2023

FREP WPH

NUTRIENT MANAGEMENT CONFERENCE

PROCEEDINGS

November 8-9, 2023 • Modesto, California

California Department of Food and Agriculture
Fertilizer Research and Education Program and Western Plant Health
Thirty-first Annual Nutrient Management Conference

Editors:
Mark Cady
Karen Adler
Nicole Nunes
Jennifer Harmon
Emad Jahanzad, Ph.D.

Image Credit:
Jennifer Harmon: cover
Nicole Nunes: pages 6, 10
FREP Staff: page 111

Publication design:
Jennifer Harmon

California Department of Food and Agriculture
Fertilizer Research and Education Program
1220 “N” Street
Sacramento, California 95814
(916) 900-5022
frep@cdfa.ca.gov
www.cdfa.ca.gov/go/frep

Credits

Special Thanks:
Renee Pinel, President/CEO, Western Plant Health
Karen Ross, Secretary, California Department of Food and Agriculture

Faciliators:
Jerome Pier, Senior Agronomist, QualiTech
C. Scott Stoddard, Merced & Madera County Farm Advisor

Speakers:
Ali Montazar, Irrigation and Water Management Advisor, University of California, Cooperative Extension
Bob Hutmacher, Cooperative Extension Specialist and Center Director, University of California West Side Research and Education Center
Brent Holtz, County Director and Farm Advisor, University of California Cooperative Extension
Phoebe Gordon, Orchard Crops Farm Advisor, University of California Cooperative Extension
Mark Cady, Fertilizer Research and Education Program
Joji Muramoto, Cooperative Extension Specialist, University of California, Santa Cruz
Daniel Geisseler, Cooperative Extension Specialist in Nutrient Management, University of California, Davis
Parry Klassen, Executive Director, Coalition for Urban and Rural Environmental Stewardship
Carlos Orozco-Riezgo, Cal Poly San Luis Obispo
Michael Cahn, Irrigation and Water Resources Adviser, University of California Cooperative Extension
Alan Blaylock, Senior Agronomist, Nutrien
Giulia Marino, Asst. Professor of Cooperative Extension in Orchard Systems, University of California, Davis

Panel:
Managing Water and Nitrogen in a Wet Year: Grower Challenges and Opportunities
Panelists: Dr. Khaled Bali, Irrigation Water Management Specialist, University of California, Cooperative Extension (Moderator), Nick Davis, Farm Manager, Davis Vineyards, Tom Devol, Senior Manager of Field Outreach and Education for the Almond Board of CA, and Mark McKean, Farmer and owner of McKean Farms

Workshops:
Fertigation Distribution Uniformity
Bill Green, Education Specialist and Manager, Mobile Pump Efficiency Trailer, Fresno State Center for Irrigation Technology
Salinity Management
Sebastian Saa, Associate Director of Agriculture Research, Almond Board of California and Mae Culumber, Nut Crop Advisor, University of California Cooperative Extension

TABLE OF CONTENTS

INTRODUCTION

31st Annual FREP/WPH Conference

Welcome to the Fertilizer Research and Education Program (FREP) and Western Plant Health (WPH) Annual Nutrient Management Conference. Over the last 31 years, this conference has provided a forum where FREP grant recipients report findings of their projects and industry representatives share valuable irrigation and nutrient management information with an audience of crop consultants, students, growers, researchers, and agricultural professionals. Since 1991, FREP has supported farming operations and California agricultural communities by funding research, demonstration, and outreach projects to increase the efficiency and adoption of irrigation and nutrient management best practices.

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, six will be presenting their ongoing research from FREP-funded projects.

Overview of Funded Research

Since 1991, FREP has committed over 29 million dollars to over 270 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 (Figure 1).

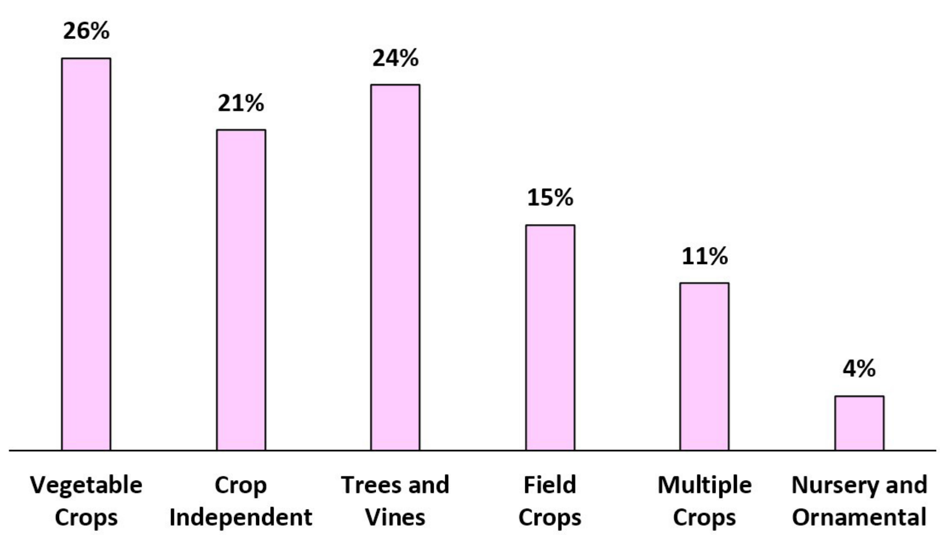


Figure 1. Distribution of commodities (%) represented in FREP-funded projects.

FREP is currently funding 28 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 CA crops.

The Crop Fertilization Guidelines website (cdfa.ca.gov/go/FREPguide) is an important resource resulting partly from FREP-funded projects. The guidelines provide insight into nutrient management for the most widespread irrigated crops in California, based on crop development stage. Many agricultural consultants and growers refer to the online guidelines when making fertilizer application recommendations and decisions.

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

Projects Beginning in 2024

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

In the Central Valley (Yuba and Butte counties), Dr. Bruce Linquist (UC Davis) will develop N fertilization recommendations for economically and environmentally viable no-till planting practices for rice, conserving water under the various field conditions farmers may encounter. This research will be performed on station and on farm. The project will disseminate research findings to rice growers to assist with successful adoption of this practice.

Dr. Daniel Geisseler (UC Davis) will develop N budgets for sweetpotato and processing tomato production in Merced County, where the crop nutrient sources include both organic amendments and mineral fertilizers as fertilizer sources. He will evaluate N release of commonly used poultry manure composts and other organic fertilizers in field trials as well as the effects of soil texture on N mineralization.

Dr. Sat Darshan Khalsa (UC Davis) will characterize the effects of recycling almond hulls and shells on nutrient dynamics, soil health, and crop productivity; optimize hull and shell management strategies by comparing outcomes of different harvest strategies; and improve nutrient management by developing cost/benefit assessments and identifying barriers to adoption of different practices where almond hulls and shells are returned to the orchard floor.

Dr. Patrick Brown (UC Davis) and his team will determine the extent and causes of in-field potassium variability in almond and pistachio orchards and develop improved cost-effective methods to identify areas of differential potassium demand. They will also identify optimized potassium fertilization strategies, including site-specific fertilization strategies suited to the fertigated orchard context and develop extension materials and platforms.

Drs. Isaya Kisekka and Thomas Harter (UC Davis) will leverage existing data to validate and strengthen existing and innovative modeling and management tools such as CV-SWAT and CropManage that are used by growers and regulators to make N and water management decisions. They will integrate results from monitoring, management, and modeling efforts to inform outreach to water quality stakeholders at multiple in-person and/or virtual events.

