334 lb ac-1 at harvest. These values are based on a small number of fields from the 2021 season. By the end of the project, we will have a much more robust dataset from three seasons.

Preliminary N budgets for five Sacramento Valley sunflower fields from the 2021 season have been calculated so far. As an example, the results for Site 3 are shown in Figure 2. Seasonal N mineralization rates in the top 4 ft of the profile ranged from 70 to 136 lb ac-1 at these sites (Table 1). These estimates include atmospheric deposition. Laboratory incubation with samples from all 4 ft indicated that on average 70% of the total was mineralized in the top 2 ft. of the soil profile. Assuming that sunflowers take up most N in the top 2 ft of the profile, the N mineralization during the growing season averaged 70 lb ac-1, or 0.54 lb ac-1 day-1

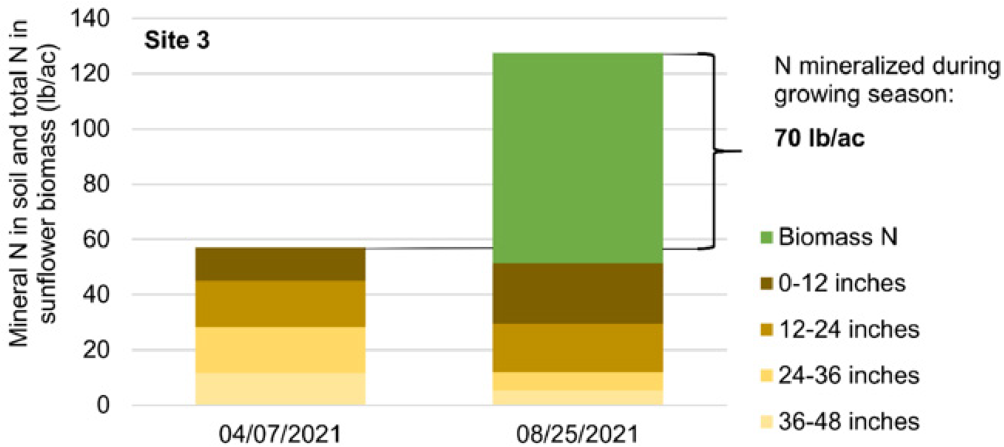

Figure 2: Preliminary N budget for Site 3 from the 2021 season. Inputs on the left include pre-plant residual soil mineral N. No N was applied with fertilizer or irrigation water at this site. Outputs on the right include residual mineral N and N in the aboveground biomass at the end of the season. The difference between inputs and outputs is used as an estimate for N mineralization. Atmospheric deposition during the growing season is not included as an input.

Table 1: Nitrogen mineralization estimates based on pre-plant and post-harvest soil samples, as well as biomass N. The estimated proportion of N mineralized in the top 2 feet of the profile is based on laboratory incubations of samples from each soil layer.

Site	Length of season	N mineralization based on budget	N mineralized in top 2 ft.		
	Days	lb ac^{-1}	% of total	lb ac^{-1}	lb ac^{-1} day^{-1}
1	146	83	80%	67	0.46
2	146	109	76%	83	0.57
3	140	70	58%	41	0.29
4	139	87	60%	52	0.37
5	105	136	78%	106	1.01
Average	**135**	**97**	**70%**	**70**	**0.54**

in that layer. With most N taken up during the first 100 days of the season (Figure 1), N mineralization from SOM contributed on average 54 lb ac-1 of crop-available N. These estimates will be refined when data from more sites are available.

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Efficient Water and Nitrogen Management Practices for Mixed Leafy Baby Green

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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), and baby spinach. 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 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-120-day lettuce crops. We had 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 were of concern since over 35% of the industry has converted to these high-density large bed production systems and this acreage continues to grow.

OBJECTIVES

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

DESCRIPTION

During winter-springs of 2019 through 2022, we completed elements of Tasks 1 through 6. Task 1 was largely associated with collecting background data on water and N requirements for baby spinach and spring mix. Tasks 2, 3 ,4, and 5, included evaluations in conventional and organic baby spinach and conventional and organic spring mix production systems and we began "Crop Manage" evaluations. In 2021-2022 Task 6 focused on optimizing timing because we found that simply using "Crop Manage alone with current N application practices, would occasionally fall short of achieving the N recovery thresholds being sought by the CWQCB.

Evapotranspiration was measured using Eddy Covariance methodology (ECV) (Figure 1). Salt balance was monitored using sensors and data loggers during the season and

Figure 1. Typical Eddy covariance set up in all fields.

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, and the VENuS microsatellite data. 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. The fertigation (Task 6) experiments are shown in Tables 1 and 2. Timed N treatments ranged from 33 to 131 kg N/ha seasonal totals but were split fertigation based on forecasted N accumulation algorithms.

RESULTS AND DISCUSSION

An example of ET and data collected are shown for one site in Figure 2. Seasonal water application efficiencies for baby spring mix and spinach are generally high. Water application efficiencies ranged from 70 to 100% and averaged about 95%. A leaching fraction of only 5% would not be sufficient for managing salt for sensitive crops grown in rotation with baby spinach and spring mix, such as lettuce. This observation is generally consistent with the soil salinity which generally increases during the production season (Figure 3). Growers in the desert often restore salt balance in a summer flood irrigation to minimize leaching during the season so that they can better manage N in-season. However, these irrigation efficiencies are at the limit when considering water distribution uniformities (DU). DU ranged from 44 to 96% with a mean and medium of 77% (data not shown). These uniformities are generally good but less than perfect. Thus, even if required leaching for salt is forgone until after harvest, some irrigation beyond ETc is required in-season so that portions of the field are not shorted. Interestingly, "Crop Manage" irrigations closely aligned with those applied to spring mix but results for spinach were less consistent (Figure 4). Actual irrigations were close to ET replacement and some adjustment in some of the parameters in "CropManage" are needed before this management tool can be implemented in the desert. As the result of field studies conducted in 2019 and 2020 and our direct measurement of crop ET, growth, and corresponding satellite measured NDVI, we now have the data to make these modifications for spring mix and baby spinach. Amounts of N applied ranged from 74 to 200 kg N/ha. However, crops removals ranged from 44 to 101 kg N/ha. If we express N recovery by crop removal, we average below 50%. Another way to look at this is relative to goals set by the California Water Quality Control Boards (CWQCB). Their goal is achieving a threshold of 50 kg N/A per year over crop removal (A-R <50 lbs N/A). In most of these evaluations, N applied was more than 50 lbs/A over crop removal. As noted previously, these poor recoveries are not due to irrigation inefficiencies. Interestingly, "CropManage" would have called for 0 to 47% less N than was applied. While we believe these rates are possible without yield reduction, this reduction would still fall a little short of the thresholds being sought by the CWQCB in some instances. Therefore, we also must seek further strategies for improved N efficiencies. It should be noted that spring mix and spinach generally show exponential growth and N accumulation (data not shown). The yields result from fertigation studies conducted in 2021-2022 show that timing N fertigation is a viable strategy for optimizing N recovery. In most situations, yields were maximized at lower rates of N than typically used in commercial settings (Table 2).

ACCOMPLISHMENTS

We completed field work associated with tasks 1, 2, 3, 4, 5, and 6.

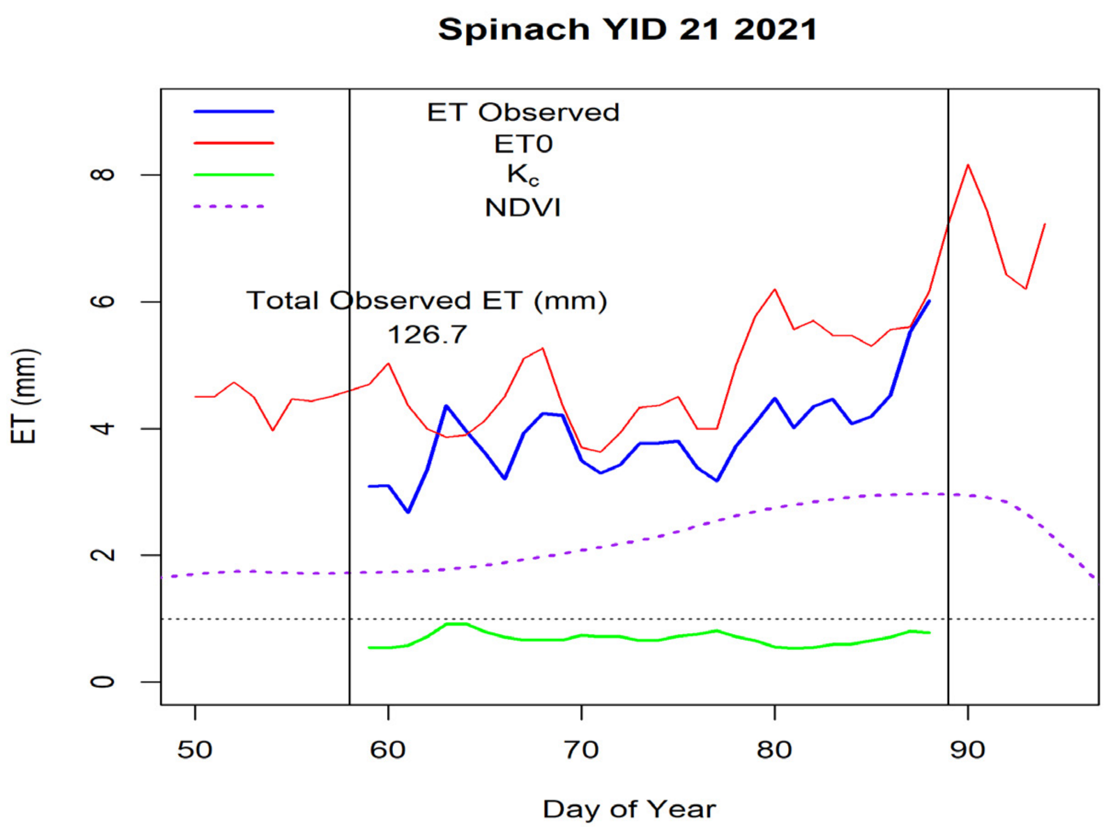

Figure 2. Measured crop ET by eddy covariance, ETo generated from nearby AZMET, satellite generated NDVI, and calculated crop coefficient for site YID 21.

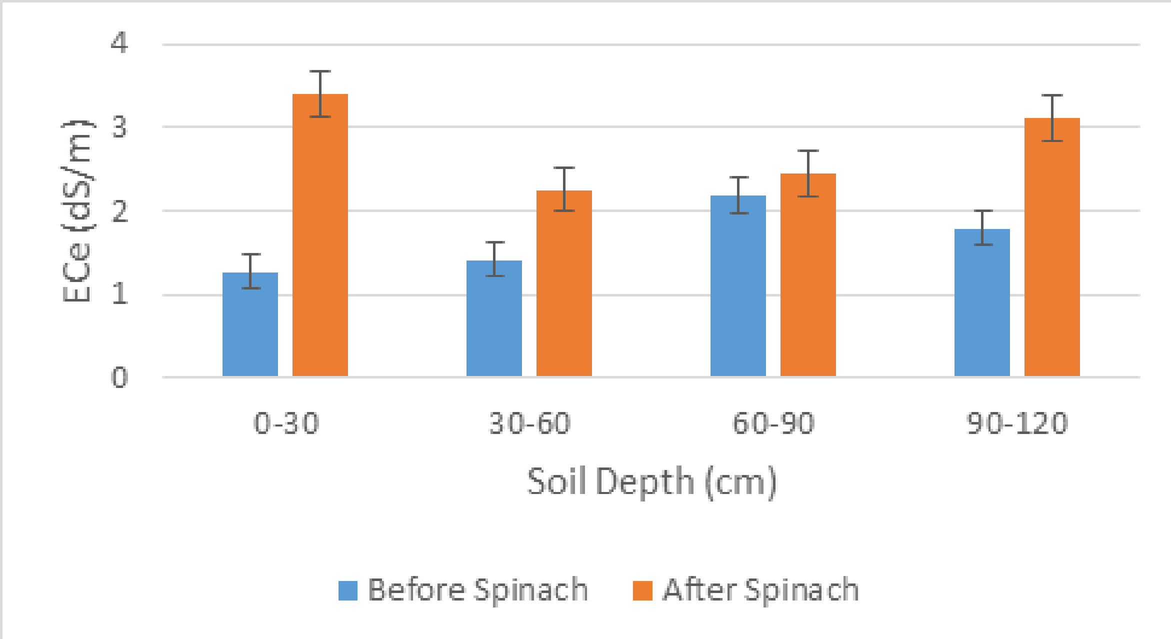

Figure 3. Salinity in soil before and after spinach for one site (YID 21).

Table 1. Fertigation studies conducted or scheduled for Fall 21, Fall-Winter, and Spring 22 at research center.

Experiment	Task	Crop	Wet Date	Harvest Date
Fall 21a	6	Spring Mix	Oct. 19. 2021	Nov. 21, 2021
Fall 21b	6	Baby Spinach	Oct. 19. 2021	Nov. 21, 2021
Fall-Winter 21a	6	Spring Mix	Nov. 22, 2021	Jan. 24, 2022
Fall Winter 21b	6	Baby Spinach	Nov. 22, 2021	Jan. 24, 2022
Winter 22a	6	Spring Mix	Feb. 8, 2022	April 1, 2022
Winter 22b	6	Baby Spinach	Feb. 8, 2022	April 1, 2022

Table 2. Yields of spring mix and baby spinach to fertigation.

Experiment	N Rate	Spring Mix	Spinach
		Yield (MT/ha)	
Fall 2021	33	14.2	16.2
	55	20.2	20.7
	75	16.6	18.7
	83	23.1	18.1
	131	16.6	22.3
	LSD	4.0	4.2
Fall Winter 2021	33	8.2	12.4
	55	19.0	14.0
	75	15.8	12.6
	83	20.3	18.0
	131	17.8	14.6
	LSD	6.7	3.4
Winter Spring 2022	33	2.1	4.0
	47	8.7	4.1
	61	5.0	3.4
	61	5.7	3.3
	89	9.7	4.1
	LSD	2.4	NS

LSD=Least significant difference $P<0.05$. NS=not significant.

RECOMMENDATIONS

Because these crops are irrigated by sprinklers, season long and ET replacement is easily achieved, and current water application efficiencies are often high. Thus, further improvements in N utilization efficiency will be largely based on implementing better timing of N fertilization.

ACKNOWLEDGEMENTS

We gratefully acknowledge support of the FREP program for sponsoring this work. We also appreciate the cooperation of participating growers.

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

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INTRODUCTION

San Joaquin Valley cotton growers aim for high yields to be able to cover production costs and pay for increasing costs of inputs such as irrigation water, fertilizer, and crop protection chemicals. These yield goals can be a significant incentive to apply high rates of fertilizer N to increase chances of achieving high yields, however, elevated amounts of applied fertilizer nitrogen (N) bring the added risk of excess N applications and groundwater contamination. Regulatory decisions made by State Water Board and other agencies raise the likelihood of a range of efforts to require more tightly managed use of fertilizer and manure-based N sources. Nitrogen management programs that are in various stages of development and implementation help point out some knowledge gaps we have regarding crop N responses, uptake and removal under a range of production conditions. Pima cotton is one relatively large acreage crop for which there has been limited data on responses to N fertilizer, or on plant N uptake and removal with harvest. Since Pima cotton can be quite different in growth habit from Upland cotton, we have conducted research center and grower site trials to evaluate responses of modern Pima cultivars to N management under practices conducive to high yields.

OBJECTIVES

1. Evaluate for high-yield potential Pima cotton cultivars the impacts of N application amount, variety and irrigation method (subsurface drip versus furrow) on total plant N uptake and harvest removal, including a comparison with Upland varieties.

2 Utilizing multiple grower farm sites with moderate to high yield potential and representing different soil types, determine total above-ground plant N uptake at open-boll timing, and N removal with harvest (measured as N content of seed, lint, gin trash) to better understand Pima N removal.

DESCRIPTION

For the N-fertilizer-rate study, matching N management trials were conducted under both furrow irrigation and subsurface drip irrigation all three years at University of CA West Side REC, clay loam soil. Row width was 40 inches, and the cotton N response study utilized two Pima cultivars (Phy-881RF, DP348RF) and two Upland cultivars (Phy764 WRF, DP 1845 B2RF) for comparison of responses. In the N-rate study, variety DP 347 RF had to be substituted in 2021due to changes in seed availability. A pre-plant irrigation of approximately 5-6 inches was applied in 2019 and 2020 in February or March to supply planting moisture. With a zero percent Westlands Water District allocation, plus problems with our deep irrigation water well, a lower pre-plant irrigation amount (about 2 to 2 ½ inches of water) was used, but when our deep well was restored to operation (early June), we provided 3 inches additional supplemental water in an early irrigation in furrow irrigated plots as well as in an earlier start in the subsurface drip irrigated plots.

Experiment sites were changed each year to place trials in field sites with uniform, low residual soil nitrate levels. Matching experiments were set up to apply N fertilizer amounts to achieve same total N application amounts under subsurface drip irrigation (SDI) and furrow irrigation (F). In the SDI plots, drip tape with 0.27 gph emitters spaced 12 inches apart were installed at a depth of 8-10 inches below the bed centers, with the system operated 2 times/week during lower evapotranspiration (ET) time of the year, and 3 times/week during higher ET periods. No pre-plant N fertilizer applications were made in either irrigation treatment. Pre-plant residual soil nitrate levels in the upper two feet of soil ranged from 26 to 45 lbs. NO3-N/acre at this site across reps across the years. N fertilizer applications in the SDI plots were initiated at the 7-9 node stage in the cotton plants (about the first week of June), and weekly applications of nitrogen (urea) were injected to match estimated plant uptake during rapid growth phases, with the final applications made the 3rd week of August (2019) or during the 4th week of August (2020 and 2021). N fertilizer applications in furrow irrigated plots were split in timing and amount, with the first half applied just prior to the first within-season irrigation in late-May/early June, and the second half applied just prior to the second in-season irrigation about 4 weeks later. Fertilizer application amounts are shown in Table 1. Pre-plant and post-harvest soil samples were collected to a depth of 8 feet in select treatments and cultivars to determine if any applied N treatments resulted in net depletion or accumulation of soil nitrate within the soil profile.

Whole above-ground plant samples were collected approximately 3 weeks prior to harvest each year and analyzed for N content in select cultivars as an approximation of peak plant N uptake, and seedcotton was collected at harvest timing and analyzed to assess harvest removal of N with cotton seed and lint removed during harvest.

RESULTS AND DISCUSSION

Seedcotton yields for Pima and Upland cotton cultivars in N rate response studies under drip and furrow irrigation at the West Side REC in general peaked at the N-75 treatment levels (data not shown). With Pima cultivars, additional applied N at the

Table 1. Applied nitrogen amounts in furrow and subsurface drip (SDI) irrigated nitrogen rate trials at teh Univ. CA West Side REC in 2020. Similar rates of applied N fertilizer were applied across treatments in 2019 and 2021.

Irrigation Method	Total applied fertilizer N (lbs/acre)				
	Trt N-0	Trt N-50	Trt N-75	Trt N-100	Trt N-125
Furrow	0	61	106	153	200
SDI	0	62	107	154	201

N-100 level did not significantly affect yields in either cultivar under furrow irrigation in the 2020 study with lower yield levels than 2019, but did increase yield of one cultivar in 2020 and one Upland cultivar in 2019. Higher N applications in the N-125 treatment either reduced yields (furrow irrigated treatments) or did not significantly impact under SDI (although a non-significant trend toward lower yields at N-125 level also existed). Plant height and leaf area were higher in N-125 treatments, suggesting added vegetative growth that was not beneficial to yields of reproductive tissue (bolls/seed/lint).

In the WSREC study, petiole nitrate-N values in the N-0 and N-50 treatments (which had significantly lower yields than the N-75 and N-100 treatments in both 2019 and 2020) were significantly lower during most of the growing season during mid-squaring to peak bloom plus 2 weeks period. The N-75 treatment was getting close to what we feel is borderline-deficient range by early open boll stage. Petiole nitrate-N values for furrow irrigated plots were generally about 20 to 25% higher than in SDI plots prior to peak bloom, and more variable but still 10 to 15% higher from peak bloom to early open boll. Above-ground whole plant samples were collected in plots of N-50, N-75 and N-100 treatments in all cultivars at peak biomass timing, plus N-0 and N-125 treatments in Phy-881 RF.

Seedcotton samples were collected at harvest in the same plots during harvests, with samples ginned on mini-gins and then acid-delinted prior to grinding in a Wiley mill. Some estimates of N removal per bale of lint removed with cotton harvests are shown in Table 2 for Pima grown in the grower and REC variety trial sites. Some noted variation in amount of N removed per bale was evident across years and sites, with one pattern seen being higher N removal/bale in lower-yielding fields.

TAKE-HOME MESSAGE

These studies represent a range of Pima cotton yield levels across different soil types, and will provide improved estimates of peak plant N above-ground uptake and N removal with harvest estimates for Pima cotton across this range of production conditions.

Table 2. Seedcotton yields and nitrogen (N) removal (in seed) per bale of cotton lint in Pima variety trial sites sampled for cotton nitrogen trial in 2019, 2020, 2021. Yield values followed by a different letter at each location were different at P<0.05 level by LSD 0.05 analyses.

Location	Variety	2019 Seedcotton yield (lbs/ac)	2020 Seedcotton yield (lbs/ac)	2021 Seedcotton yield (lbs/ac)	2019 N per bale (500 lbs of lint)	2020 N per bale (500 lbs of lint)	2021 N per bale (500 lbs of lint)
West Side REC	DP 341 RF*	4417 a	4400 a	2119 a	29.4	31.6	36.6
**data from Pima variety trial, not N rate study*	DP 348 RF **	4020 a	4071 a	2472 a	29.1	30.7	34.9
	PHY 881 RF	4092 a	4168 a	2313 a	28.1	31.9	35.9
Kings County	DP 341 RF*	4953 b	5641 b	4451 b	30.0	28.3	33.2
	DP 348 RF **	5120 a	5745 b	5138 a	32.1	31.2	31.9
	PHY 881 RF	5164 a	5996 ab	4467 b	30.8	29.6	32.5
Fresno County	DP 341 RF*	5755 a	4736 b	6109 b	28.6	30.5	29.7
	DP 348 RF **	5326 a	5048 ab	6505 a	28.7	28.1	29.4
	PHY 881 RF	5345 a	4914 b	5620 c	28.3	29.8	30.3
Kern Co.	DP 341 RF*	2864 a	4323 a	5634 a	26.7	31.5	29.4
	DP 348 RF **	2225 b	4088 a	5846 a	28.1	32.2	32.7
	PHY 881 RF	2881 a	4227 a	5595 a	25.8	29.4	31.0
Merced Co.	DP 341 RF*	3132 a	3566 a	3226 a	30.8	30.9	34.1
	DP 348 RF **	2900 ab	3134 ab	3294 a	31.2	31.2	32.7
	PHY 881 RF	2730 b	3073 b	3418 a	30.9	32.4	32.0

* some cotton varieties sampled / planted differed by on-farm location due to seed availability.
"" DP 347 was substituted for DP-341 in 2021, and DP-359 substituted for DP-348 due to changes in availability of planting seed.*

ACKNOWLEDGEMENTS

These trials have been supported by California Department of Food and Agriculture Fertilizer Research Education Program (CDFA-FREP) and the California Cotton Ginners and Growers Association, and their support is gratefully acknowledged. Multiple cotton growers and their staff and staff of the University of CA West Side REC have contributed greatly to our ability to do this work, and that support is appreciated. Finally, we are grateful to our dedicated field research staff (Jorge Angeles, Mark Keeley, Wen Flores, Miguel Mariscal, Jose Ramos) for their hard work on this study.

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 4-8 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 amendments (e.g., > 40) to temporarily immobilize residual soil nitrate during the rainiest months of the winter fallow. Growers commonly apply compost in the fall 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 early studies, we observed that 5 – 10 tons/A of almond shells ground to pass through a 2 mm screen and glycerol at 2.5 tons/A 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 more costly than composts which would reduce the adoption of this practice. In the last couple of years, we have evaluated lower cost, locally sourced high C:N ratio wood amendment called forest mulch. However, this material has not successfully immobilized nitrate because it was too expensive to grind to a smaller particle size and in addition, the carbon was less labile and did not react quick enough to immobilize the nitrate pool. We have concluded that the carbon in almond shells is ideal for immobilizing the pool of soil nitrate and the challenge is to find the ideal particle size and application rate that can immobilize adequately, but not be too expensive to grind. Our ultimate goal is to provide a best management practice (BMP) to reduce nitrate leaching during the winter fallow period and improve water quality and help growers obtain a credit for the use of high carbon amendments from the Regional Water Quality Control Board.

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

- Identify and select locally sourced high C:N ratio green waste materials. We evaluated locally sourced high C material but have not found it to be labile enough to quickly and effectively sequester the pool of nitrate in the soil during the winter fallow. We are reevaluating almond shells as the ideal C sequestration material. The C is highly labile, and the key is getting the appropriate particle size and application rate that not too expensive but that provides sufficient surface area to interact with the soil microbes. The goal is work out an economical strategy to provide the most effective material and rate.
- Conduct large scale field trials with cooperating growers in commercial vegetable production fields. A large-scale field trial was conducted in a commercial lettuce field in which 5 and 10 tons/A of forest mulch and unground almond shells were applied. Soil nitrate samples down to three feet deep were collected each month during the winter fallow period and during the subsequent lettuce crop.
- Evaluate the magnitude and longevity of the impact of the high C:N materials on subsequent crop production. After seeding the starter fertilizer 6-15-0 was applied to the bed tops at three rates: 7.8, 15.5 and 31.2 lbs N/acre. Soil nitrate and yield evaluations were conducted to determine detrimental effects of the compost on the lettuce crop.

- 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.
- 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 were calculated.
- Conduct grower outreach through blogs, trade journal articles and grower meetings. Results of this project were presented at the 2022 Salinas Valley Irrigation and Nutrient Management Meeting, and an article was included in the UCCE Salinas Valley Agriculture Blog.

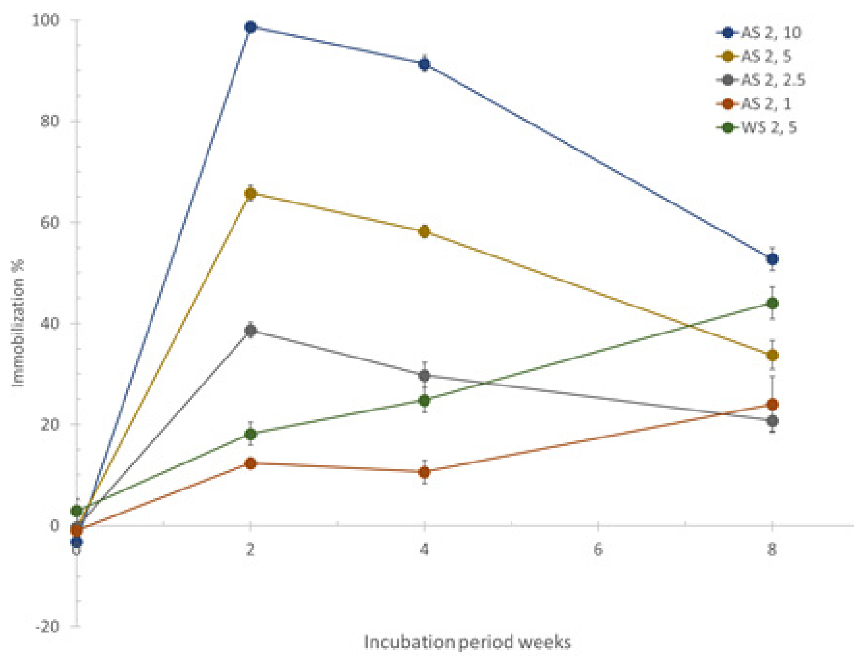

Figure 1. N immobilization by 2 mm passed almond shells at 1 (AS 2, 1), 2.5 (AS 2, 2.5), 5 (AS 2, 5), and 10 T/A (AS 2, 10) and 2 mm passed walnut shells at 5 T/A (WS 2, 5).

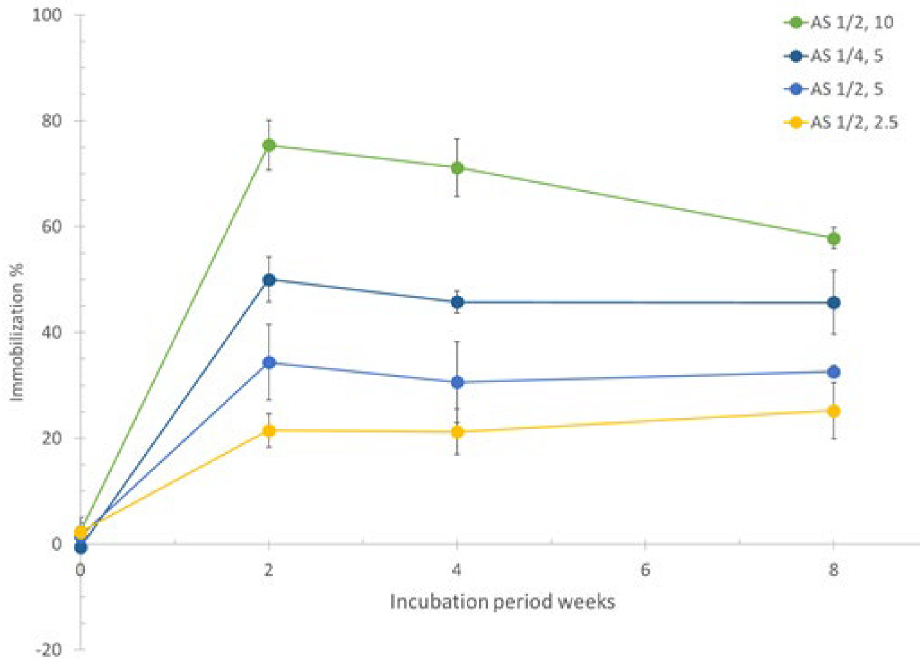

Figure 2. N immobilization by ½" or ¼" passed almond shells at 2.5 (AS ½, 2.5), 5 (AS ½, 5 or AS ¼, 5), and 10 T/A (AS ½, 10).

RESULTS AND DISCUSSION

We determined that high carbon amendment called "forest mulch" which is made from tree trunks and branches is too recalcitrant to quickly and effectively immobilize soil nitrate in winter fallow vegetable fields. We have now changed the focus of our efforts to reevaluate almond shells. The C in almond shells is labile and is an ideal material for immobilizing nitrate. The challenge is to grind it to ideal particle sizes and to determine its optimum application rate that effectively provides sufficient surface area that can interact with the soil microbes and immobilize soil nitrate. In laboratory evaluations, finely ground almond shells (2 mm) is capable of quickly immobilizing large amounts of soil nitrate (Figure 1). However, after peak immobilization, it begins to mineralize quickly as well. Almond shells ground to ½ and ¼ inch particle sizes are also capable of immobilizing substantial quantities of soil nitrate (Figure 2). They also begin to remineralize but not to the extent of the more finely ground material. We will conducting an economic analysis of grinding almond shells to these particle sizes and will conduct a large-scale field evaluation this fall.

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

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INTRODUCTION

Over 100,000 Central Valley (CV) residents lack safe drinking water because they rely on groundwater wells impacted with nitrate. Agriculture is a regionally significant source of nitrate in groundwater and is associated with leaching of fertilizers and confined animal facilities. During the past decade, millions of acres of croplands in the CV have been converted to orchards. Orchard crops have high nutrient demands; for example, almonds require approximately 170-225 kilograms (kg) nitrogen (N) per hectare (ha) annually and have replaced crops with lower nutrient requirements (i.e., alfalfa). Following this trend, the continued degradation of rural groundwater supplies is likely without intervention. The Irrigated Lands Regulatory Program (IRLP) developed by the Regional Water Boards (RWB) charges growers and their agricultural coalitions with implementing N management plans that are protective of groundwater quality by improving N use efficiency (NUE) and reducing N leaching to groundwater.

Previous research at the plot scale shows that high frequency low concentration (HFLC) fertigation can improve production through higher nitrogen use efficiency, potentially reducing impacts to groundwater. This project not only provides commercial orchard scale implementation of HFLC but also novel direct measurements of resulting groundwater quality immediately underneath the orchard.

OBJECTIVES

Demonstrate, in a commercial scale almond orchard, that HFLC fertigation practices increase NUE while successfully producing high yields and reducing groundwater quality impacts.

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.

Development of a vadose zone - crop model, a groundwater model, and an integrated groundwater-vadose zone-crop model; apply models to evaluate scaled-up regional application of HFLC as potential new best management practices (BMP) capable of minimizing nitrate leaching to groundwater and improve groundwater quality at the regional scale.

Inform and discuss interim and final findings with grower-collaborator, ILRP agricultural coalition representatives, nut and other commodity grower representatives, and orchard growers.

DESCRIPTION

This project provides the first comprehensive assessment of groundwater nitrate impact from a best management practice (in this case, HFLC) comparing three monitoring approaches to assess nitrate impact to groundwater:

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);

7 replicate multi-level, vadose zone monitoring sites (water, nitrate, and ammonium fluxes and storage at 0 -3 m depth).

20 groundwater monitoring wells (screened at 7-17 m below ground surface, in first encountered groundwater), a regulatory "gold standard" for monitoring pollution.

The project further investigates the relationship between groundwater nitrate and fluxes through the development of an unsaturated zone model and groundwater model.

RESULTS AND DISCUSSION

Water and N mass balance monitoring.

Water mass balance calculations were done on an annual and monthly basis, for each of the blocks in the orchard:

Eq. 1: R= P - ETa + IR + dS

where R is the estimated recharge to groundwater, P is the precipitation measured and reported by the Modesto Irrigation District (MID), IR is the total irrigation, measured by the grower using a flow meter, ETa is actual evapotranspiration, and dS is the change in soil moisture storage. ETa data were computed using the Cal-ETa model (3). The previous report showed a historic mass balance of 5 years of advanced growers practice (AGP) that preceded the HFLC in 2018. Data collected during 2021 growing season is added on a figure including the historic mass balance (Figure 1). HFLC nutrient management was evaluated by comparing harvest records for 2018-2021 to prior growing seasons 2013-2017. The average impact of HFLC during growing seasons 2018-2021 was approximately 15% increase in kernel yields per acre and an approximate 15% reduction in total fertilizer applied.

The N mass balance was calculated using the following:

Eq.2: N-Losses = (N-applied) +(N-deposition) +(N-mineralization)-(N-uptake)-(N-denitrification)

Applied N, N-applied, follows the HFLC practice. Atmospheric deposition, N-deposition, is set to 20 kg N ha-1 annually (a-1) due to dairies upwind of the orchard. N-uptake is based on the harvested kernel weights as reported by the grower, calculated as (kernel weight) *68/1000, to which 45 kg N ha-1 a-1 are added for tree growth. Denitrification is 5% of N inputs. Nitrogen use efficiency for growing season 2021 was high, close to 100% (94%).

Root zone monitoring occurs at seven monitoring stations distributed randomly throughout the 56-ha orchard. Each monitoring station is equipped with four tensiometers at depths of 280 and 300 cm and a datalogger collecting data every 15 minutes. Five pore water samplers are located at depths of 30, 60, 90, 180 and 280 cm, and a neutron probe is used for water content measurement. Collection of pore water samples occurred every two weeks, on average, during fertigation season. Soil water tension at depths of 280 and 300 cm (about 9 and 10 feet) were monitored continuously, using tensiometers connected to dataloggers. Measured soil water tension gradient between 280 and 300 cm and measured nitrogen concentrations at that depth are used to compute water and nitrogen flux out of the root zone. The water and nitrate fluxes estimated from measurements are more variable both spatially and temporally compared to the mass balance and numerical model. Nitrate concentrations ranged from <1mg/L to over 700 mg/L across the orchard.