On the Central Coast, Sacha Lozano (Santa Cruz Resource Conservation District), Laura Murphy (Resource Conservation District of Monterey County) and Elliott Grant (Sustainable Conservation) will facilitate grower adoption of winter cover cropping and demonstrate research-backed methods to easily and confidently estimate cover crop biomass, C:N ratio, and associated N uptake, helping growers to receive the cover crop N scavenging credit to meet the Applied (A) minus Removed (R) limits and targets in Ag Order 4.0 as approved by the Central Coast Regional Water Quality Control Board.

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. Tom Bottoms (Chair), Dr. Mike Almasri (Vice-chair), Dr. Ben Faber, Daniel Rodrigues, Dr. Jan Hopmans, Dr. Charlotte Decock, 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 and especially President and CEO Renee Pinel, as a continued valued partner in the conference.

Special recognition goes to the leadership at CDFA and Inspection Services Division. We also thank Dr. Amadou Ba, Dr. Martin Burger, and Maria Tenorio Alfred for their continued support.

SUMMARIES OF CURRENT FREP PROJECTS

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

Project Leaders

Aparna Gazula
UCCE Farm Advisor
1553 Berger Drive, Bldg 1, 2nd Floor
San Jose, CA 95112

Ruth-Dahlquist Willard
UCCE Farm Advisor
550 E. Shaw Avenue, Suite 210-B
Fresno, CA 93710

Daniel Geisseler
Cooperative Extension Specialist
One Shields Avenue
Davis, CA 95616

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:

- Evaluate N uptake, N availability, canopy development and water application of bok choy, water spinach, garlic chives, moringa, and lemongrass.
- 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.

Work Plan Year 3 – Bok Choy, Water Spinach, Garlic Chives, and Lemongrass

Task 1:

N and irrigation evaluations for lemongrass were completed in fall 2022 and a second trial of bok choy was completed in winter 2023.

Plant tissue samples are currently being analyzed.

Data analysis and interpretation is currently being conducted for all crops (moringa, lemongrass, and bok choy).

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

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

For bok choy field trials in Fresno, a replicated field study comparing fertilizer treatment and an unfertilized control was completed at KARE in the spring of 2022 and again in fall of 2022 through winter of 2023.

Data collection is complete for aboveground biomass, biomass N and soil nitrate evaluations for lemongrass and the second bok choy trial to generate N uptake curve and compare N uptake across fertilizer treatments.

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

- We installed flow meters in the above-mentioned fields.
- Using an infrared camera, we took canopy photos of the crop every two weeks.
- We installed soil moisture monitoring sensors.

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

Data analysis is ongoing for moringa, lemongrass, water spinach, garlic chives, and bok choy to determine N uptake curves and compare N uptake across fertilizer treatments.

Sub-task 1.4 Reports and extension

In the replicated trial for lemongrass in Fresno County, 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. Samples were collected for aboveground biomass, biomass N, and soil nitrate. Soil moisture and crop canopy data was also collected.

In the replicated trial for bok choy in Fresno County, four rows of bok choy were planted with four replications of each treatment: a) standard application of NPK fertilizer and b) an unfertilized control. Samples were collected for aboveground biomass, biomass N, and soil nitrate. Soil moisture and crop canopy data was also collected. Initial findings of the bok choy trials were presented at the 2022 FREP/WPH Nutrient Management Conference in Visalia.

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. We thank Hardeep Singh, Sara Qaderi, Jose Paz, Lilian Thaoxaochay, Michael Yang, and Sukhmony Brar for assistance with field work and data analysis. We would also like to thank Dan Spalding and Vincent Silva with their help in field preparation and maintenance throughout the FREP trials.

Next Generation Nitrogen Management Training for Certified Crop Advisors

Project Leaders

Doug Parker
Director
California Institute for Water Resources
University of California Agriculture & Natural Resources
doug.parker@ucop.edu

Amanda Crump
Assistant Professor of Teaching
Department of Plant Sciences
University of California Davis
acrump@ucdavis.edu

Sat Darshan S. Khalsa
Assistant Professional Researcher
Department of Plant Sciences
University of California Davis
sdskhalsa@ucdavis.edu

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

Course and Exam Execution

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

Competency Area 2. Nitrogen Cycling - Soil Transformations

Competency Area 3. Nitrogen Uptake - Plant Utilization

Competency Area 4. Nitrogen Sources

Competency Area 5. Nitrogen Budgeting

Competency Area 6. Irrigation and Nitrogen Management

Competency Area 7. California Cropping systems

Detailed performance objectives for each competency areas can be found here:

https://www.certifiedcropadviser.org/files/certifiedcropadviser/california-nitrogen-management-specialty-performance-objectives.pdf

Starting in November 2020 and through July 2023 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, 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

Evaluation

The evaluation team has been conducting qualitative research on the online courses offered thus far. We have downloaded comments and reflections from those who consented. Comments and reflections are from each of the online modules for five iterations of the online course. These were completed as learners completed each module and wrote a reflection to receive the code for continuing education units. Reflections were open ended but we provided a reflective prompt if needed. The reflective prompt was to complete the blanks in one of the following sentences:

- I used to think/feel _________, but now I think/feel ________.
- I used to think/feel _________, and I still think/feel ________.
- I knew that ______, but it was surprising to learn/realize that ________.
- I didn't know/realize that ________, and I want to know more about ________.

Data were downloaded and all identifying information about the respondents was removed. Data were uploaded into NVivo (a qualitative analysis software) and coded. Data were coded using an inductive coding method looking for common themes. Broad themes were developed in the first pass of coding. These themes were then regrouped and re-coded in a second pass. Researchers are still coding the second pass.

Preliminary data from the first pass of coding indicate that most learners were satisfied with the course. Some learners suggested that we integrate interactive elements into the videos similar to trainings they may have had at work. Other learners asked for worksheets to practice some of the lessons after the modules.

Data will continue to be coded through a third pass where the most salient themes from the second pass will be re-grouped and then analyzed against adult learning theory before determining the impact of the online courses on learning.

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.certified-cropadviser.org/exams/

ACKNOWLEDGEMENTS

We wish to thank CDFA FREP for funding this project, and Dawn Gibas from ASA for their support. We also acknowledge Mallika Nocco, Patrick Brown, Daniel Geisseler, Mae Culumber, Khaled Bali, Sarah Light, Jessica Rudnick, Phoebe Gordon, Ben Faber, Nicholas Clark and Michelle Leinfelder-Miles from UC Davis and UCANR as well as Jerome Pier, Carl Bruice and Mark Cady for their contributions to the exam and course.

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

Project Leaders

Joji Muramoto
Assist. Cooperative Extension
Organic Production Specialist
Center for Agroecology
Dept. of Environmental Studies
University of California, Santa Cruz
jmuramoto@ucanr.edu

Richard Smith
Vegetable and Weed Science Advisor
University of California, Cooperative Extension
Monterey County
rifsmith@ucanr.edu

Michael Cahn
Irrigation and Water Resources Advisor
University of California, Cooperative Extension
Monterey County
mdcahn@ucanr.edu

Daniel Geisseler
Assoc. Cooperative Extension
Nutrient Management Specialist
Dept. of Land, Air and Water Resources
University of California, Davis
djgeisseler@ucdavis.edu

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 a 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 field demonstration.

DESCRIPTION

Creating N mineralization database.

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. The results of a trial are reported below.

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. Two trials were completed.

Integrate the model into CropManage (CM).

The model developed under Objective 2 is incorporated into CM. This process is ongoing.

Conduct outreach and a field demonstration.

We reported results at the Annual Salinas Valley Irrigation and Nutrient Management Meetings (2/23/2021, 2/23/2022, Virtual), the Annual FREP/WPH Conference (10/26/22), the Practical Training on Nitrogen Management in Organic Production of Vegetables and Strawberries (3/2/2021, 11/29/22, 12/05/22, 12/12/22, Virtual), and Organic Agriculture workshops in San Diego County (12/08/2022) and Imperial County (4/13/2023).