Groundwater monitoring demonstrates a high spatial variability in nitrate concentrations across the orchard. The standard deviation of the annual mean concentrations in wells ranged between 12.8 and 23 mg/L N between 2017 and 2021. Since 2017, the median concentration in the wells across the orchard has increased from around 20 mg/L closer to 30 mg/L in 2022, indicating an increase in nitrate concentrations of about 2 mg/L per year.

Root Zone Modeling. In the previous reporting periods, we developed a one-dimensional physical model of the entire 7 m thick unsaturated zone to obtain an estimate of groundwater recharge during the five-year period from fall of 2012 to fall of 2017 (before HFLC). During the current reporting period, the model was expanded to predict water and nitrate fluxes through the vadose zone for an extended time period from 1957-2047.

Model results predict that under HFLC, NUE will improve from an average of 83% to 90%. There also exists a lag time between N inputs at the surface and leaching at the water table (7 m below) of 10-20 years, due to the low recharge rate. Beginning around 10 years after the switch to HFLC, average nitrate concentrations in recharge begin to decrease, and continue to decrease for the remaining 20 years of the model (Figure 2). At the end of the simulation the average nitrate concentration in recharge was 45 mg/L and was still decreasing.

Groundwater Modeling Even though the nitrate concentrations in recharge decreased in response to HFLC, the model predicts it will take >30 years to see decreasing nitrate concentrations in the monitoring wells. Spatial variability in nitrate concentrations observed in the monitoring wells was found to be caused by spatial variability in N leaching from the vadose zone. It was not caused by soil heterogeneity in the saturated aquifer.

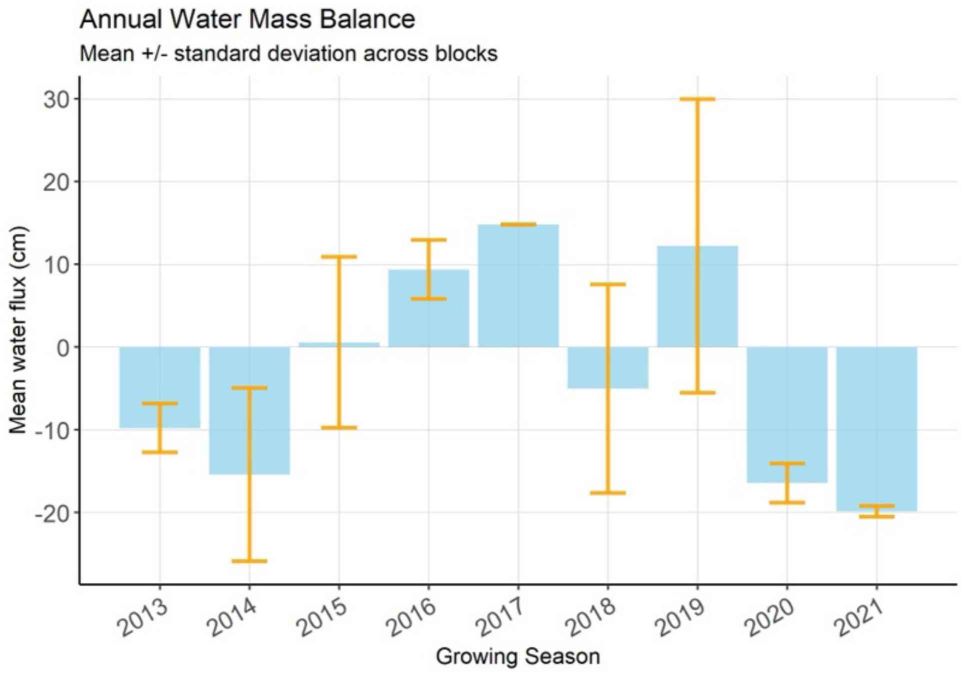

Figure 1: Annual water mass balance

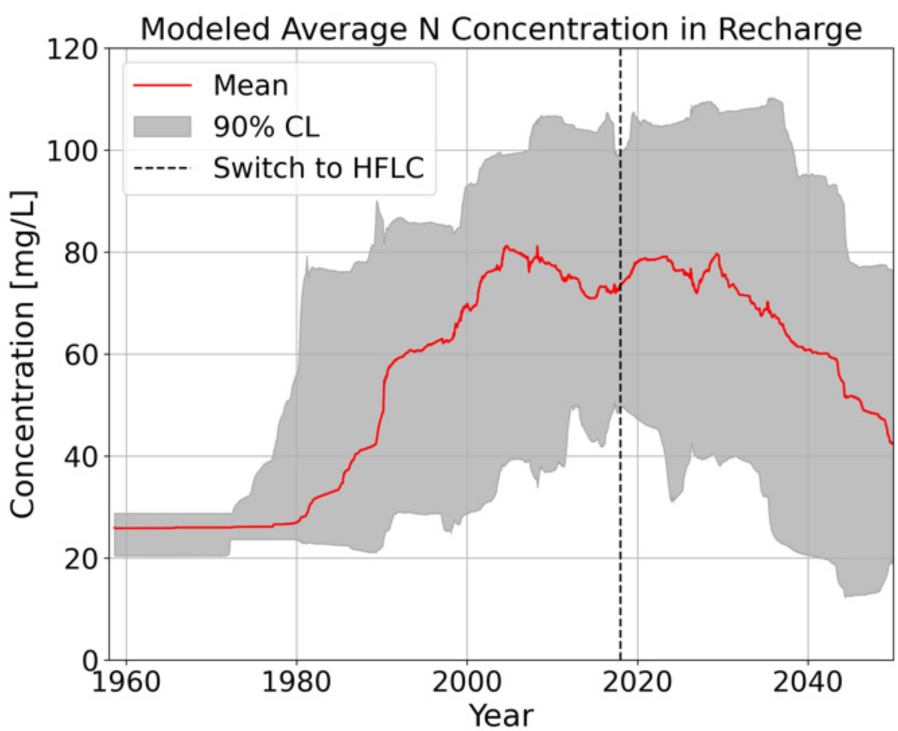

Figure 2: Orchard Summary of Modeled Nitrate Concentrations in Groundwater Recharge Across the 20 modeled soil profiles.

TAKE-HOME MESSAGE

HFLC is shown to both increase harvest yields and decrease nitrate leaching into groundwater. The historic mass balance is a straightforward tool but may be misleading when used to estimate N losses from agriculture in years with low precipitation and low recharge. Modeling shows some downward N fluxes even though the annual water mass balance is zero or even slightly negative. Model simulations show that HFLC has the potential to significantly lower nitrate loading into groundwater. They also suggest groundwater nitrate variability observed across many monitoring wells within a single orchard is highly dependent on the variably of nitrate leaching from the vadose zone (root zone). However, averaged across the orchard and after considering time-lags for groundwater, vadose zone data and groundwater data are consistent with long-term mass balance-based leaching estimates. Modeling (as opposed to mass balance) explains some highly variable downward N fluxes due to variable water flux (variable year to year) and nitrate concentration (less variable year to year but variable spatially).

ACKNOWLEDGEMENTS

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Nitrogen Content of the Harvested Portion of Specialty Crops to Estimate Crop Nitrogen Removal and Improve Nitrogen Management in Crops

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INTRODUCTION

The Irrigated Lands Regulatory Program (ILRP) has issued waste discharge requirements (WDRs) that affect agricultural operations throughout California. The WDRs are intended to improve water quality by affecting grower implementation of more efficient nitrogen (N) management practices. One metric to assess grower progress in improving N management is the difference between applied (A) and removed (R) nitrogen in harvested crop biomass (A-R). The Central Coast Regional Water Quality Control Board (CCRWQCB), Region 3, approved Ag Order 4.0 in April 2021 and uses the A minus R metric to assess nitrogen use. The CCRWQCB requested development of R coefficient values for crops that represent 95% of the acres in Region 3. UC Researchers have developed total crop N uptake (U) to improve N management for a number of commodities grown in Region 3; however, R values were not determined for harvested product for many of these commodities (Bottoms et al. 2012; Breschini and Hartz 2002; Heinrich et al. 2013; Smith et al. 2016a; Smith et al. 2016b). Under Ag Order 4.0 growers will be required to comply with A-R limits and targets according to a schedule. Producers will need to estimate N removed from fields in harvested crop biomass. Depending on the crop, the harvested biomass could include leaves, bulbs, roots, flowers, stems, or a combination of plant parts. Additionally, the same commodity may be harvested into different products. For example, romaine lettuce is harvested as trimmed, cored, and heart products, which likely have different N and dry matter contents.

OBJECTIVES

1. Assess N removed in harvested product for 35 commodities identified in the special request for proposals over three growing seasons.
2. Develop N removal coefficients that can be multiplied by grower yield data to provide an estimate of N removed (R) in the harvested crop.
3. Expand knowledge and promote appropriate use of N-removal coefficients (as part of routine N-management planning, and evaluation) by growers, advisors, and consultants.

DESCRIPTION

- Assess N removed in harvested product for 35 commodities identified in the special request for proposals over three growing seasons. Significant progress has been made to sample 15 fields of each of the 35 commodities proposed to study. For the lettuces we increased the number of fields to 20. Due to feedback from growers, we included new crops to evaluate such as baby kale, baby lettuces and clipped spinach. The total commodities evaluated are shown in Table 1.
- Develop N removal coefficients that can be multiplied by grower yield data to provide an estimate of N removed (R) in the harvested crop. Final coefficients will be calculated once we have sampled all of the fields proposed.
- Expand knowledge and promote appropriate use of N-removal coefficients (as part of routine N-management planning, and evaluation) by growers, advisors, and consultants. A presentation was made at the 2022 Irrigation and Nutrient Management Meeting in February.

RESULTS AND DISCUSSION

Coefficients have been developed for the 35 commodities proposed in this project. In addition, as the project was being conducted, we had conversations with growers that asked us to develop coefficients for additional crops. In addition, we also strengthened the number of samples collected for other crops such baby lettuces and spinach to get all crops to a minimum of 15 fields sampled for each commodity. Table 1 shows the coefficients developed by this project developed to date. The coefficient is multiplied by the weight of harvested product per acre to give the lbs N/A removed by the crop. The coefficients shown are developed by multiplying the percent N and moisture content of the product. Each of these values is the average of a range of observed values. Therefore, coefficients are not absolute and in the real world they vary up or down to some degree. However, crop removal coefficients tend to fall into a certain range depending upon the which part of the plant that the vegetable represents (e.g., leaves, whole heads, flowers, bulbs, etc.). For instance, on average petiole vegetables (celery) have the lowest coefficient (0.00156); head vegetables (lettuce, cabbage, bok choy, etc.) and bulb vegetables (onions, shallots) are moderately low, 0.00270 and 0.00275, respectively; whole plants (beets, leeks, and radishes) and fruits (peas and bell peppers) and intermediate, 0.00333 and 0.00389, respectively; flowers vegetables (broccoli, cauliflower and rapini) have higher coefficients, 0.00583 and leaf vegetables (cilantro, parsley and spinach) have the highest coefficients, 0.00612.

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"Crop Nutrient Minute" Video Series

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INTRODUCTION

The Irrigated Lands Regulatory Program (ILRP) mandates that producers of irrigated crops minimize or eliminate excessive nitrate movement beyond the root zone where it can pose a risk to drinking water sources. While extensive amounts of information have been published on how to accomplish this, many growers and crop advisors lack access to easy-to-digest information and how-to guides for their specific crop needs in an online video format. The goal of this project is to produce two video series in English and Spanish: 30-minute segments useful for Continuing Education (CE) requirements and succinct 5-minute videos called "Crop Nutrient Minutes" that enable growers on a busy schedule access to succinct presentations on information that has taken years to develop and is currently used in crop production today. The CE segments help address the lack of online resources for growers who have completed the Irrigation and Nitrogen Management Plan (INMP) Self-Certification Program. For maintaining their certification, growers must complete three-hours of Continuing Education Units (CEU) in a three-year period. CE courses are typically in-person meetings, which are always difficult for busy growers. Online CE courses are instrumental in ensuring growers and CCAs are able to fulfill their Continuing Education requirements. This project includes an "INMP Continuing Education" video series, creating seven 30-minute videos that will be posted on the CURES website and linked to other sites for self-certified growers and to use to complete their CEUs. The videos will also supplement the new Certified Crop Adviser (CCA) online training and facilitate CCAs in obtaining CEUs. The videos will cover seven crops including almonds, citrus, pistachios, processing tomatoes, wine grapes (high tonnage), strawberries and romaine lettuce. This CURES educational video series will focus on California's major acreage crops and be accessible to Central Valley and Central Coast growers and crop advisors.

OBJECTIVES

1. Compile irrigation and nitrogen management information on the seven major acreage crops in the Central Valley and Central Coast.
2. Develop and produce seven, 5-minute videos in English and Spanish for the "Crop Nutrient Minute" video series.
3. Develop and produce seven 30-minute videos in English and Spanish that expand on "Crop Nutrient Minute" video content for Continuing Education uses.
4. Post "Crop Nutrient Minute" videos online and conduct outreach.
5. Apply for CEU credit for "INMP Continuing Education" and CCA trainings, post videos online, fulfill sponsor requirements and conduct outreach.

DESCRIPTION

Video content will be developed by the Project Leaders, University of California Cooperative Extension (UCCE) specialists and University of California (UC) personnel in each crop category. The foundational information for the videos will be the 4R principles (Right time, Right place, Right amount, and Right product) developed by FREP and the UC for California crops. Video content will also include information on soil health, nitrogen processes in the soil, leaf sampling, crop nutrient tracking and efficient irrigation practices, as well as tips gained from crop advisors, UCCE specialists and UC personnel who work with the crops featured in a specific video. Scripts for each of the seven 30-minute videos will then be written by the Project Leaders and Cooperators using information gathered from the CDFA Crop Nutrient Guidelines and findings from past FREP-funded research. Each draft script will be reviewed by a Review Committee, comprised of Project Leaders, Cooperators, and subject matter experts to obtain edits and comments. Once the scripts are approved by the Review Committee, videos will be taped using CURES, UC and PCA/CCAs with crop-specific footage recorded in the field. Animation and art will also be used to illustrate information. Videos will be recorded and produced in English and Spanish, using English- and Spanish-speaking farm advisors and PCAs/CCAs specializing in a specific crop.

After the 30-minute videos are produced and approved by the Review Committee, CURES staff will condense the content to create the 5-minute "Crop Nutrient Minute" series. These more succinct videos will focus briefly on the fundamentals and will cover crop-specific tips and techniques to properly implement the 4Rs. Once approved, the finished 5-minute videos will be posted on the CURES, CDFA and UCCE websites. Outreach will then be conducted to growers, crop advisors, commodity groups, Water Quality Coalitions, and other agricultural education entities to notify them of the series. In addition to CURES presentations and workshops, the crop-specific videos could be shown during Coalition member meetings, CCA trainings, UC agronomy classes, commodity group outreach, and other events targeting growers and crop advisors that focus on a specific crop. These videos are modeled off a FREP-funded 4R video produced for walnuts: https://www.curesworks.org/best-management-practices/

Once approved to offer CEUs, the finished "INMP Continuing Education" videos will be posted on the CURES website and linked to other sites. Self-certified growers and CCAs and PCAs will be notified via email and postcard of the online CE opportunities. CDFA and Water Quality Coalitions will be encouraged to send out email blasts, postcards and/or blog posts informing growers and crop advisors of the online courses. Quiz questions will be developed and included with each video, in compliance with current INMP CE requirements (5 questions per 30 minutes). The mandatory quizzes will be automatically graded, results recorded, and Certificates of Completion sent to growers who pass.

RESULTS AND DISCUSSION

For the "Crop Nutrient Minute" video series, project success will be measured through view counts and feedback surveys. The total number of video views will be tracked quarterly. If views decrease, CURES will perform analyses on outreach methods to ensure we are reaching growers and crop advisors in the most efficient ways. Optional feedback surveys will also be posted with each video. Survey responses will be recorded and used to determine if viewers find the videos helpful or need improvements. For the "INMP Continuing Education" video series, project success will be measured by grower participation and feedback surveys. Grower quiz results will be used as a metric to track grower participation and understanding of content. Optional feedback questions will be included with the quizzes to determine if growers find the videos helpful or need improvement. In the long-term, project success will be measured by Continuing Education completion and measurable reductions of nitrate in Central Valley and Central Coast groundwater. To date, 3,600 growers have completed their self-certification courses but only a fraction of them have maintained their certification through Continuing Education. These videos will allow more growers to complete their CEUs, which are tracked and recorded through the INMP Self-Certification Program. In addition, project success can be measured by reduced nitrate levels in groundwater over the next few decades. There are many programs and educational efforts being done across the state to minimize groundwater leaching. If nitrate levels decrease over the next few decades, it would mean this project and the many other efforts contributed to the overall success.

ACCOMPLISHMENTS

The research-based information delivered to growers and crop advisors by

this project will help support the reduction of agricultural contributions of nitrate to groundwater in the Central Valley and Central Coast. The management practice recommendations will be vital to the approximately 25,000 landowners/operators in the Central Valley and 2,000 on the Central Coast who are affected by requirements to improve nutrient and irrigation application practices for reducing salt and nitrate discharges to ground and surface water. Giving growers access to an easily accessible, more efficient source of information will advance the knowledge of proper nitrogen stewardship and, over time, may improve overall groundwater quality in California.

Furthermore, this project will serve as a conduit to transfer the latest information on efficient nitrogen fertilizer applications and the practices that can minimize or prevent movement of nitrate to groundwater developed by FREP, UCCE and UC. Some new information is likely to come from interviews with Certified Crop Advisors, agronomists and farm advisors who have crop-specific tips, techniques or other knowledge gained through their work in the field. Much knowledge has already been developed through UC, UCCE and FREP projects to improve nitrogen efficiency and needs to be disseminated to growers and crop advisors who would benefit from the information. This project provides another option of communicating this information using media that is popular with an increasing number of growers and crop advisors.

ACKNOWLEDGEMENTS

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Ventura County Nitrogen Management Training Program

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INTRODUCTION

The third iteration of the Los Angeles Regional Water Quality Control Board's Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands within the Los Angeles Region ("Conditional Ag Waiver", Order No. R4-2016-0143) was adopted on April 14, 2016. To address existing water quality issues, the 2016 Conditional Ag Waiver included a requirement that growers located in areas associated with nutrient water quality exceedances or Total Maximum Daily Load (TMDL) specific requirements, develop certified Nutrient Management Plans for their farms. Approximately 70% of the agricultural acreage in Ventura County is located in an area where these requirements currently apply.

The required elements of the plans themselves, as well as the certification options, were modeled after the requirements already in effect for Central Valley growers. To provide local growers with the tools and training needed to implement these requirements, the Ventura County Agricultural Irrigated Lands Group (VCAILG, administered by the Farm Bureau of Ventura County) worked collaboratively with CDFA FREP, the University of California Cooperative Extension, and Fruit Growers Laboratory to expand the Central Valley self-certification training programs in Ventura County. Many more growers will need to complete this training and develop Irrigation and Nutrient Management Plans to comply with the upcoming Ag Order, which will include the East San Joaquin River Watershed Waste Discharge Requirements precedential requirements related to nitrogen tracking and reporting. This Ag Order is expected to be adopted in late 2022.

OBJECTIVES

The project objectives include the following:

1. Provide growers with the information and credentials needed to develop site-specific Nitrogen Management Plans (NMPs) and Irrigation and Nitrogen Management Plans (INMPs) for their farms
2. Improve surface and ground water quality through an education program focused on the principles of crop-specific irrigation and nutrient management
3. Increase awareness of grower resources, including crop-specific nitrogen demand/removal factors
4. Provide training program and resources for Spanish-speaking audiences

DESCRIPTION

The primary tasks included in this education project include the following:

- Update current NMP training program to include INMP components and other ESJ precedential requirements.
- Translate training program and resources for Spanish-speaking audiences.
- Conduct three training programs per year, one of which will include active Spanish translation.
- Provide English and Spanish versions of training binders and other resources.

RESULTS AND DISCUSSION

The planned implementation schedule for this education project has been impacted by both the ongoing COVID-19 public health emergency, as well as two extensions of the current Conditional Ag Waiver term, which was originally set to expire in April 2021 but was first extended through April 2022 and then extended a second time through December 31. 2022. The timeline for the renewal of the Conditional Ag Waiver is significant in that it will include requirements for the implementation of the East San Joaquin precedential order. Once the Ag Order is adopted and an implementation program is established for the precedential requirements, the training program will be updated and translated for Spanish-speaking audiences.

An update and translation of the training program is anticipated to be completed by Summer of 2023.

ACCOMPLISHMENTS

A two-day online training session were conducted in 2021: one on April 6 and 7 and a second on November 3 and 4, 2021. Additional training sessions were put on hold as a new Ag Order is being developed and CDFA's training program is being updated.

ACKNOWLEDGEMENTS

The implementation of this project has been supported through CDFA FREP grant funding. Additional support and training program collaboration has been provided by Ben Faber and Andre Biscaro with the University of California Cooperative Extension, Ben Waddell and Scott Bucy with Fruit Growers Laboratory, Amy Storm with Larry Walker Associates, and Nichole Nunes with CDFA FREP.

Assessment of Harvested and Sequestered Nitrogen Content to Improve Nitrogen Management in Perennial Crops, Phase 2

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INTRODUCTION

Through 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 by providing, among other things, information on field nitrogen (N) balances. In addition, the Agricultural Expert Panel convened by the State Water Resources Control Board recommended metrics composed of N applied (A) and N removed (R) to gauge program progress in reducing the mass of leachable N (Burt et al., 2014). To comply with this new reporting requirement, growers and their water quality coalitions need reliable data about N removed from fields in harvested crop materials. Also, growers can use rates of N removal in crops to plan nutrient management programs that reasonably minimize N at risk of leaching below the root zone.

With the participation of several cooperating coalitions, the SSJV MPEP Committee contracted and worked with Dr. Daniel Geisseler of UC Davis to complete and publish usable, literature-based yield-to-N-removed conversion factors for 72 crops, representing more than 98% of Central Valley irrigated lands. The report, Nitrogen Concentrations in Harvested Plant Parts - A Literature Overview (N-concentrations Report), was prepared by Dr. Geisseler (2016). The N-concentrations Report noted that some of the conversion factors are based on datasets that were small, more than 20 years old, or from outside the Central Valley, and / or reflected cultivars, yields, cropping systems, and soil types other than those common under contemporary Central Valley conditions. The N-concentrations Report showed that well-established coefficients were available for only 10 of the 72 crops, accounting for approximately 12 percent of irrigated lands in the Central Valley. Further, there are even fewer data on the amount of N sequestered into perennial crop biomass, which growers need to know when planning N fertilizer programs for younger orchards, groves, and vineyards during rapid early growth of perennial tissues. To refine currently available coefficients, additional data need to be obtained from analysis of recent crop samples over several years.

In Phase 1 of this project, updated conversion factors for 11 crops were incorporated into a 2021 N-Concentrations Report and the Yield to N-Removed Calculator (http://agmpep.com/calc-y2r/). As a part of Phase 2 (this project), updated conversion factors will be developed for an additional approximately 33 additional crops.

OBJECTIVES

The overall objective of this project is to assess harvested and sequestered N content for priority crops. Specific objectives include the following:

1. Assess N concentration of harvested material removed from fields (N removed [R]) for approximately 33 crops over several growing seasons, and N sequestration rates for eight perennial crops (which are included among the 33 total crops), by working with grower/packer/shipper partners to obtain samples, and UC Davis to analyze samples and interpret results.
2. Refine crop yield (Y)-to-R conversion factors, and add N-sequestration rate estimates, for use by growers and grower advisors during nutrient management planning and by coalitions for large-scale performance assessment.
3. Promote and enable expanded knowledge and appropriate use of N-removal coefficients and N-sequestration rates (as part of routine N-management planning and evaluation) by growers, grower advisors, and coalitions. This includes the following:
    - Incorporate results in an update of Geisseler (2016, 2021).
    - Update existing online and off-line tools for estimating N removed in crops and incorporate into regional assessments of N balance in irrigated crop lands. Update N accumulation rates in crop models used in the ILRP.

DESCRIPTION

By partnering with commodity organizations, growers, processors, packers, and retailers, it is possible to procure hundreds of samples that represent a range of varieties and growing environments for each crop. Currently, samples are planned to be or are being collected and analyzed for apricots, nectarines, cherries, Valencia and Navel oranges, lemons, tangelos, grapefruit, figs, table grapes, raisins, sweet corn, corn grain, sorghum grain, non-alfalfa hay/haylage, cantaloupe, honeydew, watermelon, summer squash, cucumber, onion, garlic, potato, sweet potato, fresh market tomato and bell pepper.

Results will be incorporated into the assessment and planning tools available to growers, grower advisors, and coalitions. This includes updates of the N-concentrations Report (Geisseler 2016, 2021) and the N removed calculator on the agmpep.com website.

RESULTS AND DISCUSSION

Work completed since the commencement of Phase 1 includes coordination of four years of sampling with grower/packer/shipper partners, along with preparation and analysis of the samples obtained. Results from Phase 1 are documented in Geisseler (2021) and have been incorporated into the N removed calculator on the agmpep.com website (http://agmpep.com/calc-y2r/). These results are also presented in Table 1. Results from Phase 2 are not yet available.

Results from this project improve our understanding of N removed in harvested materials from crops grown within the Central Valley. As shown in Table 1, in some cases (e.g., corn silage, cotton, and walnuts), the N-removal coefficient changed little after integration of new data obtained from this project, while with other crops (e.g., peaches and pomegranates), it changed substantially. Differences in updated conversion factors can be caused by many variables related to how relevant and comprehensive the previously used data were to current Central Valley conditions. Regardless of whether the coefficient changed considerably or not, the collection and integration of current data from the Central Valley that span differing climates, soils, management practices, and years, provides a clearer picture of N removal dynamics within Central Valley agriculture and helps growers, advisors, and coalitions better plan and refine nutrient management into the future.

Table 1. Initial (Geisseler 2016) and Updated (Geisseler 2021) N removal Coefficients.

Crop	Geisseler (2021)		Geisseler (2016)		Change
	Av. Lbs N/ton	CV* (%)	Av. Lbs N/ton	CV* (%)	%
Corn Silage	7.53	10.9	7.56	10.5	-0.4
Cotton	43.4	16.1	43.7	29.5	-0.69
Safflower	51.7	10.2	56.8	20.0	-9.0
Sunflower	63.2	11.1	54.1	14.3	17
Carrots	2.80	22.7	3.29	22.4	-15
Tomatoes, Processing	2.92	15.0	2.73	11.1	7.0
Peaches	3.04	19.0	2.26	20.7	35
Pistachios**	20.4	21.6	56.1	3.5	-
Plums	2.27	14.5	2.83	11.2	-20
Pomegranates	3.96	15.4	15.2	15.0	-74
Walnuts	31.8	10.9	31.9	11.2	-0.31

*Coefficient of variation.
**N removed for pistachio in Geisseler (2016) was based on tons of dry yield (CPC), while the updated N removal coefficient is based on tons of net green weight. Net green weight was selected because it does not require any assumptions related to moisture content and the weight of dried in-shell nuts produced from fresh fruit removed from the field.

TAKE HOME MESSAGES

A sound understanding of N removed in harvested portions of crops is a vital component of any nutrient management plan and helps growers determine fertilizer requirements for a growing season. To use these N removal coefficients, it is paramount to understand what they represent. The Geisseler (2016, 2021) reports provide important information on the coefficients related to their associated yield units, presumed moisture contents, and what plant materials are represented (e.g., the cotton coefficient includes N in lint and seed, and needs to be adjusted if yields only consider lint). Furthermore, the reports contain metrics on the degree of variability of N in harvested materials to show how N concentrations may differ across space and time and potential reasons for that variability. Other considerations for estimating fertilizer requirements should include other sources of N besides fertilizers (e.g., N in irrigation water and crop residues) and N required for non-harvested plant materials such as leaves, stems, roots, and perennial tissues. Proper N application rates, timing, and placement should be tailored to crop growth stage, nutrient demand, and irrigation practices. Local conditions (e.g., soil and climate) should also be factored in to ensure better fertilizer-use efficiency.

As our understanding of crop N-removal coefficients continues to improve, stakeholders can continue to work towards a productive and sustainable future for Central Valley agriculture.

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Enhancing Nitrogen and Water Use Efficiency in California Carrot Production through Management Tools and Practices

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INTRODUCTION

Nitrogen and irrigation water must be effectively used in mineral soils to produce carrots with high yield and minimal environmental impact. There is lack of sufficient information on efficient water and N management practices in carrot production systems. This study aims to develop more accurate information on carrot water use and N uptake patterns under different soil types, climate, and irrigation practices which can help producers determine the optimal timing and amount of water and N fertilizer applications.

OBJECTIVES

1. Develop data and information on crop N uptake curve, net N removal, and recommendations on N applications in California carrot production.
2. Develop data and information on crop water use in California carrot production.
3. Adapt the CropManage tool for water and N management in carrots.
4. Disseminate the project outcomes to growers and stakeholders.

DESCRIPTION

A three-year project with extensive field measurements is ongoing at the UC Desert Research and Extension Center (DREC) and commercial fields in Imperial and Kern Counties to comprehensively represent various N and water management practices, soil types, climate, and carrot cultivars in California carrot production system.

In the DREC trials (Fig. 1), four N fertilizer strategies (most common N fertilizer amounts used by regional/local growers, N1; 120% N1; 80% N1, and 60% N1) are assessed under two irrigation regimes (100% crop ET and 120% crop ET). In each plot, irrigation regime (as main driver) and N strategy (as secondary driver) are investigated in a Randomized Complete Block Design with Split Plot Arrangement over four replications. In the commercial trials (12 trials in Imperial County and 6 trials in Kern County), due to logistical limitations, the experiments are carried out in plots with an area of 400 feet by 400 feet under irrigation and N fertilizer management practices followed by growers.

Soil nitrate content (NO_3-N) and total N percentage in tops and roots are determined monthly through laboratory analysis. Preplant and post-harvest soil samples are taken from six depths (1-6 ft.). At other sampling dates, soil is collected from the top three depths (1-3 ft.). A composite soil sample is analyzed from each layer for NO3-N content. Plant measurements is carried out on 40-plant samples collected randomly (per plot at the DREC trial, and from five sub-areas at the commercial sites) and determinations are made on root yield and biomass accumulation. Fresh weight and dry weight of roots and foliage are measured on a regular basis.

RESULTS AND DISCUSSION

Effect of irrigation regimes and N application rates. While an insignificant impact was found from the interaction of irrigation and nitrogen regimes on the fresh and dry matter root yields, these measures were significantly lower in I100N120 (100%ET and N application rate of 275 lbs. ac^{-1}) and I120N60 (120%ET and N application rate of 140 lbs. ac^{-1}) treatments (Fig. 2). The findings suggested insignificant root yield reduction because of reducing a 40% N rate (N application rate of 140 lbs. ac^{-1}) in 100%ET irrigation regime. The N concentration in fresh carrot roots varied from 4.2 to 4.7 lbs. ton^{-1} at harvest, however, no significant differences were found among the treatments ($P<0.05$).

Nitrogen management. The N uptake curves suggested that nearly 50% of the total N was taken up during a 50-day period (80-130 days after seeding) (Fig. 3). This 50-day period appears to be the most critical period for N uptake, particularly in the storage roots, when carrots developed the large

Figure 1. An aerial view of the carrot trial (2021-2022) during an irrigation event.

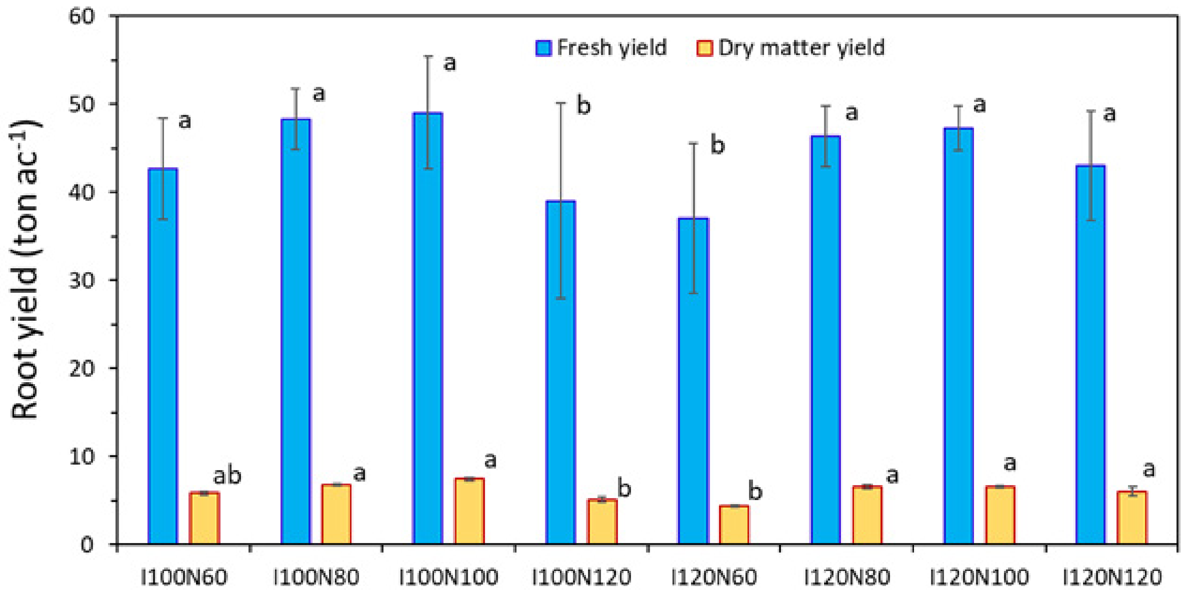

Figure 2. Effect of irrigation regimes and N application rates on fresh and dry matter root yields at harvest (2021-2022 trial). The different letters above the columns indicate significant differences among the treatments at $p < 0.05$.

canopy and the extensive rooting system. For a 160-day crop season, 22% of N uptake could be accomplished over the last 30-day before harvest.

Carrots have a deep rooting system that allows for improved capture of N from deep in the soil profile. The fibrous roots were present at the depth of five feet below the soil surface the DREC trials (Fig. 3). There is a risk of leaching soil residual N due to heavy pre-irrigation (a common practice for salinity management in the low desert) in late summer prior to land preparation. N is likely accumulated at the deeper depths by the beginning of the growing season, and consequently, there is a potential N contribution from the soil for carrots when the roots are fully developed.

RECOMMENDATIONS

Careful management of N applications in the low desert carrots is crucial because fertilizers are the main source of N, particularly due to low organic matter content of the soils and very low nitrate level of the Colorado River water. The majority of N is taken up during the months of December to February, and hence, proper N fertility in the effective crop root zone is essential during this period. An integrated optimal N and water management needs to be approached to accomplish greater N and water efficiency, and consequently keeping lower rates beneficial to overall profitability.

TAKE-HOME MESSAGE

The findings of this study suggested that nitrogen application rates greater than 140 lbs. ac^{-1} couldn't have a significant impact on root yield in a well-managed irrigated field. However, higher N rates are likely necessary in over irrigated carrot fields to maximize root yield. The Carrot CropManage Module was developed and verified using the data of the research trials. This tool could be considered as a robust irrigation and nutrient management decision support tool to assist growers in implementing better irrigation scheduling and N rates in carrots.