RESULTS AND DISCUSSION

To evaluate the N mineralization model, we monitored N dynamics during broccoli production in a commercial organic field in Watsonville, CA, from May to August 2022. A randomized complete block-designed field trial with 4 replicates was established to separate the N provision from different organic sources. Treatments included soil-only (A) A + crop residues (B), B + compost (C), C + pre-plant fertilizer (D), D + in-season fertilizer 1 (E), E + in-season fertilizer 2 (F) with 4 replications (Table 1). Each plot was 30′ x 40′, including 12 of 40″ wide beds, of which the middle 5 beds were used for all samplings. The soil type is Clear Lake clay. Total biomass-N in transplants and shoots at the early (6/23/22), mid (7/14/22), and harvest (8/16/22) stages were measured, and soil inorganic N in 0′-1′, 1′-2′, and 2′-3′ depths were determined 5 times at each plot. Changes in biomass-N in broccoli (lb-N/ac) and soil inorganic N (lb-N/ac/3 ft soil depth) at each treatment are shown in Figures 1 and 2, respectively. Nitrate and ammonium concentrations in irrigation water and irrigation rates were also monitored (data not shown). These data will be used to validate the N mineralization model we developed.

Table 1. Nitrogen sources evaluated in the field trial

Treatment	N source	Total N (lb-N/acre)	C/N	Date applied or sampled
Soil (A)	Residual soil inorganic N and soil organic matter in 0-3ft depth	15,217	11.7	5/9/22
A + Crop residue (B)	Iceberg lettuce (pre-crop) residues	66.4	15.2	5/19/22
B + Compost: Lime (3:1 mix) (C)	Compost 0.75: 0.65: 0.5	67.1	14.2	5/23/22
C + Pre-plant fertilizer (D)	Meat and bone meal 8-6-5	64.3	4.9	5/24/22
D + In-season fertilizer 1 (E)	Blood meal, poultry manure, feather meal 10.5:0.5:0.5	99.4	4.1	6/20/22
E + In-season fertilizer 2 (F)	Seabird guano 12-12-2.5	58.0	1.1	7/12/22

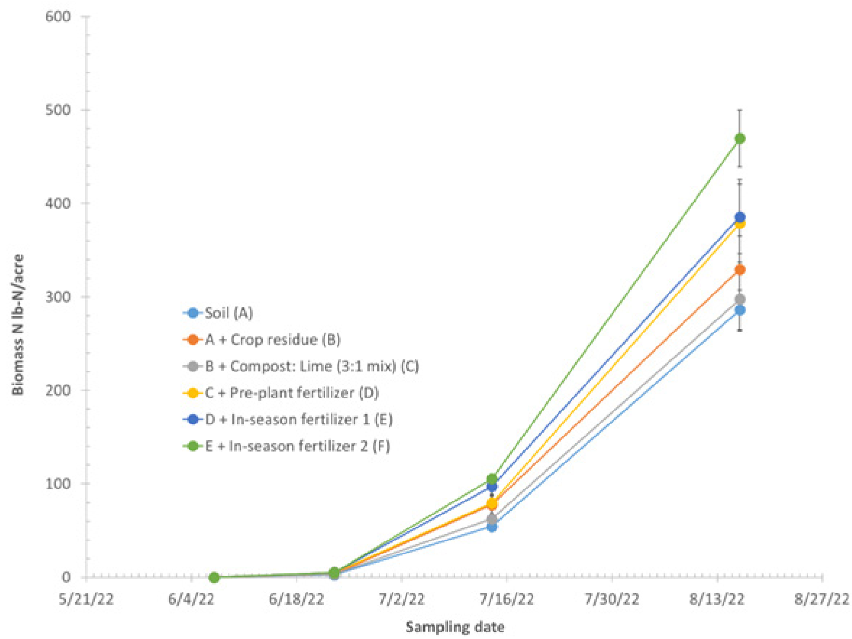


Figure 1. Changes in biomass-nitrogen in broccoli crop at each treatment.

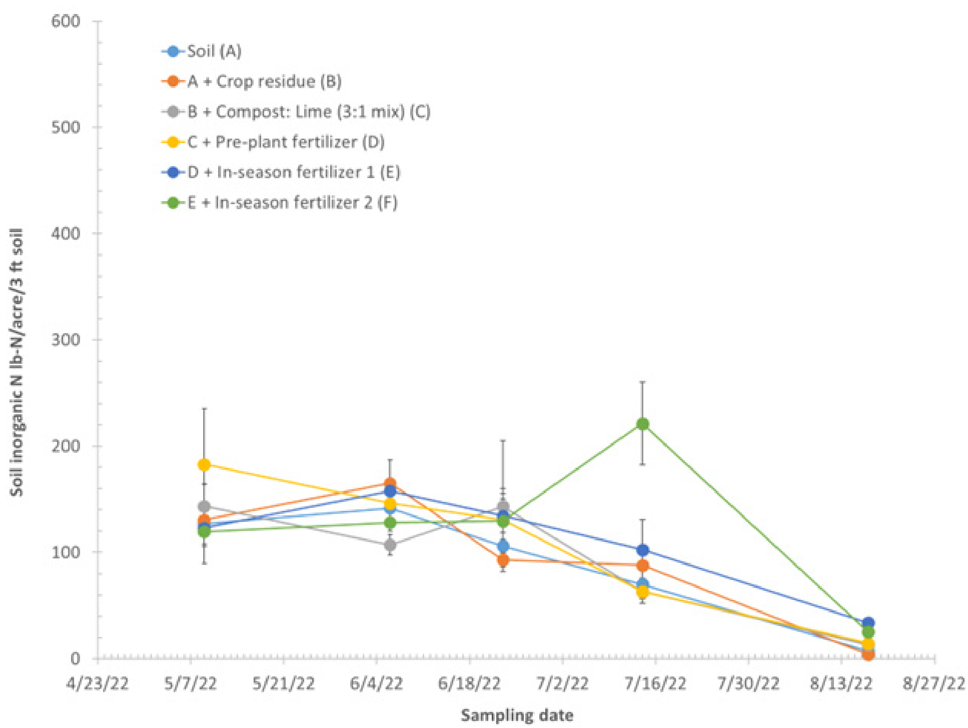


Figure 2. Changes in inorganic-nitrogen in 0'-3' depth soil profile at each treatment.

ACKNOWLEDGEMENTS

We thank staff and student workers of University of California Santa Cruz and staff of University of California Cooperative Extension, Monterey County for assisting incubation and field trials for this project. We appreciate the California Department of Food and Agriculture, Fertilizer Research and Education Program (FREP) for funding this project.

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

Project Leaders

Richard Smith
UCCE Vegetable Crops Farm Advisor, Monterey, San Benito and Santa Cruz Counties, 1432 Abbott Street, Salinas, CA 93901, 831 759-7357
rifsmith@ucdavis.edu

Joji Muramoto
UCCE Organic Specialist, Dept of Environmental Studies, UC Santa Cruz, 1156 High Street, Santa Cruz, CA 95064, 831 247-3804
joji@ucsc.edu

Mike Cahn
UCCE Irrigation Farm Advisor, Monterey, San Benito and Santa Cruz Counties, 1432 Abbott Street, Salinas, CA 93901, 831 759-7377
mdcahn@ucdavis.edu

Daniel Geisseler
Extension Specialist, Department of Land, Air and Water Resources, 1 Shields Ave. Davis, CA 95616, 530 754-9637 djgeisseler@ucdavis.edu

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 it is tilled and listed into fallow beds for the winter. Cool season vegetable crop residues contain high concentrations and quantities of nitrogen (N) which allows for 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 reduce the risk of leaching of this nitrate by taking up a large portion and maintaining it in their biomass until the following spring, thereby reducing 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. Fall applications of compost is a common practice used by vegetable growers, and the goal of this project is to test whether substituting a high C:N soil amendments could successfully immobilize a portion of residual soil nitrate in winter beds and thereby serve as a viable practice to reduce nitrate leaching during this critical time of the year.