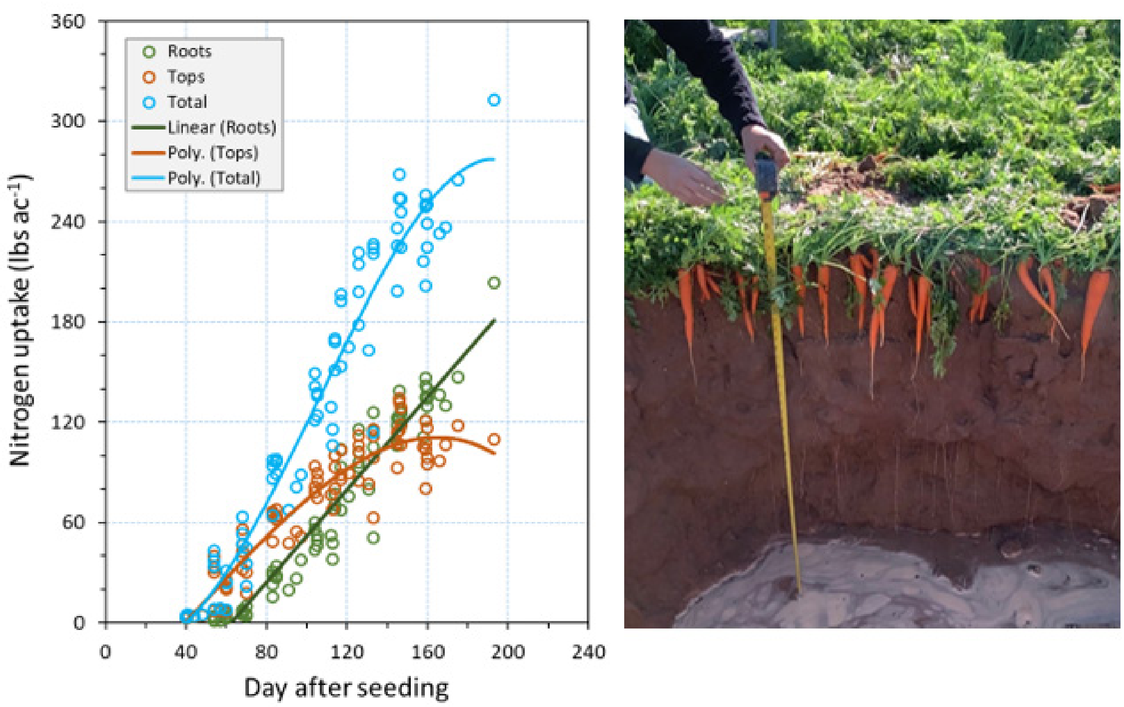

Figure 3. N accumulation trends in storage roots, tops, and total (plants) over the growing season at the experimental sites (left). Carrot storage and fibrous carrot roots system at the DREC trials (right).

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ACKNOWLEDGEMENTS

Funding for this study was provided by the California Department of Food and Agriculture (CDFA) - Fertilizer Research and Education Program (FREP). The research team gratefully acknowledges the farms that are being contributing to this project, the UCCE Imperial County staff, the UC DREC staff, and several student assistants for their help in field-work-related tasks during this study.

Certification and Distance Learning for Fertigation

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INTRODUCTION

Fertigation is the application of fertilizers plus water treatment chemicals such as soluble gypsum, acid, and other related chemicals to crops via irrigation systems. There is a lack of accessible training for irrigators and specialists regarding both simple and complex concepts of the chemistry, fertilizer needs, application hardware, and irrigation system characteristics. This project is intended to address that with both English and Spanish training materials and certifications.

OBJECTIVES

1. Prepare written material for training.
   - The recent English second edition of the book Fertigation, sponsored by FREP, was already available for free download
   - Spanish material would be developed.
2. Prepare approximately 21 training modules would be developed; 11 would be in Spanish.
3. The laboratory exercises would be available on YouTube videos in English and Spanish.
4. ITRC will work with the Irrigation Association and others to develop a certification program in both English and Spanish.

DESCRIPTION

The videos and training materials are to be improved versions of the Fertigation class that has been taught in the Cal Poly BioResource and Agricultural Engineering Dept. since about 1980.

RESULTS AND DISCUSSION

The original proposal did not include the translation of the Fertigation book into Spanish, but it was soon realized that the book represents an essential background document for anyone who wants to go beyond the video modules. So, the book was translated into Spanish. Furthermore, it was decided by ITRC that most if not all of the laboratory videos and lecture PowerPoints should also be available in Spanish. Dr. Carlos Orozco (former Secretary of Agriculture of Baja California Norte) is narrating the Spanish videos and PowerPoints.

The current status of various modules is seen below.

	English Title	Spanish Title	Spanish YouTube link (hidden)
Lecture 1	Overview	Visión general	https://youtu.be/ZMtrVYFxccQ
Lecture 2	Basic Fertilizer Chemistry and Vocabulary	Química y Vocabulario Básico de Fertilizantes	These lectures have been translated, but not yet narrated
Lecture 3	N and the Environment	Manejo del nitrógeno y medio ambiente	
Lecture 4	Basic Soil Principles	Principios básicos del suelo	
Lecture 5	Crop Fertilizer Requirements	Requisitos de fertilizantes de los cultivos	
Lecture 6	Testing of Plants Soil and Water	Análisis de plantas, suelo y agua	
Lecture 7	Fertilizer Labels Characteristics and Usage	Etiquetas, características y uso de fertilizantes	
Lecture 8	Nitrogen Conversions	Conversiones del nitrógeno	
Lecture 9	Irrigation System Uniformity and Efficiency	Uniformidad y eficiencia del sistema de riego	
Lecture 10	Safety	Seguridad	
Lecture 11	Chemigation for Soil Infiltration Problems	Quimigación para problemas de infiltración del suelo	
Lecture 12	Chemigation for Drip System Maintenance	Quimigación para el mantenimiento del sistema de goteo	
Lecture 13	Proportional Injection	Inyección proporcional	
Laboratory 1	Calibration of Fertilizer and Chemical Injectors	Calibración de Inyectores Químicos	https://youtu.be/NpaxLzKmb_Q
Laboratory 2	Purging Media Tanks of Chemicals	Tiempo Requerido Para Purgar Productos Químicos de los Tanques de Filtración	https://youtu.be/yUHR6LZJROA
Laboratory 3	SO2 Generators	Generadores de SO2	https://youtu.be/wquVfiOwEbY
Laboratory 4	Varying Venturi Injection Rates	Variación de Tasas de Inyección de Químicos Cuando se Utiliza un Venturi	https://youtu.be/W4BnfRuCqY0
Laboratory 5	Volatilization of ammonia from irrigation water	Volatilización de Amoníaco del Agua de Riego	https://youtu.be/O_NBD03PMpY
Laboratory 6	Incompatibility of Different Fertilizers	Incompatibilidad de Fertilizantes Diferentes	https://youtu.be/l9UjvRyjuF8
Laboratory 7	Calibration, Titration, and Travel Time	Calibración, Titulación y Tiempo de Viaje	https://youtu.be/ZqK36FH2jdA
Laooratory 8	Fertilizer and Chemical Injection Devices	Dispositivos de Inyección de Fertilizantes y Productos Químicos	https://youtu.be/hapSHiOzIpU

Other key points for this project include:

- Discussions are planned with the Education Committee and the Certification Committee of the Irrigation Association (IA) during its annual conference in Las Vegas during the week of Nov. 5. There has been a change in leadership in the IA, so conversations need to be re-started.
- Dr. Gaudi of Cal Poly resigned from his teaching position and is no longer listed as a project co-leader. Fortunately, he completed his assigned tasks before leaving.
- It is anticipated that both Spanish and English lectures will be available on YouTube by the end of November 2022.
- Two small YouTube videos remain to be completed – an introduction, and field interviews.
- Although questions have been developed for each of the lectures, the details of how to incorporate interactive quizzes have not been solved. YouTube was selected because of its popularity and accessibility. But YouTube does not offer interactive abilities. This is somethings that will be discussed at the IA meetings.

TAKE-HOME MESSAGE

Excellent, free downloadable training materials are now available via the ITRC web site (www.itrc.org/books/) that were not there before this program was funded. They are:

- "Fertigation" in English
- "Fertirrigación" in Spanish
- "Drip and Micro Irrigation Design and Management" in English

A variety of YouTube videos are also available. See www.itrc.org, and select the YouTube symbol on the home page. The Spanish videos are still hidden but can be accessed using the web addresses in the previous table.

ACKNOWLEDGEMENTS

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Outreach and Revenue Generation for Sustaining CropManage Irrigation and Nutrient Management Decision Support Tool

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INTRODUCTION

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

CropManage (CM) is an online decision support tool developed by UCANR for assisting growers with efficiently managing water and nitrogen fertilizer to match the site-specific needs of their crops. CM also allows growers to track fertilizer and water applications on each of their fields. This record keeping capability of the software allows multiple users to share and review water and N applications on each field of their ranch, and for growers to maintain data required to comply with water quality regulations. With financial support of CDFA-FREP, CM was originally developed in 2011 to help farmers estimate irrigation schedules in lettuce using CIMIS ETo data and determine fertilizer N needs using the soil nitrate quick test and models of N uptake. Later CM was expanded to include other coastal crops, including baby salad greens, broccoli, cabbage, cauliflower, celery, spinach, strawberry, and raspberry. Funding from CDFA-FREP and DWR facilitated adapting CM for central valley crops including alfalfa, almond, walnut, pistachio, and processing tomato.

CM is used by growers, farm managers, consultants, governmental and nonprofit agencies. With the addition of new crops and features grower adoption of CM has steadily increased during the past 10 years, often providing more than 1500 recommendations per month during the growing season (March – November). Nevertheless, more outreach in the form of dedicated user support, hands-on workshops, and presentations at industry meetings could potentially boost grower adoption of the decision support tool, especially for regions such as the central valley and the southern desert where growers are less familiar with CM, or with the new features and commodities that have been recently added to the software. Also training of technical support providers such as consultants, resource conservation staff, and extension advisors on CropManage is needed in these regions to facilitate grower adoption.

Although CM has always been free for users, fixed costs of maintaining and updating the software have become an increasing concern. Hosting CM on a professional cloud server and storing user data has fixed costs. UC Farm Advisors have relied on grants to pay these expenses as well as the salary of a full-time professional software engineer who keeps CropManage running smoothly and adds new capabilities and features to the decision support tool.

This project addresses both increasing outreach and training on CM to growers, consultants, technical support providers, and UC farm advisors as well as explore and implement a strategy to continue funding software development.

OBJECTIVES

The proposed project would accomplish two goals that would increase the impact of CropManage on improving irrigation and nutrient management in California:

1. Target outreach on irrigation and nitrogen management using the CropManage decision support tool for growers

and industry groups producing commodities recently added to the software or are unfamiliar with the decision support tool.

2 Develop and implement a plan that would generate funding to sustain CropManage software into the future.

DESCRIPTION

Outreach on CropManage will be accomplished through introductions at industry and grower meetings and through hands-on trainings taught virtually or through in-person meetings.   Additionally, help resources for CM will be developed including adding tutorial articles to CM knowledge base (help.cropmanage.ucanr.edu), a quarterly newsletter to introduce new features that will be delivered electronically to CM users, Spanish language translation of terms and labels, and Spanish language how-to videos. One-on-one help will be offered to users through contacts from the CM hotline or the CM "feedback" link.

Revenue generation for sustaining CM will be explored through an oversight committee that will evaluate options such as subscription and donation-based models, as well as sponsorship from for-profit, and non-profit organizations. Automated reporting capabilities will be augmented which may also increase the user-base as well as lead to revenue generation. These reports include summaries to assist growers with regulatory compliance such as calculating the applied nitrogen from fertilizer and water sources and for determining N removal in harvested products.

Finally, adding task management capabilities to CropManage may lead to a larger user-base and potential revenue generation. This may be accomplished by interfacing CM with existing software used by growers and/or developing a simple native app that can be used on a smartphone. Adding task management capabilities would greatly simplify data entry for farming operations that want to adopt CM on a large scale.

ACCOMPLISHMENTS

Outreach

Six presentations were made to introduce CropManage at grower meetings in the Central Valley, Imperial Valley, and the Central Coast during 2022. In-depth, hands-on workshops were also conducted in Modesto, Parlier, Coachella, Imperial, as well in Soledad and Watsonville. Participants at the workshops learned how to set up CM for their farms and use the software as a decision support tool for irrigation scheduling and N fertilizer management. One-on-one assistance on CM was provided to growers and their staff as well as consultants and technical service providers throughout the season (approximately 2 to 4 questions answered per week). Assistance included responding to queries on how to use software features, setting up plantings, or interpreting recommendations. Ten instructional articles were published in the help section of CM (help.cropmanage.ucanr.edu) and two e-newsletters were distributed to CM users that provided updates about new features and training opportunities. Outreach was also accomplished through more than 100 field demonstrations throughout California, which often included the installation of flowmeters and soil moisture sensors so that participating growers could compare their applied water use with CM recommendations.

Revenue Generation

Progress was made on activities to integrate CropManage into third party software. The application protocol interface (API) was improved so that CM can be more easily integrated into other farm management software. GeoVisual Analytics, a private company, has integrated CM recommendations into their farm management software (SeedGreen) using the CM API. Another company has used the API to develop a simple-to-use app to report the hours that crops were irrigated to the CM platform. This app could potentially reduce the burden of data entry by allowing irrigators in the field to use their smartphones to quickly update plantings hosted in CM.

In addition to developing avenues for CM to better integrate with commercial software, the CM project was awarded several grants that will add new capabilities and crop types to the software platform and potentially expand the user-base.

ACKNOWLEDGEMENTS

We thank the California Tomato Research Institute, Almond Board of California, and Central Coast Grower Shipper Association for their assistant and support of this project as well as funding from CDFA Fertilizer Research and Education Program.

University of California Nursery and Floriculture Alliance Fertilizers and Plant Nutrition Workshops for Greenhouse and Nursery Growers

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INTRODUCTION

Fertilizers are an essential part of greenhouse and nursery plant production. Crops in these systems are grown in substrates that are "synthetic" in that they contain little to no natural mineral soils. Due to the limited fertility provided by these substrates, nutrition must be provided, mostly with fertilizers, for healthy and productive growth.

Another challenge to greenhouse and nursery production in California is that the majority of these crops are grown in containers, although there is some field production of specific nursery and floriculture crops. In either case, since these crops are grown in highly intensive systems, high plant densities and shortened crop times, there is also a high demand for resources including water, energy, labor, and nutrients.

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

This project will utilize workshop programs and materials developed under Agreement Number 16-0678-000-SA. The previous project presented 8 workshops in English and Spanish, and this proposal would provide 8 additional short courses (4 in English, 4 in Spanish) to respond to the requests we have received for this workshop.

OBJECTIVES

Objective 1: Review and improve the workshops that were provided by the previous CDFA FREP grant (Agreement Number 16-0678-000-SA). Workshops will be modified from half-day events to full-day events to allow for grower schedule accommodation, more content and demonstrations, greater discussion amongst attendees, and minimization of travel for project staff. Improvements will be made based on grower-attendee feedback from previous post-workshop surveys and instructor insight. Content will be expanded and may include demonstrations of how to monitor irrigation water and media conditions.

Objective 2: Provide 8 new workshops (4 in English, 4 in Spanish) for growers on plant nutrition and fertilizer management. Workshop locations may include areas with high concentrations of nursery and greenhouse production such as San Diego, Ventura, the San Joaquin Valley, and Salinas/Watsonville. At each location, day 1 will be the English workshop and day 2 will be the Spanish workshop. Workshop attendees will be surveyed to determine if workshops on additional topics regarding managing plant nutrition and the use of fertilizers would be helpful to growers for efficiently using fertilizers to optimize crop growth and minimize environmental impacts.

Objective 3: Continue to monitor the plant nutrition YouTube videos produced under the previous grant (Agreement Number 16-0678-000-SA). These videos were announced at the UCNFA website (http://ucnfa.ucanr.edu/), included a link to the list of the videos (http://ucnfa.ucanr.edu/Fertilizers_and_Plant_Nutrition_Videos), and posted on the UCNFA YouTube channel (https://www.youtube.com/channel/UC7OYtL9PEKN4CzcJLBYoFdg) for easy access by growers and their personnel. Viewership totals and video comments will be monitored. Videos will be assessed and improvements to the existing videos may be proposed. Additional topics for future videos may also be proposed.

DESCRIPTION

This project builds upon prior work by the University of California Nursery and Floriculture Alliance (UCNFA) and a previously awarded CDFA FREP grant (Agreement Number 16-0678-000-SA).

As part of a long-term project, the UCNFA team has been providing half-day English and Spanish workshops on plant nutrition and fertilizer management since 2011. Over the years, these workshops have been revised, expanded, and offered to growers throughout California. A listing of previous workshops can be found at http://UCNFA.UCANR.edu. In the previously awarded CDFA FREP grant titled "University of California Nursery and Floriculture Alliance Fertilizers and Plant Nutrition Education Program," 8 half-day workshops (4 in English and 4 in Spanish) were offered during the 2017-2018 project period. These workshops included new topics and demonstrations incorporated by the UCNFA team in response to feedback from attendees on previous events. This grant also provided funding for the production of educational nutrient management YouTube videos.

The success of the workshops led to numerous requests for more events. This project will provide 8 additional workshops (4 in English, 4 in Spanish) to meet grower demand. Workshops will be held throughout California in locations of high concentrations of nursery and greenhouse growers such as San Diego, Ventura, the San Joaquin Valley, and Salinas/Watsonville. The workshops will be modified from half-day events to full-day events. This will accommodate the incorporation of more content and demonstrations and greater discussion amongst attendees. Post-workshop surveys will provide feedback for continuous workshop improvement and insight on grower likelihood of implementing efficient fertilizer management practices. The earlier workshops delivered content in 2 half-day sessions. On the first day, Part 1 of the workshop series described the roles of plant nutrients. Content was provided in English in the morning and to a different audience in Spanish in the afternoon. About 1 month later, Part 2 of the series discussed operational topics related to fertilizer use and management, again in English in the morning and Spanish in the afternoon. This format was used based on surveys of attendees of the pilot workshop conducted in the previous project. However, we found that the audiences of Parts 1 and 2 were different, so few attendees received the entirety of the information presented by the program. This project proposes to provide all of the content in a single day so that attendees will receive all of the relevant information on plant nutrition and fertilizer management. This format also reduces travel costs since the transportation costs per workshop are reduced.

ACCOMPLISHMENTS

As this is an outreach and extension project of in-person workshops, no events took place before July 2022 due to COVID restrictions. Gerry Spinelli has joined the team to add his expertise in nursery water and nutrient management. Topics are focused on plant production in greenhouse and nursery systems and covered in the workshops include:

- The essential plant nutrients
- Nutrient uptake processes
- Nutrient allocation in plants
- Diagnosing plant nutrient disorders
- Measuring nitrate in water
- Hands-on activities include using several methods to measure in water samples:
- Nitrate and nitrate-N
- pH
- electrical conductivity

Workshops were planned in Vista, CA (July 12th in English and 13th in Spanish), Ventura (August 9th in English and 10th in Spanish), Modesto (August 23rd in English and 24th in Spanish), and in Salinas (November 9th in English and 10th in Spanish). A video of the Vista English presentation is posted on the UCNFA website along with the ten videos produced from the previous FREP supported project.

ACKNOWLEDGEMENTS

We would like to acknowledge the support from CDFA FREP for this project under agreement 20-0963-000-SA and the earlier project that initiated and developed this extension program under agreement 16-0678-000-SA.

Nitrogen Response of Industrial Hemp Cultivars Grown for CBD, Essential Oils

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OBJECTIVES

1. Evaluate for two biotypes of industrial hemp (autoflower/shorter-season types, full-season photoperiod-sensitive types) grown for essential oils such as cannabidiol (CBD) the impacts of N application amount and variety/growth habit/plant type on plant N uptake, harvest removal, yield responses.
2. Assess impacts of N management approach on THC and CBD tissue content, including partitioning to harvested portions of plants.

DESCRIPTION

Trial sites were prepared at the UC West Side REC (WSREC) in Fresno County with a Panoche clay loam soil, and at the UC Davis Campus Farm (UCD) in Yolo County with a Yolo fine sandy loam soil. Preliminary soil samples were collected and analyzed for N, P, K at field sites, and samples analyzed for use in N, P, K fertilization decisions. At each site, subsurface drip irrigation lines were installed (8-10 inches deep, two lines per bed 30 inches apart on 60-inch-wide beds). For the 2021 growing season, seeds were provided by two seed companies (Phylos and Kayagene for autoflower varieties N study), and transplants were provided by one company (Cultivaris for full season varieties in the nitrogen studies). Full-season, photoperiod-sensitive cultivars selected were "Scarlett" and "The Wife", while "Maverick" and "Alpha Nebula" were chosen for the Autoflower, short season types. In 2022, due to multiple issues regarding seed and transplant availability, we direct seed cultivars for both autoflower (Maverick, Alpha Nebula and Rincon cultivars) and full season (Early Wu, Cookie Crush cultivars). Seed companies provided Certificates of Analysis for expected THC levels, and cultivars were selected for acceptable low THC content. In 2021, transplants of full-season cultivars were planted the third week of June at UCD site and fourth week of June at West Side REC. The plantings were not successful in producing an acceptable stand of plants at either location due to variability in planting depths and related problems impacting emergence. Different types of planters were used for a second round of direct seed plantings of the autoflower cultivars, with the second plantings the second week of July (UCD) and third week of July (WSREC site). Good stands of plants were achieved in this second planting at both sites. In 2022, both the autoflower and full-season types of plants were planted from seed, with autoflower planted late May and full season types planted late June. Plantings were established (through complete seedling emergence) using sprinkler irrigation (WSREC) or surface drip irrigation (UCD), after which irrigations were applied using subsurface drip systems. Drip-injection units were used to establish five fertilizer levels for each study, with applied N for autoflower cultivars (five treatments ranging from 20-30 lbs N/acre to 120 lbs N/acre) versus 20 to 200 lbs N/ac in full season cultivars. In past trials, time to harvest will differ markedly between autoflower types (estimated 70-85 days emergence to harvest for CBD) versus approximately full-season types (100-130 days for the photoperiod-sensitive (PPS) types). Based on differences in ultimate size of plants, growth duration, and optimal planting densities, we are running the nitrogen management experiments on these two very different types of hemp cultivars (autoflower versus full-season) as completely separate field trials, with different irrigation water application totals based on plant size and duration of growth. Plant densities used were approximately 17,000-20,000 plants/ac for autoflower varieties (typically smaller plants) and about ¼ of those populations for larger, longer growing season photoperiod-sensitive cultivars.

RESULTS AND DISCUSSION

The autoflower varieties begin first cola (flower buds) development generally about 2 to 4 weeks earlier than full season types in summer plantings. For the purposes of running a nitrogen fertilizer response trial, we have attempted to also adjust the irrigation water application amounts to also reflect the difference in plant size and canopy cover between the smaller autoflower cultivars versus the full season cultivars, resulting in about 40 plus percent lower water applications for autoflower cultivars due to a reduced irrigation water amount per week (lower crop coefficient) and shorter duration of growth. Soil water measurements have indicated that we are not markedly over-irrigating or under-irrigating autoflower cultivars in these trials. There were significant differences in plant width and height of both autoflower and full-season cultivars to increasing nitrogen applications, as might be expected when beginning stored soil nitrogen is low to moderate. Harvests were done in September and October 2021 and provided information on total plant dry weight and cola dry weight responses across treatments. 2022 field trials are still underway, so data is not yet available for this summary. Plant total dry weights will be measured along with cola fresh and dry weights to determine yield responses, and cola versus stem plus leaf total nitrogen content will be determined on select plants to assess peak above-ground nitrogen uptake in these trial sites.

Table 1. Cola (flower bud) yields (in lbs/acre) as a function of applied nitrogen treatments for Autoflower cultivars in 2021 at UCD and WSREC sites. Mean separation analyses were conducted for each site and cultivar type, different letters indicating differences at the 5% level.

Trial Site	Cultivar name	Cola yields (all colas larger than 3" length on main stem and branches) (lbs/acre)				
		Within growing season N application level				
UCD		T1 (0 lbs/ac)	T2 (15 lbs/ac)	T3 (50 lbs/ac)	T4 (75 lbs/ac)	T5 (110 lbs/ac)
	Maverick	1399 b	1395 b	1595 a	1561 a	1507 ab
	Alpha Nebula	1166 a	1144 a	1099 ab	954 b	1137 a
WSREC		T1 (0 lbs/ac)	T2 (30 lbs/ac)	T3 (60 lbs/ac)	T4 (90 lbs/ac)	T5 (120 lbs/ac)
	Maverick	1676 b	1899 ab	2186 a	2344 a	2407 a
	Alpha Nebula	1532 b	1682 b	1971 ab	2126 a	2034 a

Table 2. 2021 Cola (flower bud) yields (in lbs/acre) as a function of applied nitrogen treatments for Full-Season cultivars in 2021 at UCD and WSREC sites. Mean separation analyses were conducted for each site and cultivar type, with different letters indicating differences at 5% level.

Trial Site	Cultivar name	Cola yields (all colas larger than 3" length on main stem and branches) (lbs/acre)				
		Within growing season N application level				
UCD		T1 (0 lbs/ac)	T2 (45 lbs/ac)	T3 (85 lbs/ac)	T4 (135 lbs/ac)	T5 (170 lbs/ac)
	The Wife	975	1192 b	1469 ab	1818 a	1896 a
	Scarlett	1536 b	2102 a	2018 a	2104 a	2142 a
WSREC		T1 (12 lbs/ac)	T2 (55 lbs/ac)	T3 (110 lbs/ac)	T4 (165 lbs/ac)	T5 (220 lbs/ac)
	The Wife	885 c	1230 b	1589 ab	1812 a	1762 a
	Scarlett	712 b	860 b	1075 ab	1179 a	1269 a

In the 2021 trials, cola yield levels in autoflower cultivars were more responsive to increasing N application levels at WSREC site than at UCD, with fairly large increases in cola yields at WSREC from T1 on to the T3 level of N application (about 60 lbs N/acre). There was less of a response with increasing N beyond the 60 or 90 lbs N/acre rate. There was little or no response to applied N rates with the autoflower varieties at the UCD site with the Alpha Nebula cultivar, but a slight increase at the T3 (60 lbs N/acre) rate when compared to lower applications (Table 1). In the Full-Season cultivars (Table 2), at both sites and with both cultivars there appeared to be a strong cola yield response to increasing applied N fertilizer going from the T1 to the T3 level of applications (more consistent across sites than observed with autoflower types), with a more variable yield response to increases in applied N in T4 and T5 treatments. Similar data will be collected in the 2022 field trials.

TAKE-HOME MESSAGE

Research on best management practices for industrial hemp is made more complicated by the fact that there are a wide range of available cultivars of hemp with widely different plant characteristics including plant size, duration of growth and required growing season length for commercial harvests, final product of interest (earlier harvests of colas (flower buds) for essential oils, versus later harvests of mature plants when grown for fiber or seed). This current nitrogen study includes both full season and autoflower cultivars, but this trial is evaluating nitrogen management practices of industrial hemp is only for hemp cultivars grown for essential oils such as CBD, so it also is of importance that we will be testing for harvest timing concentrations of THC and CBD across cultivars and treatments. Differences in the prevailing growth habit of autoflower cultivars versus full-season photoperiod-responsive cultivars are large in the tested varieties, and this was the basis for the decision to use a lower range of N fertilizer application treatments in the shorter-season smaller autoflower cultivars than with the much larger plants in the longer growing season full-season cultivars.

ACKNOWLEDGEMENTS

This industrial hemp multi-year nitrogen management trial is supported by the California Department of Food and Agriculture Fertilizer Research Education Program (CDFA-FREP) as project #20-0964, and that support is gratefully acknowledged. As shown on the title page, donations of hemp transplants/clones and seed for conducting the trials were received from the multiple companies listed. In addition, we are receiving donated services for THC and CBD analyses from Alkemist Labs of Garden Grove, CA. These are incredibly valuable donations from each of these companies to assist with this project, and we wouldn't be able to do the study without this additional assistance. Finally, we are grateful for the hard work and attention to great attention to detail provided by our field research staff in these trials, including Jorge Angeles, Maya Hotz, Chris de Ben, and additional part-time staff.

Techniques to Minimize Nitrate Loss from the Root Zone During Managed Aquifer Recharge

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INTRODUCTION

Agricultural management of floodwaters (Flood-MAR) is of broad interest in California as a tool to recharge aquifers. Novel approaches are necessary to sustain irrigated agriculture in the face of new public policy constraints and challenges imposed by climate change, such as more intense precipitation whiplash. However, there are concerns to be analyzed before this practice can be safely implemented, such as contamination of groundwater by leaching residual soil nitrate (NO_3).

We assumed an overarching hypothesis that Flood-MAR would enhance NO_3 leaching compared to no Flood-MAR (business-as-usual). However, we hypothesized that early Flood-MAR timing would leach less NO3 than late Flood-MAR timing over the long-term, due to lower rates of mineralization when soils are cooler. Additionally, higher frequency Flood-MAR pulses (shorter interval between water applications) would leach less NO_3, since there would be less time for soils to generate NO3 from decay of soil organic matter (SOM) between Flood-MAR applications. Finally, NO_3 leaching risk would be offset partially by denitrification in finer textured soils by increasing periods of soil saturation and anaerobic conditions due to Flood-MAR.

OBJECTIVES

This research evaluated contrasting seasonal timing and frequency of Flood-MAR as strategies to minimize NO3 leaching by leveraging the Root Zone Water Quality Model (RZWQM), a widely validated tool developed and maintained by a team at USDA-ARS, to evaluate interaction of Flood-MAR with the N-cycle and inherent soil properties.

DESCRIPTION

RZWQM modeling included 33 Central Valley soil series representing distinct taxonomic family particle-size classes (termed here Coarse, Loamy and Fine) and five different 37-year climate records obtained from the California Irrigation Management System, spanning a precipitation gradient from relatively wet-to-dry in space and time (n=990 unique scenarios). The climatic gradient summarized by town from wettest to driest is as follows: Durham, Davis, Parlier, Five Points, and Shafter. Biogeochemical and physical parameters were established using end-of-run values from a preliminary 37-year business-as-usual run of each unique soil x climate modeling combination (n=165). This produced unique initial biogeochemical conditions for each of the soil x climate combinations to test again under another 37-year business-as-usual run and contrasting Flood-MAR strategies. In RZWQM simulations, Flood-MAR was practiced during the 10-wettest water years of each specific 37-year climate record, applying 600-cm additional water through Flood-MAR. During a Flood-MAR year, four 15-cm water applications were made in either January or March, using an application frequency of either 3- or 7-day intervals. A fifth scenario tested a 21-day Flood-MAR interval January-March.

RESULTS AND DISCUSSION

Multi-decadal RZWQM simulations suggest Flood-MAR can be used with near negligible risk of additional NO_3 leaching in relatively wet Central Valley locations (Durham and Davis, median annual precipitation > 400 mm yr-1) across a range of soil textures. Steady-state residual NO_3 in the wetter climates (Durham and Davis) were typically 60-100 kg N $Ha\text{-}_1$ after 37-years of the business-as-usual scenario (Figure 1). This is because in-situ precipitation during the wet years, which is when Flood-MAR is expected to be practiced, was capable of removing most residual NO_3 through deep percolation. This is true even in the finest textured soils, which are most difficult to leach due to their expansive microporosity. As precipitation declines, the Flood-MAR NO_3 leaching risk increased most clearly in loamy soils, even though the central tendency did not differ substantially across textural groups (Figure 1 & 2). Additional nitrate leaching risk increased in dry climates, because lack of precipitation allowed for residual NO_3 accumulation across growing seasons.

Loamy soils tended to present the greatest possibility of risk of additional NO_3 leaching with Flood-MAR in drier climates (Figure 2). In the driest climate (Shafter), 4 of 11 loamy soils leached >3000 kg additional NO_3-N ha_{-1} using 21-day frequency Flood-MAR with median fluxes of 1,270 kg additional NO_3-N ha_{-1}. In fine soils, NO_3 leaching risk was mitigated by denitrification, preventing build-up of residual NO_3. Flood-MAR timing strategies (January Flood-MAR vs. March Flood-MAR, combined with variable pauses among applications (3 vs. 7 vs. 21-day intervals, the latter January-March Flood-MAR) had only a negligible effect on NO_3 leaching risk. In fact, the effect of Flood-MAR timing strategies was only noticeable in wet climates where additional NO_3 leaching risk was comparably very low. While results demonstrated that Flood-MAR practices would be expected to increase net NO_3 flux to groundwater across all climates and soils, consistent Flood-MAR practices would also be expected to improve groundwater quality compared to business-as-usual irrigated agriculture. This is due to sustained provision of higher quality deep percolation water, which is especially limited in dry climates.

Thus, climates with median precipitation > 400 mm yr-1 were sufficient to leach rootzones in this simulated, fertilized agroecosystem, suggesting that Flood-MAR practiced in wetter climates is of low additional NO_3 leaching risk (Figure 2).

The most direct mechanistic explanation for additional nitrate leaching risk in loamy soils from drier climates is due to their moderate level of microporosity and capacity to accumulate $NO_{3.}$ Loamy soils require more percolating water to leach effectively compared to coarse soils, explaining their conduciveness to residual NO_3 accumulation.