In earlier studies, we observed that 5 – 10 tons/ac of almond shells ground to pass through a 2 mm screen, as well as glycerol at 2.5 tons/ac 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 limit adoption of this practice. To provide a cheaper alternative, we evaluated locally sourced high C:N ratio woody amendments. However, these materials were not sufficiently labile and did not quickly immobilize the soil nitrate pool to effectively reduce nitrate leaching. We have concluded that the carbon in almond shells is ideally suited for immobilizing soil nitrate and have renewed our investigations of this material. Given that grinding adds significant cost to the use of almond shells we are evaluating the minimum particle size of the shells that can effectively immobilize nitrate and supply a more affordable material for growers. 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 have concluded that the locally sourced materials are not sufficiently labile to effectively and rapidly immobilize soil nitrate during the winter months.

Conduct large scale field trials with cooperating growers in commercial vegetable production fields.

A large-scale field trial was conducted in the winter of 2022-23 in a commercial lettuce field in which 10 tons/ac of minimally ground almond shells were applied. Soil nitrate samples down to three feet deep were collected each month during the winter fallow period. Laboratory evaluations were conducted to determine optimal almond shell particle size to effectively immobilize soil nitrate.

Evaluate the magnitude and longevity of the impact of the high C:N materials on subsequent crop production.

Earlier studies evaluated the use of minimal rates of starter fertilizers to ensure against immobilization from the fall application of almond shells damaging lettuce seedlings.

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 2023 Salinas Valley Irrigation and Nutrient Management Meeting.

RESULTS AND DISCUSSION

Laboratory incubation studies: A study examining the effect of rate (0, 1.25, 2.5, 5, 10 tons/ac) and almond shell particle size (unground shells, ½”- particles, ¼” - particles, and 2 mm- particles) showed generally that the finer the particle size, the faster the immobilization and re-mineralization of soil nitrate (Figures 1 and 2). Five tons/ac of 2 mm-particles and ¼”-particles almond shells immobilized 65% and 50% of soil nitrate in 2 weeks, respectively, whereas 5 tons/ac of unground almond shells needed 4 weeks to immobilize 38% of soil nitrate (Figure 1). This trend was amplified at 10 tons/ac rate (Figure 2). In past field studies, we found that the field soil in the fall is often dry but that the first significant rain activates the mineralization and immobilization by soil microbes while also initiating leaching of soil nitrate. To be effective in reducing the quantity of soil nitrate, therefore, almond shell particles must be fine enough to immobilize soil nitrate quickly before leaching can occur. Further, a past field trial showed a significant reduction of soil nitrate with 2 mm sized almond shells at 5 tons/ac, but that 10 tons/ac had a negative effect on the yield of a successive lettuce crop caused by prolonged immobilization of soil nitrate.

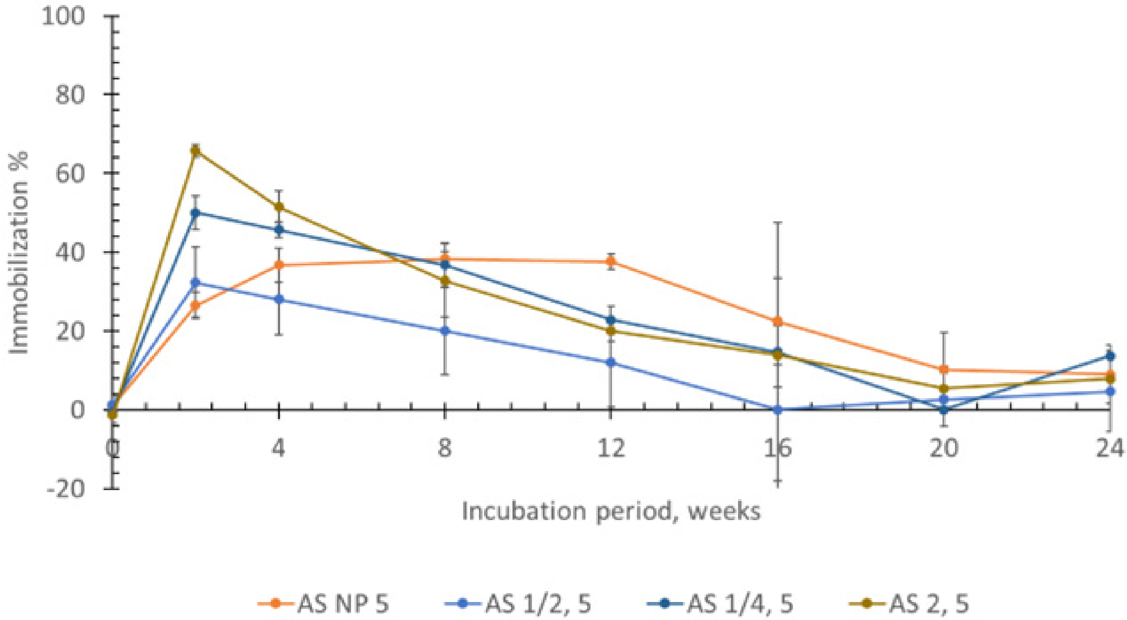


Figure 1. N immobilization by almond shells with different particle sizes at 5 tons/ac rate: AS NP 5 - unground shells; AS ½, 5 - ½" particles; AS ¼, 5 - ¼" particles; and AS 2, 5 - 2 mm particles.

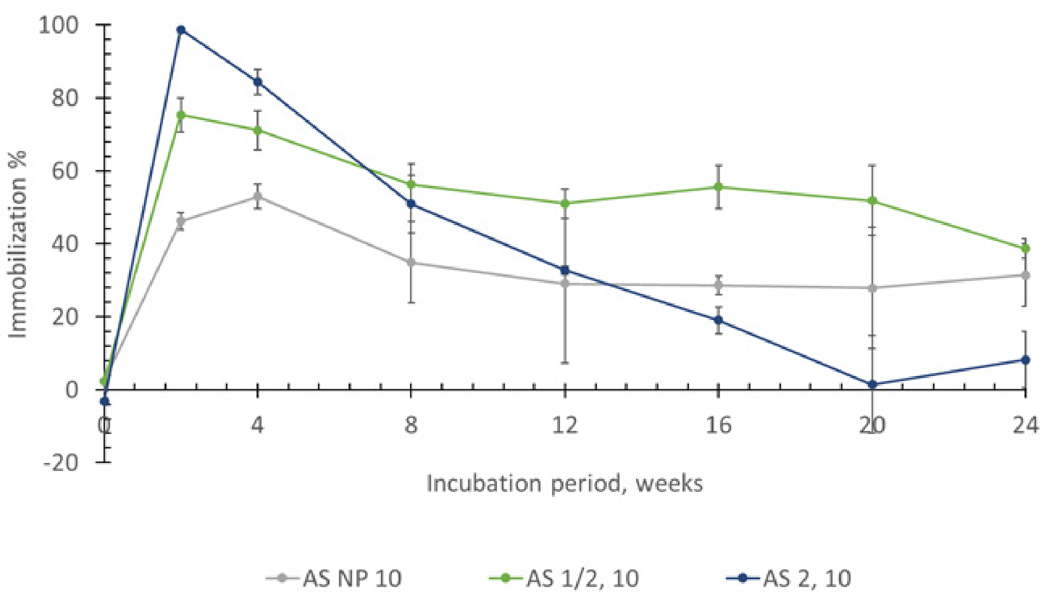


Figure 2. N immobilizaton by almond shells at 10 tons/ac rate: AS NP 10 - unground shells; AS ½, 10 – ½" particles; and AS 2, 10 - 2 mm-particles.

Taken together, ¼" or smaller particle size almond shells at 5 to 7.5 tons/acre can provide significant immobilization of soil nitrate without causing negative impacts on subsequent vegetable crops.

Field study:

Following a fall broccoli crop, a field study was conducted in the winter of 2022-23. The study evaluated a 10 tons/ac rate of applied almond shells with a control treatment. The shells were ¼ inch or less in size. Almond shells were spread on flat soil after incorporation of the prior crop. Soil incorporation subplots were established in which the soil was chiseled one time or two times to evaluate the level of incorporation needed for optimal immobilization. Unfortunately, the field was inundated two times by flood waters from the Salinas River during the high-rainfall winter. As a result, the data from the trial was highly compromised and is not included here.

LITERATURE CITED

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

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

Smith, R.F., J. Muramoto, L.J. Tourte, A. Haffa, F. Melton and P. Love. 2019. Immobilization of nitrate in fallow winter vegetable production beds. UCCE Blog, Jan. 3. (https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=29071

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

Project Leaders

Thomas Harter
Dept. Land, Air and Water Resources, UC Davis
thharter@ucdavis.edu

Isaya Kisekka
Dept. Land, Air and Water Resources/
Biological and Agricultural Engineering, UC Davis
ikisekka@ucdavis.edu

Patrick Brown
Dept. Plant Sciences, UC Davis
phbrown@ucdavis.edu

Cooperators

Gabriele Ludwig
Almond Board of California
gludwig@almondboard.com

Garret and Art Bowman
Cooperator Grower
Modesto, CA
glbowman77@gmail.com

Spencer Jordan
MSc student
Dept. Land, Air and Water Resources,
UC Davis
shjordan@ucdavis.edu

Will Lennon
MSc student
Dept. Land, Air and Water Resources,
UC Davis
wnlennon@ucdavis.edu

Christine Armstrong
Staff Research Associate
Department of Plant Sciences
UC Davis
tmarmstrong@ucdavis.edu

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 (e.g., 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 and modeling of resulting groundwater quality immediately underneath the orchard.

OBJECTIVES

1. Demonstrate, in a commercial scale almond orchard, that HFLC fertigation practices increase NUE while successfully producing high yields and reducing groundwater quality impacts.
2. Perform, compare, and assess three independent monitoring approaches to estimate groundwater nitrate contribution from an orchard to guide growers, agricultural coalitions, and regulatory agencies on the compliance process.
3. Development and calibration of an integrated groundwater-vadose zone-crop model to assess the long-term impacts of HFLC on shallow groundwater quality. Apply model to evaluate several scenario analyses to include the use of agricultural managed recharge (AgMAR) projects and varying measurements of ET, precipitation, and irrigation at the orchard.
4. 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-replicated 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 year 2100 via 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.

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 2022 growing season is added on a figure including the historic mass balance (Figure 1). Wet years such as 2017 can provide almost 30 cm of groundwater recharge, while in drier years such as 2020-2022, the mass balance becomes negative suggesting a loss of water storage in the orchard. Average NUE for growing season 2022 was 87%.

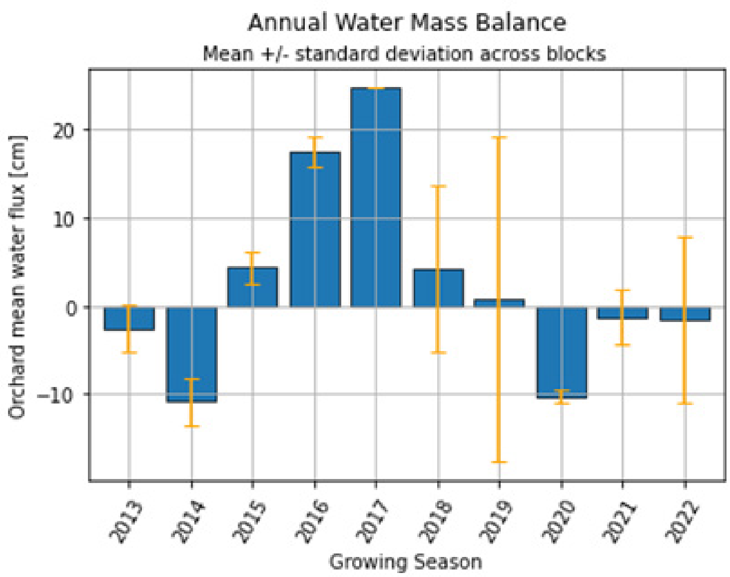


Figure 1: Annual water mass balance

HFLC nutrient management was evaluated by comparing harvest records for 2018-2022 to prior growing seasons 2013-2017. The average impact of HFLC during growing seasons 2018-2022 was an approximate 17% increase in NUE and 15% increase in reported kernel yields.

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 which measure N concentrations 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. Since the introduction of HFLC in 2018, average peak shallow N concentrations (30, 60, 90 cm) in pore water have reduced by 56% (Figure 2). The deeper measurements (180, 280 cm) were excluded in this analysis because they are not representative of N applied during each growing season, as the travel time to those depths can take several years. Tensiometer readings are proving problematic over the long run requiring possible updated instruments.

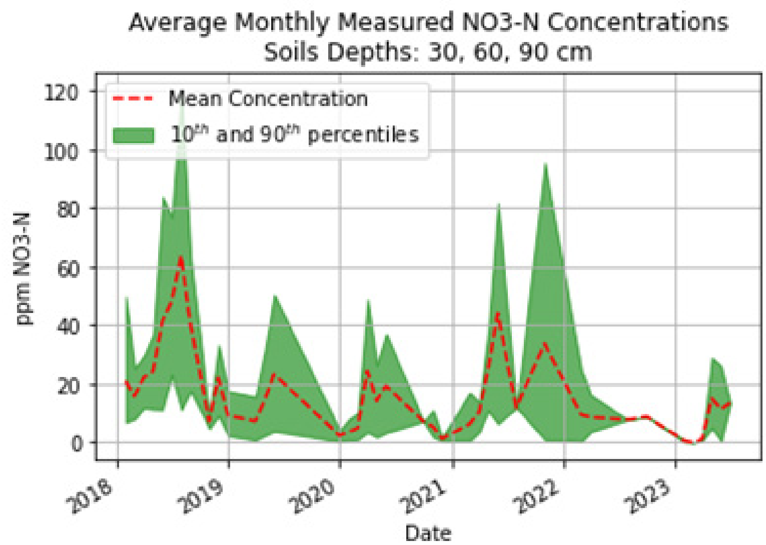


Figure 2: Monthly average $N0_3$-N concentrations measured in pore water samplers at depths of 30, 60, and 90 cm.

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 12.9 and 23.3 mg/L N between 2017 and 2022. Since 2017, the median concentration in the wells across the orchard has increased from around 20 mg/L closer to 35 mg/L in 2022, indicating an increase in nitrate concentrations of about 3 mg/L per year.

Root Zone Modeling. In the previous reporting periods, we developed a one-dimensional physical model of unsaturated zone to obtain an estimate of groundwater recharge during the period of 1957-2047. 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 1957-2100 in order to assess the full effects of HFLC on N concentrations. Model results predict that under HFLC, NUE will improve from an average of 83% to 94%. There also exists a lag time between N inputs at the surface and leaching at the water table (7 m below) of 10-30 years, due to the low recharge rate. Beginning around 20 years after the switch to HFLC, average nitrate concentrations in recharge rapidly decrease from 75 to a value of 30 mg/L under continued HFLC (Figure 3).