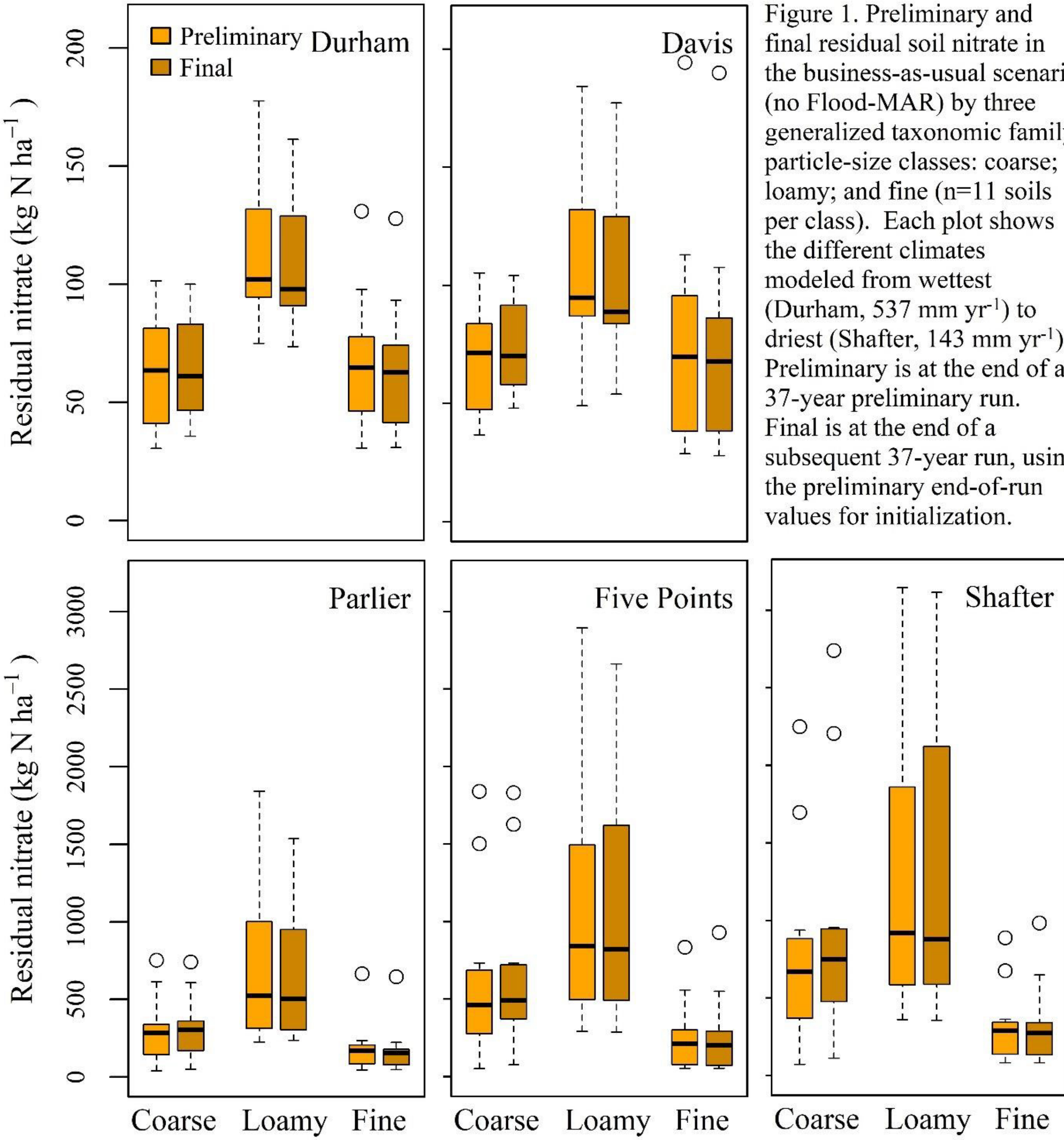

Figure 1. Preliminary and final residual soil nitrate in the business-as-usual scenario (no Flood-MAR) by three generalized taxonomic family particle-size classes: coarse; loamy; and fine (n=11 soils per class). Each plot shows the different climates modeled from wettest (Durham, 537 mm yr^{-1}) to driest (Shafter, 143 mm yr^{-1}). Preliminary is at the end of a 37-year preliminary run. Final is at the end of a subsequent 37-year run, using the preliminary end-of-run values for initialization.

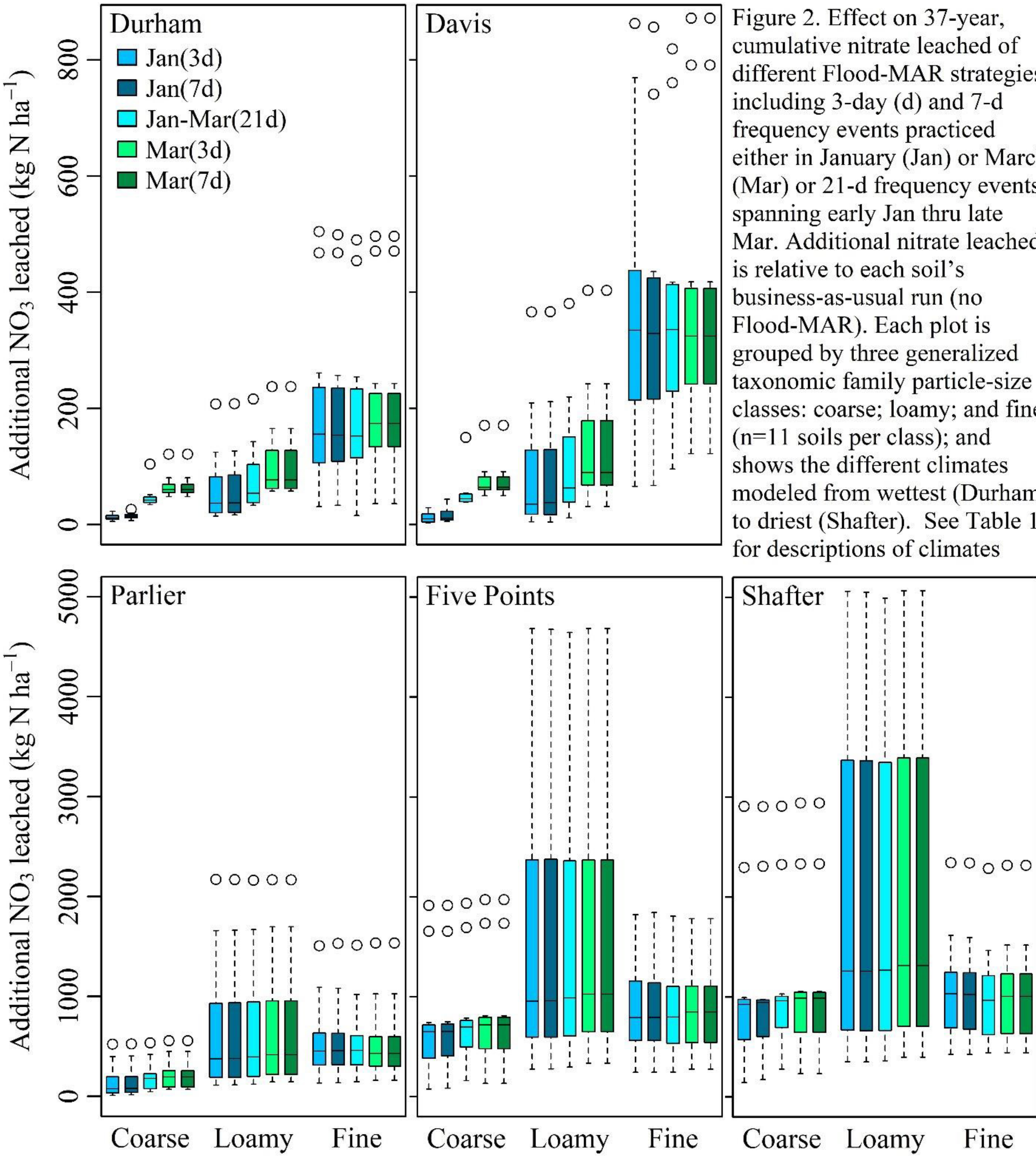

Figure 2. Effect on 37-year, cumulative nitrate leached of different Flood-MAR strategies, including 3-day (d) and 7-d frequency events practiced either in January (Jan) or March (Mar) or 21-d frequency events spanning early Jan thru late Mar. Additional nitrate leached is relative to each soil's business-as-usual run (no Flood-MAR). Each plot is grouped by three generalized taxonomic family particle-size classes: coarse; loamy; and fine (n=11 soils per class); and shows the different climates modeled from wettest (Durham) to driest (Shafter). See Table 1 for descriptions of climates

Although coarse soils typically present the greatest risk to NO_3 leaching in agriculture. This truism did not hold up to evaluations of the effect of Flood-MAR on additional NO_3 leaching risk. Except in the driest climates, precipitation is sufficient in the Central Valley to leach residual NO_3, such that the additional NO_3 leaching risk presented by Flood-MAR is typically lower in coarse soils compared to loamy soils.

ACKNOWLEDGEMENTS

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Nutrient Management and Irrigation Efficiency Outreach and Education for Latino and Southeast Asian Farmers

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INTRODUCTION

Adopting changes for optimal nutrient management and irrigation efficiency is inherently complicated as it depends on crop types with different nutrient and water needs and timing, multiple site-specific factors (e.g., soil characteristics, slope, irrigation system), and climate (e.g., rainfall, temperatures). Furthermore, social and economic barriers and inequitable technical assistance (TA) provisions hinder management changes among farmers. Farmers are typically risk averse and management adjustments can lead to uncertainty, a barrier to enhancing nutrient management and irrigation efficiency. This is harder to overcome in communities that lack TA services. Many California producers do not speak English as a first language and therefore receive TA at lower rates than their English-speaking counterparts. Lack of TA delivery with linguistically and culturally proficient service providers familiar with production practices of small-scale diversified vegetable systems, coupled with historical uneven distribution of services across ethnic and racial groups, and risk aversion inherent in farming, prevents California agriculture from realizing its nutrient management and irrigation efficiency potential.

OBJECTIVES

1. Increase nutrient management and irrigation efficiency technical assistance and information distribution for underserved farmers and farm workers.
2. Increase management efficiencies and adoption of sustainable nutrient management and irrigation efficiency practices

DESCRIPTION

1. Technical assistance services and information distribution for underserved farmers

Eleven on-farm tailgates are being delivered to serve Southeast Asian growers and farm workers in the San Joaquin Valley and

Latino growers and farm workers in the Central Coast, Southern California, and San Joaquin Valley in the primary languages of the audience. Four tailgates will be held in Fresno County, three in Riverside County, and four in Santa Barbara County. Each will focus on providing technical information to growers and demonstrating efficient fertilizer selection, application, and timing; fertigation; micro-irrigation; adoption of practices of compost application, cover cropping, and mulching; and compliance with ILRP, ILP, CARP, other WDRs, depending on RWQCB jurisdictions from which growers and farm workers are attending.

These 11 tailgates are collectively reaching 165 growers and farm workers that will facilitate direct and potentially lasting connections with local TA providers, including agricultural consultants that speak their primary languages and fertilizer industry professionals and agricultural retailers as well as Water Quality Coalition staff that can assist growers in WDR compliance requirements, including development of Nitrogen Management Plans.

2. Increase management efficiencies

AFT's Predictive Soil Health Economic Calculator (P-SHEC) tool estimates the potential short-term and long-term costs and benefits of adopting a variety of practices and changes in fertilizer and irrigation management. AFT is connecting with agricultural consultants, retailers, and other industry professionals to participate in tailgates and assist in the predictive assessments with recommendations and pricing of products that can enhance nutrient management and irrigation efficiency. Involving these consultants will provide an opportunity for mutual learning and enhance their abilities to work with growers.

Training is being provided to growers to carry out their own farmer-led predictive assessments through augmenting and delivering business development training curriculum through a partnership with the Asian Business Institute and Resource Center (ABIRC). Two business development trainings will be carried out in the Fresno region with Hmong growers and farm workers and two in the Santa Maria region with Latino growers and farm workers, delivered to a minimum total of 80 growers and farm workers. The curriculum and delivery will also be augmented with financial management and economic benefits of matching and applying the appropriate fertilizer types and amounts to the right crops at the right time using efficient methods on diverse leafy green, cole, cucurbit, and solanum vegetable cropping systems.

Fifteen Spanish radio broadcasts on KCHJ El Gallito are being organized to reach many Spanish-speaking growers at once with efficient fertilization information on diverse vegetable cropping systems. These broadcasts will also discuss the importance of efficient fertilization in helping growers comply with local water quality regulations and in seeking further technical assistance.

The project will be conducted and/or translate into Spanish and Hmong and can be made publicly available online FREP resources. AFT staff have a preliminary list of suggested resources to translate that consists of FREP's Nitrate Quick Test guide, FREP's Soil Test Sampling guide for phosphorous and potassium, FREP's Sampling for Soil Nitrate Determination, and handout versions of FREP Fertilization guides for beans, broccoli, cauliflower, lettuce, melons, onion, and processing tomatoes. In addition to making these translated resources available online for an indefinite period, these resources will also be used as education aids in the above-mentioned tailgates and business development trainings. AFT will coordinate with FREP on the most appropriate place online on which to publish these translated resources.

RESULTS AND DISCUSSION

AFT has 2 farmer tailgate meetings currently planned with partners ABIRC in Fresno on Sept 8, 2022, and Cachuma RCD in Santa Maria on October 12, 2022. In Fresno, AFT and ABIRC have partnered to provide timely information on the impacts the drought will have on small scale producers in the San Joaquin Valley, local groundwater regulations and specific soil and water practices that can be implemented to address these resource concerns. Additionally, local technical service providers such as Sierra Resource Conservation District and the Natural Resource Conservation Service in Fresno will be available for follow up implementation. This event will be conducted in English with interpretation to Hmong, Lao and Spanish to be able to reach farmer communities that have been historically underrepresented and under resourced.

The Santa Maria farmer tailgate meeting is focused on soil health and irrigation efficiencies demonstrating the use of distribution uniformity evaluations (DU) and Nitrate Quick Tests (NQT) to help farmers identify the inefficiencies in irrigation and the ideal timing of the fertilization applications. These demonstrations are being conducted in Spanish with a group of small-scale diversified vegetable and strawberry farmers.

The coordination of these events has so far resulted in a deeper understanding of key partnerships who have technical capacity related to nutrient and irrigation management including financial assistance that can support the implementation of these management practices. This coordination has also been a way to see where there is need for culturally appropriate outreach efforts in Spanish and Hmong to be able to provide long lasting relationships within the underserved farmer communities that can directly lead to adoption of sound soil and water practices.

ACKNOWLEDGEMENTS

We wish to express gratitude to partners: Asian Business Institute and Resource Center (ABIRC), Cachuma Resource Conservation District (CRCD), as well as the California Department of Food and Agriculture Fertilizer Research and Education Program (CDFA-FREP) for providing funding and technical support for this project.

Nitrogen Fertilizer and Irrigation Best Management Practices for the Low Desert Sudan Grass Production Systems

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INTRODUCTION

The low desert, particularly the Imperial Valley, is the major Sudan grass producing region of California. Sudan grass hay immensely contributes to the agricultural economy of California due to the rise in exports to Japan, as well as overall increased domestic forage demand. Most growers of the low desert apply excessive amounts of N to the Sudan grass fields with the assumption that it will maximize crop yield. Although, Sudan grass responds very well to Nitrogen (N) fertilizer and can accumulate higher levels of N in its tissue, excessive amount of N fertilizers results in high tissue concentration of N in hay and becomes toxic to livestock or leaches out of the fields and cause environmental pollutions. Higher amounts of tissue N concentration in Sudan grass hay is unacceptable for export, hence cause diminished hay market value. Environmental pollution from excess fertilizer is exacerbated when eroded or leached due to excess irrigation water that carries (drains) contaminated water into the Salton Sea where it causes severe damage to the ecological zone and aquatic life. This project is aimed at developing improved N and irrigation management strategies for Sudan grass production in the low desert.

OBJECTIVES

1. Develop N fertilization practices combined with best irrigation management that may improve the efficiency of crop N fertilizer use (NUE) and water inputs for sudangrass production systems.

2 Layout strategies that reduce N loss from agricultural crop fields and at the same time, maintain Sudan grass crop yield of higher export quality and less risk of animal poisoning.

3 Develop fertilization practices that will improve the efficiency of nitrogen fertilizer inputs, improve marketability of hay production, and maximize grower's economic benefit while reducing loss from sudangrass production systems.

DESCRIPTION

The trial was conducted at the University of California Desert Research and Extension Center (UC DREC) with DREC support for crop establishment and maintenance. Three fertilizer rates (sub plots); (1) Lower rate of 50 lbs of fertilizer N / acre at each cutting, (2) Higher rate conventional N fertilizer rates of 80 lbs of fertilizer N / acre, and (3) N fertilizer at successive cutting based on crop N needs and three irrigation levels (main plots), (1) 80% crop ET, (2) 100% crop ET, and (3) 120% crop ET were tested using split plot design with 4 replications per treatment. Fertilizers were applied as common pre-plant and as treatments following each crop cutting cycles. Each irrigation treatment is controlled by gated pipes. Plant establishment was performed using sprinkler irrigation for all treatment plots. Preplant soil samples were taken from four depths (0-1, 1-2, 2-3, and 3-4 ft.) from 4 sites each. Composite soil samples were analyzed for various components (Table 1).

The soil was generally low for N and phosphorus, but high for K, pH, Ca, Mg, NA, Fe and Mn. It is a silty clay soil, dominantly. Trial

Table 1. General information for pre-plant experimental site soil at DREC (D1, D2, D3, D4 are soil sampling depths of 0-1, 1-2, 2-3, and 3-4 ft, respectively)

Date Area	**D1**	**D2**	**D3**	**D4**	**Optimum Levels**	
Soil Depth	--	--	--	--	**Low**	**High**
Total N, *Combustion/%*	0.08	0.07	0.06	0.05	-	-
Org. Matter, *Combustion/%*	1.36	1.22	0.95	0.91	-	-
Org. Matter (Walkley Black) *Combustion/%*	1.14	1.46	0.66	0.43	-	-
Ammonium, *OLSEN/PPM*	3.9	3.9	5.8	5.8	-	-
NO3-N, *OLSEN/PPM*	21.6	10.5	4.1	2.1	**25.0**	**50.0**
PO4-P, *OLSEN/PPM*	5.6	2.9	1.1	2.5	**10.0**	**20.0**
K, *OLSEN/PPM*	243	220	178	201	**80**	**160**
SP, *SATURATION PASTE/%*	66.3	73.8	82.1	68.3	**30.0**	**70.0**
Soil Texture *ESTIMATED*	SILTY CLAY	SILTY CLAY	CLAY	SILTY CLAY	**-**	**-**
CEC, *MEQ/100 GMS*	39.4	45.3	51.9	41.0	**-**	**-**
ECe dS/M, *SATURATION PASTE dS/M*	3.1	3.4	6.4	8.9	**2.0**	**4.0**
pH, *SATURATION PASTE/UNITS*	8.09	7.98	7.96	7.97	**6.50**	**7.50**
Ca, *NEUTRAL AMMONIUM ACETATE/PPM*	5,633	5,812	6,041	6,671	**300**	**600**
Mg, *NEUTRAL AMMONIUM ACETATE/PPM*	1,081	1,178	1,236	1,361	**40**	**125**
Na, *NEUTRAL AMMONIUM ACETATE/PPM*	584	729	1,264	1,747	**100**	**200**
ESP%, *CALCULATED %*	4.8	5.7	9.2	11.2	**10.0**	**15.0**
Fe, *DTPA/PPM*	8	22	24	24	**3**	**5**
Mn, *DTPA/PPM*	4.0	4.8	3.9	4.3	**2.0**	**3.3**

Figure 1. trial field preparation, planting and sprinkler irrigation for crop germination and early-stage establishment. Irrigation was resorted to flood irrigation following crop establishment.