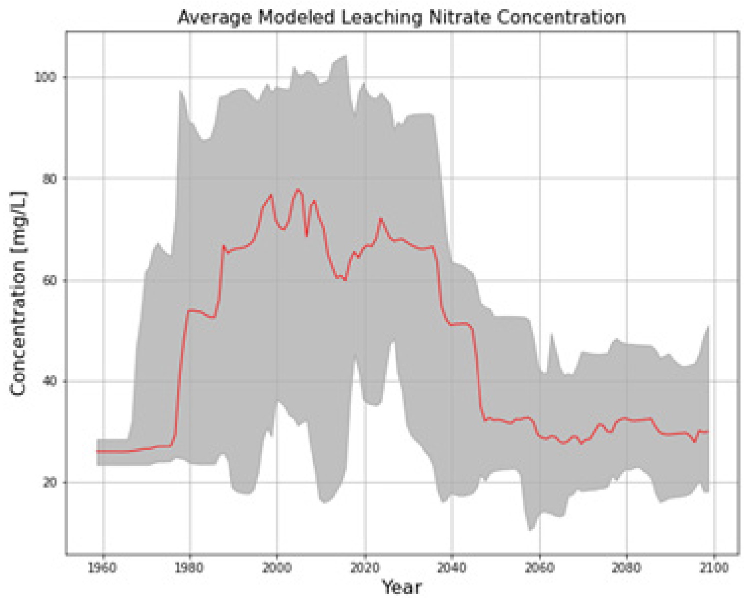


Figure 3: Orchard summary of modeled nitrate concentrations in groundwater recharge.

Groundwater Modeling.

Our previous work showed that the effects of HFLC would take >30 years to be seen in the shallow groundwater due to the long travel time of groundwater recharge. We also found that the spatial variability in groundwater N concentrations was due to the spatial variability of N leaching from the vadose zone, not from aquifer geologic heterogeneity. During the current reporting period, the groundwater model was updated to include an AgMAR project performed at the orchard in the summer of 2022. Results suggest that with enough applied water, AgMAR can be an effective tool for rapidly improving groundwater quality by diluting residual N in the unsaturated zone.

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 misleading when used to estimate N losses from agriculture. Modeling shows that most leaching occurs in wet years when residual N is flushed from the unsaturated zone, with little to no leaching during years with low precipitation. Model simulations show that HFLC has the potential to lower nitrate loading into groundwater. They also suggest that AgMAR can be used in conjunction with HFLC to rapidly improve shallow groundwater quality.

LITERATURE CITED

Paul G, Dickey J, Chong CS, Yimam YT, Schmid B, Hawkins T, et al. Remote Sensing Based Statewide Actual Evapotranspiration Mapping Program (CalETa) for Water Resources Management. In 2018.

Gurevich H, Baram S, Harter T. Measuring nitrate leaching across the critical zone at the field to farm scale. Vadose Zo J. 2021;(September 2020):1–16.

ACKNOWLEDGEMENTS

We thank the grower for allowing us to conduct this research and being supportive and cooperative. This research is funded in part by The Almond Board of California, project number PREC6.HARTER, FREP project number 19-0968 and CDFA project number 19-0001-017-SF.

Development of Site-specific Nitrogen Fertilization Recommendations for Annual Crops

Project Leaders

Daniel Geisseler
Cooperative Extension Specialist; UC Davis; Department of Land, Air and Water Resources; One Shields Avenue; Davis, CA 95616;
(530) 754-9637
djgeisseler@ucdavis.edu

Sanjai Parikh
Associate Professor of Soil Chemistry; UC Davis; Department of Land, Air and Water Resources; One Shields Avenue; Davis, CA 95616;
(530) 752-1265
sjparikh@ucdavis.edu

Nick Clark
UCCE Farm Advisor, Kings, Tulare, & Fresno Counties, 680 Campus Drive Suite A, Hanford, CA 93230
(559) 852-2788
neclark@ucanr.edu

Michelle Leinfelder-Miles
UCCE Farm Advisor, San Joaquin County, 2101 East Earhart Avenue, Suite 200, Stockton, CA 95206.
(209) 953-6120
mmleinfeldermiles@ucanr.edu

Sarah Light
UCCE Farm Advisor Sutter, Yuba, and Colusa Counties; 142A Garden Highway; Yuba City, CA 95991;
(530) 822-7515
selight@ucanr.edu

Konrad Mathesius
UCCE Farm Advisor, Yolo, Solano & Sacramento Counties; 70 Cottonwood Street; Woodland, CA 95695
(530) 666-8704
kpmathesius@ucanr.edu

Rob Wilson
Intermountain REC Director, UCCE Farm Advisor, ANR Intermountain Research & Extension Center, 2816 Havlina Road, Tulelake, CA, 96134.
(530) 667-5117
rgwilson@ucanr.edu

Project Manager

Suzette Turner Santiago
Graduate Student; UC Davis; Department of Land, Air and Water Resources; One Shields Avenue; Davis, CA 95616
snturner@ucdavis.edu

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 analytical methods for SOM quality 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:

- Validate N mineralization estimates in field trials in the Central Valley, including the Delta, as well as in the Tulelake basin.
- Characterize the chemical composition of SOM using FTIR and correlate it to soil organic matter quality and N mineralization.
- 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 from 2021 to 2023. 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. Net N mineralization in unfertilized plots was calculated as:

Net N mineralization=N outputs-N inputs "Equation 1"

Where N outputs include N in the aboveground biomass and residual mineral N in the soil profile at harvest. N inputs consist of preplant residual mineral N in the soil profile, N in irrigation water and atmospheric N deposition. The FTIR-based method to assess soil organic matter quality was conducted in fall 2022 and winter 2023. Air-dried samples collected from more than 70 fields across northern and central California in previous and ongoing projects were analyzed. 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 and incubation studies with undisturbed soil cores. Data analysis is ongoing. The online N calculators will be developed with site-specific features based on the results of this study.

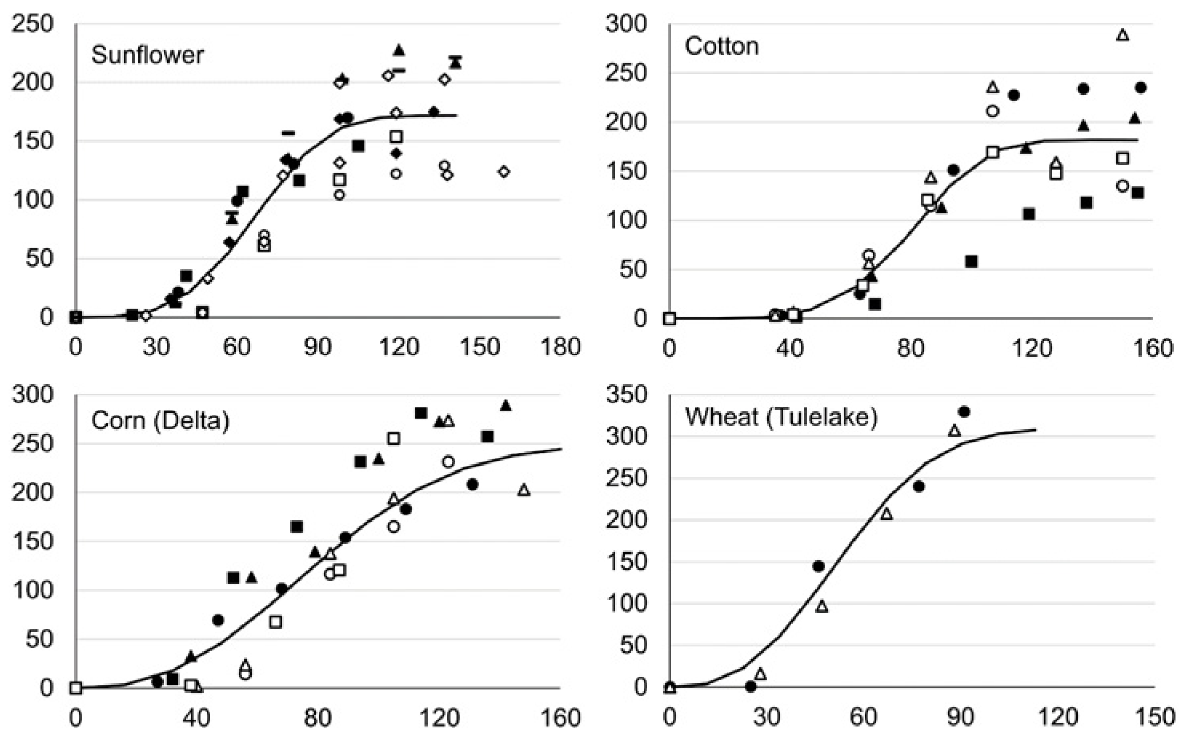


Figure 1: Increase in total nitrogen in the aboveground biomass of sunflower, cotton, corn and spring wheat grown in fields in Northern and Central California in 2021 and 2022. Different symbols represent different fields. The corn and wheat sites were on soils with a high soil organic matter content and a high N mineralization potential. The uptake values may not be representative for typical Central Valley fields with a low soil organic matter content.

RESULTS AND DISCUSSION

Field trials were conducted in a total of 35 fields during three growing seasons from 2021-23. Plant and soil analyses for the 2021 and 2022 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 maximum increase in aboveground biomass N during a 3-week period reached 3.7, 4.7, 7.5 and 6.4 lb ac^{-1} day^{-1} for sunflower, cotton, corn and spring wheat, respectively. Total N in the aboveground biomass averaged 172, 182, 244, and 308 lb ac^{-1} at harvest. The corn and wheat sites were on soils with a high soil organic matter content and a high N mineralization potential. The uptake values in Figure 1 may not be representative for typical Central Valley fields with a low soil organic matter content.

Table 1: Nitrogen mineralization estimates based on Equation 1. 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	Duration days	N inputs lb ac^{-1}	N outputs lb ac^{-1}	N mineralization (lb ac^{-1}) 0-4 ft	0-2 ft
1	146	258.9	338.9	80.0	64.0
2	146	232.5	342.3	109.8	83.5
3	138	243.3	422.9	179.6	119.3
4	140	59.1	113.1	53.9	31.3
5	139	114.1	202.5	88.4	52.9
6	105	133.0	283.5	150.6	121.9
7	159	103.6	244.7	141.2	103.8
8	159	220.5	252.8	32.3	20.4
9	159	135.6	230.5	94.8	70.5
Average	**143**	**166.7**	**270.1**	**103.4**	**74.2**

Preliminary N budgets for nine Sacramento Valley sunflower fields from the 2021 and 2022 seasons indicate that the N mineralization in the 4-ft profile averaged 103.4 lb ac^{-1} during a 143-day growing season (Table 1). Estimates for atmospheric deposition were included as N inputs. Laboratory incubations 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, N mineralization during the growing season provided on average 74.2 lb ac^{-1}, or 0.52 lb ac^{-1} day^{-1}. With most N taken up during the first 100 days of the season (Figure 1), N mineralization from SOM contributed on average 52 lb ac^{-1} of crop-available N.

ACKNOWLEDGEMENT

We would like to thank Makena Savidge, Jesse Zepeda, Zhixu Zhang, Ben Halleck, Chaitanya Muraka and Darrin Culp for help with laboratory analyses and field work. We also thank our grower collaborators. Funding for this project was provided by the CDFA Fertilizer Research and Education Program.

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

Project Leaders

Richard Smith
UCCE Vegetable Crops Farm Advisor, Monterey, San Benito and Santa Cruz Counties, 1432 Abbott Street, Salinas, CA 93901, 831 759-7357
rifsmith@ucdavis.edu

Mike Cahn
UCCE Irrigation Farm Advisor, Monterey, San Benito and Santa Cruz Counties, 1432 Abbott Street, Salinas, CA 93901,
831 759-7377
mdcahn@ucdavis.edu

Aparna Gazula
UCCE Farm Advisor, Santa Clara County, 1553 Berger Drive, Bldg. 1, San Jose, CA 95112, (408) 282-3110
agazula@ucanr.edu

Andre Biscaro
Formerly, UCCE Farm Advisor, Ventura, Los Angeles and San Bernardino Counties

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) N 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 N 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. Evaluation of 15 fields of each of the 35 commodities proposed in this study is nearly complete. For the lettuces we increased the number of fields to 20. Due to feedback from growers, a number of additional crops were evaluated. Commodities evaluated thus far by this project 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.

RESULTS AND DISCUSSION

Coefficients have been developed for the 35 commodities proposed in this project. In addition, as the project was being conducted, we received feedback from growers and from staff of the CCRWQCB and have included coefficients for additional crops: amaranth, pea tips, Malabar spinach, a choy (celtuce or stem lettuce), yu choy/yu choy sum/choy sum, gailan, tatsoi, chayote tips, and daikon radish. Given that there are so many flower species we decided to sample two flower species that can be used as model flowers by growers: gerberas (no leaves on the harvested product) and snap dragons (with leaves on the product). In addition, we also supplemented the number of samples collected for 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 (not including the crops just mentioned). 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 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) are intermediate, 0.00333 and 0.00389, respectively; flower vegetables (broccoli, cauliflower and rapini) have higher coefficients, 0.00583 and leaf vegetables (cilantro, parsley and spinach) have the highest coefficients, 0.00612. The final report will include tables of all the commodities evaluated and will include the minimum and maximum values recorded for each commodity (on a field basis).

LITERATURE CITED

Bottoms, T., R. Smith, M. Cahn, and T. Hartz. 2012. Nitrogen requirements and N status determination of lettuce. HortScience 47(12): 1768-1774.

Breschini, S., and T. Hartz. 2002. Drip irrigation management affects celery yield and quality. HortScience 37(6): 894-897.

Heinrich, A., R. Smith and M. Cahn. Nutrient and water use of fresh market spinach. 2013. HortTechnology 23(3): 325-333.