Figure 2. Sudan grass crop growth during early growth stage (left) and patchy growth during later growth season (right).

field preparation, planting, and sprinkler setup and irrigation was perfectly laid out for initial crop germination and establishment (Figure 1).

RESULTS AND DISCUSSION

It was unfortunate that this year's trial was not successful. Although Crop establishment was successful during early growth stages, most trial fields ended up in patchy growth (Figure 2), during subsequent growth stages. The patchy growth was unrelated to treatment effects. Since no effective data can be collected from such growth, this year's trial was terminated. There was no justification for the patchy growth but is suspected that it may be due to some internal soil residual effects or mismanagement of irrigation system. Accordingly, no data was collected for this year's trial. The trial is postponed for next year. DREC promised for next year planting (as of last weeks of February or early weeks of March 2023) and crop establishment at another field within the research center.

Regardless of trial failure for this year, two knowledge extension events were organized or delivered. In collaboration with county advisors, we organized a webinar of Agronomic crops and Irrigation water management field day and workshop in Imperial County (May 2022). I gave slide supported presentation titled Resource (fertilizer & irrigation) management for effective crop productivity. My presentation covered low desert grower's practices of resource use, excess fertilization, over irrigation problems, N uptake potentials of Sudan grass, tissue N accumulation, and the potential toxicity of such crops to livestock. Fifty-five people, including CCAs, PCAs, growers, Industry people and researchers attended this field day and workshop (combined). Although, I did not provide any data at this time, I believe that my presentation of a project in progress alerted growers on the need for proper fertilizer use and usefulness of the potential outcomes of the planned project. I also gave an update (virtual zoom presentation) on this Sudan grass resource use project, its status, future plans, and the need for conducting best fertilizer and irrigation management for low desert Sudan grass during a UCANR Agronomy Team meeting in May 2022. Thirty-five UCANR researchers and scholars were on the virtual meeting.

Expected outcomes and future benefits of the project

If fully conducted and data collected, the project is expected to develop information and tools on Sudan grass N and water use and develop best resource management practices. Best resource management for optimum, economical, and safe crop productivity will be disseminated to growers, farm mangers, irrigators, farm workers, and stakeholders for implementation.

ACKNOWLEDGEMENT

Funding for this study was provided by the California Department of Food and Agriculture (CDFA) - Fertilizer Research and Edcation Program (FREP). Regardless of the outcomes from the trial, the research team gratefully acknowledges the UCCE Imperial County staff and the UC DREC staff, for their help in crop establishment, planning for a next term field-work-and related tasks.

Optimizing Nitrogen Fertilizer Concentrations in Vegetable Transplant Production

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INTRODUCTION

California's $7.68 billion vegetable crop industry (CDFA 2021) is dependent on the use of vegetable transplants to increase productivity. Vegetable field production is supported by 2,524 vegetable transplant producers in the U.S. and in California, 147 growers produced $159 million of these crops (USDA 2019). Vegetable crop growers expect transplant producers to provide high-quality vegetable transplants that will ensure a successful crop. To produce high-quality plants, sufficient plant nutrients are commonly supplied as soluble fertilizer in irrigation water. In most crop production systems, fertilizer is a small percentage of total cost, therefore supplying excessive fertilizer to ensure plant health is only a minor financial cost. However, excessive fertilizer can cause environmental problems. Additionally, excessive fertilizer application can produce undesirable plants with unnecessary, weak, or poor shoot growth, decreased root growth, or that are more prone to disease.

Currently, there are no clear nitrogen fertilizer application guidelines for the diverse range of vegetable transplants produced in California. For example, soluble nitrogen recommendations for lettuce range from 60-600 ppm. Extension publications have general recommendations, such as providing more nitrogen for solanaceous and less for cucurbit crops. However, these same extension publications on vegetable transplant production revealed similarly broad recommendations ranging from 15-100 ppm nitrogen without specific guidelines for individual crops.

To provide clarity for vegetable transplant producers, we propose evaluating nitrogen uptake of the top five vegetable transplant crops in California. To elucidate optimal nitrogen concentrations for the top vegetable transplant crops, we will measure total plant nitrogen uptake and water use to calculate optimal nutrient solution nitrogen concentration.

OBJECTIVES

1. Determine nitrogen requirements for top five California vegetable transplant crops.
2. Convey results to transplant growers through publications and presentations.

DESCRIPTION

Each experiment will consist of a single vegetable crop from the top five vegetable transplant crops in California. Plug trays of each crop will be germinated on a mist bench before being placed on individual ebb and flood benches for nutrient solution application. Growing media will be refilled to container capacity each day and daily water use will be recorded. Each ebb and flood bench will be built on a weighing lysimeter to record daily evapotranspiration. Once plants are considered commercial size and are established in media, the number of days from experiment initiation to completion will be recorded. A rating index will be developed and plants will be evaluated according to this rating index on the last day of the experiment.

At experiment completion, shoot and root samples will be separated and dried at 55°C for 48 hours. Roots will be washed free of media before drying. Plant samples from each individual plug tray will be kept together and dried in a single paper bag, resulting in a composite plant sample for each plug tray. Dried root and shoot biomass for each plug tray will be recorded and samples will be analyzed for nitrogen content. Root media extract samples will be collected for nitrogen concentration analysis.

The nitrogen concentration in plant tissue will be multiplied by the total biomass harvested from each plug tray to get the total nitrogen mass per plug tray. Optimal nitrogen concentration for each vegetable transplant crop will be calculated as the total nitrogen mass in all plant tissue in a plug tray divided by the total plug tray water usage.

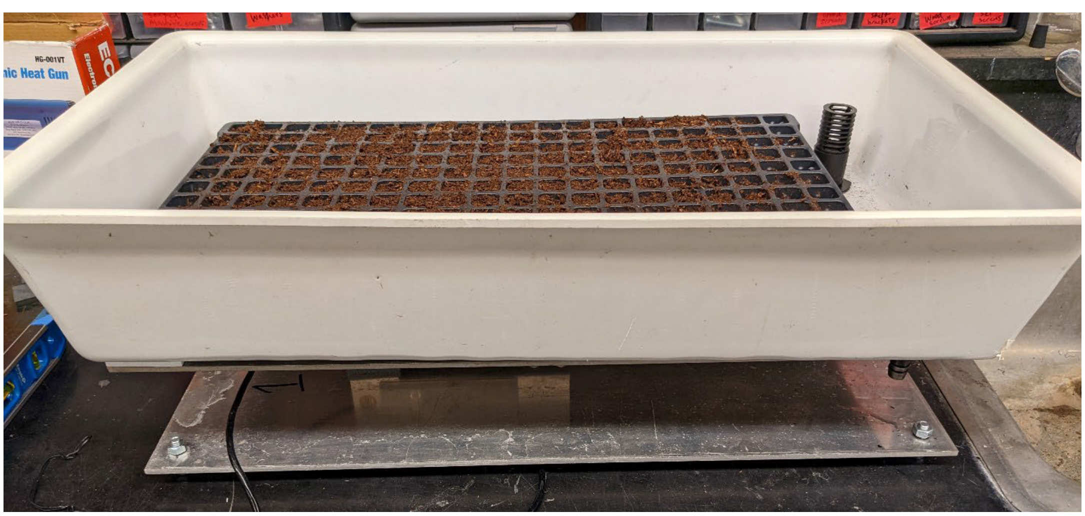

Figure 1. Weighing lysimeter ebb and flood tray for applying fertilizer treatment and measuring daily evapotranspiration.

RESULTS AND DISCUSSION

According to the 2019-2020 California Agricultural Statistics Review (CDFA 2021), the top five vegetable transplant crops in California in order of total sales are processing tomatoes, head lettuce, broccoli, romaine lettuce, and celery. Popular production cultivars of each vegetable will be used for developing the optimal nitrogen concentrations. The varieties we will use are processing tomato Nunhem's 'N 6428', head lettuce 'Grazion MT0', broccoli 'Green Magic F1', romaine lettuce 'Blue Rock OG MT0', and celery 'Kelvin F1 OG'.

Seeds of each crop were placed in petri dishes and germinated in a growth chamber. Time until radicle emergence was 6, 1, 2, 1, and 3 days for processing tomato, head lettuce, broccoli, romaine lettuce, and celery, respectively. Seeds of each crop were also planted into peat media and germinated on a mist bench in greenhouse. Two other media, peat:vermiculite (70:30%, V:V) and peat:perlite (70:30%, V:V), were tested after poor germination of some crops in peat media. Superior germination results were obtained for each crop utilizing the peat:vermiculite media. Physical properties of each media were tested. Seedling survival of most crops was greatest in the peat:vermiculite media and we will use this media for all crops except celery. Celery seedling survival was less successful and we are still evaluating optimal media for celery production.

Table 1. Physical properties of each media evaluated for use in plug trays. Media was 4 cm deep.

Media	100% Peat	Perlite (30%)	Vermiculite (30%)
Total Porosity	99.7%	98.1%	96.6%
Water-holding capacity	79.6%	65.2%	62.2%
Air-filled porosity	20.1%	32.9%	34.3%
Bulk density (g cm^{-3})	0.064	0.062	0.110

We are actively seeking vegetable transplant growers who are willing to share information about their production system and advise on plant quality objectives for this project. If you are interested in the work we are doing and would like to participate, please contact the project leader at bjpitton@ucdavis.edu.

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Quantify and Model Overlooked Pathways of Nitrogen Loss from Organic Inputs Across Contrasting Soil Types

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INTRODUCTION

The recently adopted Agricultural Order 4.0 regulation in the Central Coast region allows for compost and other organic amendments to be included in nutrient management plans, with a discount factor for N depending on the expected timing of N mineralization. Increased use of organic inputs makes paramount the need for site specific recommendations to reduce unintended externalities, such as N loss to groundwater. Scientific confidence is still lacking in the ways in which the amount, type, and timing of compost application interact with soil edaphic properties to improve nitrogen use efficiency (NUE) and reduce N loss1. While, on average nitrate (NO_{3-}) leaching is reduced in systems using organic inputs, the variability in N loading is high, highlighting the need to account for the heterogeneity across systems and landscapes[1]. For instance, long-term N balance research by Collaborator Brennan showed that compost use in an organic vegetable rotation led to >100 kg N/ha/yr that was either lost or stored in soil N below 30cm2. This makes the wide scale adoption of compost use challenging. First, our understanding of whether adding compost supports crop N demands at the right time so as to minimize potential for groundwater contamination is growing but still incomplete. Second, there is emerging evidence that leaching of dissolved organic N (DON) from organic inputs could be a considerable, but overlooked, N loss pathway[3]. On average almost one third of N losses across agricultural systems were in the form of DON_3. While much of the concern over the consequences for human health have focused on NO_{3-} in drinking water, DON could act as a source of NO_{3-} in groundwater as it is mineralized and on its own can be harmful to human consumption due to the formation of disinfection byproducts[4]. This project proposes to understand how compost application at varying rates interacts with soil edaphic properties to influence both inorganic and organic N retention and loss dynamics in agricultural landscapes within California's Central Coast.

OBJECTIVES

This three-year project addresses how compost can be managed to support productivity while protecting water quality. We will leverage a long-term experiment and sampling from 28 farms in prior related projects. Our specific objectives are:

1. Generate, synthesize and classify data on N availability, losses and retention across a diversity of farms to inform model development.
2. Calibrate and validate a crop-ecosystem model, Ecosys, for lettuce production in the Central Coast of California.
3. Develop and test scenarios of compost application rates and timing across contrasting soil types to quantify N dynamics and losses in order to develop guidance on how to apply compost to support both productivity and N losses.
4. Conduct outreach to vegetable growers across the study region (Santa Cruz, San Benito, and Monterey Counties), as well as to the Central Coast Water Quality Control Board, and professional agricultural extension and support (e.g., CCAs, PCAs, RCD, NRCS, UCCE personnel).

DESCRIPTION

In this first, partial year of the project, we conducted a column experiment in a greenhouse to test the effect of compost additions on leaching of DON and inorganic N from a sandy soil (Obj 3; Figure 1). Sandy soils from the top 30cm depth were collected in early June, 2022 from an organic field at the USDA ARS experiment station in Salinas, CA. Soils were packed into 40cm high columns with small marbles on the bottom to allow for free drainage of leachate to be collected. Field capacity was determined on 15 reps of soil using the imbibing method. Soils were packed to an approximate field bulk density of 1.33 g/cm^3. Soils were analyzed for initial inorganic N and DON and subsamples were kept and stored for total soil carbon and N, and soil texture. We used an experimental regression design where linearly increasing rates of compost additions were applied across 15 columns. This allows for quantifying non-linear/threshold effects of compost addition. Compost rates were 0, 1.9, 3.8, 5.7, 7.6, 11.4, 15.2, 19, 22.8 Mg/ha and compost was added on a per dry weight basis. Three of the rates were replicated three times (lowest, middle, and highest rates) while other rates had one rep. The first irrigation started on 6/26/22 and leachate was collected and analyzed for ammonium (NH_{4+}), NO_{3-}, and DON. Irrigations occurred once a week and columns were brought to 10% above field capacity each irrigation event. Leachate collection finished 8/24/22 and lettuce was harvested, dried, and ground for later determination of plant N content. Soil samples will be taken from each column and final concentrations of NH_{4+}, NO_{3-}, and DON will be assessed. Future analysis will include a repeated column experiment using the experimental regression design on a heavy clay soil from the Central Coast area and is set to begin at the end of September, 2022.

In addition to the column experiment, deep coring (0-1m) from the USDA long term trial was conducted in late August, 2022 and soils were stored for later analysis of total N. This will help shed light on whether N surpluses documented in Brennan's work were leached or stored deeper in the soil profile.

Figure 1. Experimental columns with lettuce, using a wide range of rates of compost addition to assess leaching of DON and inorganic N.

RESULTS AND DISCUSSION

Preliminary results from the column experiments suggest that total N loss is greatest after a disturbance event and that more N is leached as DON than NO_{3^-}. After the disturbance (packing of the columns, akin to a tillage event) resulted in large amounts of DON being released and lost during the subsequent irrigation event on 6/24/22 (Table 1). Continued analysis will compare the N species lost over time until harvest. While NO_{3^-} values in the leachate after the first irrigation were above the 10ppm MCL, subsequent irrigations led to NO_{3^-} loads below. Future data analysis for the rest of the irrigations will determine if DON is the dominant loss of N in systems using compost.

ACCOMPLISHMENTS

Thus far, we have successfully completed a greenhouse column experiment quantifying the N species in leachate lost from the root zone of a sandy soil. We also successfully conducted deep coring down to a meter in the long-term trial (180 samples collected).

Table 1: Average nitrate (NO3-) and DON in leachate over time from the lowest, middle, and highest compost rate treatments along with standard deviations (n=3)

Compost Rate (Mg/ha)	Date	Average NO_3^- (ug N/ml)	Standard Deviation	Average DON (ug N/ml)	Standard Deviation
0	6/24/22	12.5	3.6	38.6	12.5
7.6	6/24/22	21.8	5.2	79.9	13.3
22.8	6/24/22	16.4	1.0	23.9	6.4
0	6/27/22	0.1	0.0	5.9	2.0
7.6	6/27/22	0.2	0.1	10.1	6.9
22.8	6/27/22	0.2	0.1	10.9	7.2
0	7/11/22	6.4	1.7	1.0	0.9
7.6	7/11/22	3.0	0.8	ND	
22.8	7/11/22	3.3	1.0	ND	

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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.

Evaluation of Certified Organic Fertilizers for Long-Term Nutrient Planning • *William Horwath and Xia Zhu-Barker, 16-0670*

Understanding Influences on Grower Decision-Making and Adoption of Improved Nitrogen Management Practices in the Southern San Joaquin Valley • *Sat Darshan Khalsa and Mark Lubell, 18-0596*

Improving Nitrate and Salinity Management Strategies for Almond GRown Under Micro-Irrigation • *Patrick Brown- 18-0549*

A System Nitrogen Balance for Container Plant Production • *Lorence Oki, 17-0516*

Assessment of Harvested and Sequestered Nitrogen Content to Improve Nitrogen Management in Perennial Crops • *Charlotte Gallock, 17-0488*

Promoting the adoption of soil nitrogen quick tests by Spanish-speaking operators on strawberry ranches in Santa Cruz and Monterey Counties, • *Gerry Spinelli*, 18-0535

Developing a Review Process for Continuing Education Courses for Growers who Complete the Nitrogen Management Plan Training Course, • *Parry Klassen,* 16-0703

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*

Remediation of Tile Drain Water Using Denitrification Bioreactors • *T.K. Hartz and Mike Cahn, 11-0462*

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Comparing the Efficiency of Different Foliarly-Applied Zinc Formulations on Peach and Pistachio Trees by Using 68Zn Isotope • *R. Scott Johnson, 07-0669*

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Relationship between Fertilization and Pistachio Diseases • *Themis J. Michailides, 97-0365 M99-06*

The Effect of Nutrient Deficiencies on Stone Fruit Production and Quality - Part II • *Scott Johnson, 97-0365 M99-05*

Nitrogen Fertilization and Grain Protein Content in California Wheat • *Lee Jackson, 97-0365 M99-04*

Development of Fertilization and Irrigation Practices for Commercial Nurseries • *Richard Evans, 97-0365 M99-03*

Irrigation and Nutrient Management Conference and Trade Fair • *Sonya Varea Hammond, 97-0365 M99-02*

Agricultural Baseline Monitoring and BMP Implementation: Steps Towards Meeting TMDL Compliance Deadlines within the Newport Bay/San Diego Creek Watershed • *Laosheg Wu & John Kabashima, 97-0365 M99-01*

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Potassium Responses in California Rice Fields as Affected by Straw Management Practices • *Chris Van Kessel, 97-0365 M98 03*

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Development of Nitrogen Best Management Practices for the "Hass" Avocado • *Carol Lovatt, 97-0365 M98-01*

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