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

Smith, R. M. Cahn and T. Hartz. 2016b. Evaluation of N uptake and water use of leafy greens grown in high-density 80-inch bed plantings and demonstration of best management practices – Final Report. https://www.cdfa.ca.gov/is/ffldrs/frep/pdfs/completedprojects/12-0362-SA_Smith.pdf

Table 1. List of commodities evaluated to date

Commodity	Product	Pack Type	Mean Coefficient	Commodity	Product	Pack Type	Mean Coefficient
Artichoke	Fresh Market	Carton	0.00382	Lettuce, Butter	Fresh Market	Carton	0.00199
Arugula	Bulk	Bulk	0.00580	Lettuce, Green Leaf	Fresh Market	Carton	0.00207
Beet	Fresh Market	Carton	0.00305	Lettuce, Iceberg	Bulk Cored	Bulk	0.00120
Bok Choy[1]	Fresh Market	Carton	0.00209	Lettuce, Iceberg	Fresh Market	Film Wrap	0.00127
Broccolini	Fresh Market	Carton	0.00520	Lettuce, Iceberg	Fresh Market	Naked	0.00129
Brussels Sprout	Bulk/Fresh Market	Bulk/Carton	0.00628	Lettuce, Iceberg	Fresh Market	All	0.00128
Cabbage, Green	Bulk Cored	Bulk	0.00183	Lettuce, Red Leaf	Fresh Market	Carton	0.00224
Cabbage, Green	Bulk Whole	Bulk	0.00173	Lettuce, Romaine	Bulk Tops/Tails	Bulk & RPC	0.00152
Cabbage, Green	Fresh Market	Carton	0.00221	Lettuce, Romaine	Bulk Whole	Bulk & RPC	0.00149
Cabbage, Red	Bulk Cored	Bulk	0.00205	Lettuce, Romaine	Bulk	All	0.00150
Cabbage, Red	Fresh Market	Carton	0.00201	Lettuce, Romaine	Fresh Market	Carton	0.00184
Cauliflower	Fresh Market	Carton	0.00283	Lettuce, Romaine	Hearts	Bag/Carton	0.00188
Celery	Fresh Market	Carton	0.00106	Onion, Dry Red	Bulk	Bulk	0.00126
Celery	Processing	Bulk	0.00100	Onion, Dry Yellow	Bulk	Bulk	0.00164
Celery	All	All	0.00103	Parsley, Curly	Fresh Market	Carton	0.00440
Chinese Celery	Fresh Market	Carton	0.00301	Parsley, Italian	Fresh Market	Carton	0.00436
Cilantro	Clip	Bulk	0.00595	Parsley	Fresh Market	All	0.00438
Cilantro	Bunch	Carton	0.00413	Pea, Snap	Fresh Market	RPC	0.00472
Endive	Fresh Market	Carton	0.00274	Radicchio	Bulk	Bulk	0.00216
Escarole	Fresh Market	Carton	0.00242	Radicchio	Fresh Market	Carton	0.00235
Fennel	Fresh Market	Carton	0.00202	Radicchio	All	All	0.00233
Gai Choy	Fresh Market	Carton	0.00360	Red Radish	Bulk	Bulk	0.00167
Jalapeno	Fresh Market	Carton		Red Radish	Fresh Market	Carton	0.00248
Kale	Multi Pick	RPC	0.00548	Rapini	Fresh Market	Carton	0.00605
Leek	Bulk	Bulk	0.00235	Shallot	Bulk	Bulk	0.00241
Leek	Fresh Market	Carton	0.00213	Tong Ho	Fresh Market	Carton	0.00344
Leek	All	All	0.00231	Yam Leaves	Fresh Market	Carton	0.00510

"Crop Nutrient Minute" Video Series

Project Leaders

Parry Klassen
Executive Director
Coalition for Urban Rural Environmental Stewardship (CURES)
1480 Drew Ave, Suite 130, Davis, CA
559-288-8125
klassenparry@gmail.com

Patrick Brown, Ph.D.
Professor of Plant Sciences
University of California, Davis
Department of Plant Sciences
One Shields Ave, Davis, CA
530-752-0929, phbrown@ucdavis.edu

Cooperators

Katherine Jarvis-Shean, Ph.D.
Orchard Systems Advisor, University of California Cooperative Extension,
530-377-9528
kjarvisshean@ucanr.edu

Phoebe Gordon, Ph.D.
Orchard Crops Farm Advisor, University of California Cooperative Extension,
559-675-7879, pegordon@ucanr.edu

Jacqueline Vasquez Mendoza
Staff Research Associate, University of California Cooperative Extension
jvasquezmendoza@ucanr.edu

Doug Parker, Ph.D.
Director, UC Agriculture and Natural Resources
510-987-0036, doug.parker@ucop.edu

Zheng Wang, Ph.D.
Vegetable Crop Advisor, University of California Cooperative Extension,
209-525-6822, zzwwang@ucanr.edu

Richard Smith
Vegetable Crops and Weed Science Farm Advisor, University of California Cooperative Extension
831-759-7357, rifsmith@ucanr.edu

Gabriele Ludwig, Ph.D.
Director, Almond Board of California,
209-765-0578
gludwig@almondboard.com

Casey Creamer
President/CEO, California Citrus Mutual
559-592-3790
casey@cacitrusmutual.com

Alan Reynolds
Board Chairman, East San Joaquin Water Quality Coalition
209-394-6200
alan.reynolds@ejgallo.com

Joseph McGahan
Executive Director, Westside San Joaquin River Watershed Coalition, 559-582-9237
jmcgahan@summerseng.com

Bruce Houdesheldt
Executive Director, Sacramento Valley Water Quality Coalition
916-442-8333
bruceh@norcalwater.org

Michael Wackman
Executive Director, San Joaquin County and Delta Water Quality Coalition,
916-684-9359
michael@wackmanconsulting.org

Supporters

Gail Delihant
Director of California Government Affairs, Western Growers
916-325-4265, gdelihant@WGA.com

Renee Pinel
President and CEO, Western Plant Health Association,
916-574-9744
reneep@healthyplants.org

Nicole Bell
Manager, Kern River Watershed Coalition Authority,
661-616-6500
nbell@krwca.org

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 CE requirements. This project includes an "INMP CE" 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 N 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 CE uses.
4. Post "Crop Nutrient Minute" videos online and conduct outreach.
5. Apply for CEU credit for "INMP CE" 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, N 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 CE" 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 CE" 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 CE 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 CE. 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 N 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 N 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 N 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

CURES acknowledges these leaders, cooperators, and supporters (see references page 1): Patrick Brown, Richard Smith, Katherine Jarvis-Shean, Phoebe Gordon, Jacqueline Vasquez Mendoza, Doug Parker, Zheng Wang, Gabriele Ludwig, Casey Creamer, Alan Reynolds Joseph McGahan, Bruce Houdesheldt, Michael Wackman and CURES dedicated staff, Maureen Thompson, Eva Dwyer, Monica Quezada.

Ventura County Nitrogen Management Training Program

Project Leaders

Jodi Switzer
Water Program Director
Farm Bureau of Ventura County
5156 McGrath Street, Ventura, CA 93003
Phone: (805) 289-0155
jodi@farmbureauvc.com

Cooperators

Dr. Ben Faber
University of California, Cooperative Extension Ventura County
669 County Square Drive, #100, Ventura, CA 93003
Phone: (805) 645-1462
bafaber@ucanr.edu

Supporters

Natural Resource Conservation Service
3550 S Harbor Blvd. suite #2-202, Oxnard, CA 93035
Phone: (805) 984-2358 x101
brooks.engelhardt@usda.gov

Jamie Whiteford
Ventura County Resource Conservation District
3380 Somis Road, Somis, CA 93066
Phone: (805) 764-5132
jamiewhiteford.vcrcd@gmail.com

INTRODUCTION

The third iteration of the Los Angeles Regional Water Quality Control Board's (LARWQCB) 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 (ESJ) River Watershed Waste Discharge Requirements precedential requirements related to nitrogen tracking and reporting. This Ag Order is expected to be adopted on September 28, 2023.

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 groundwater 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 included in the upcoming Ag Order.
- Translate training program and resources for Spanish-speaking audiences.
- Following the adoption of the upcoming Ag Order, 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 COVID-19 public health emergency as well as the delayed incorporation of the ESJ precedential requirements into the LARWQCB's Irrigated Lands Regulatory Program order. These requirements were anticipated to take effect in the Los Angeles Region in April of 2021, coinciding with the expiration of the existing Conditional Waiver and the expected adoption of a new order. However, three consecutive extensions of the existing Conditional Waiver, currently extended through September 30, 2023, have delayed the development and adoption of a new regulatory order that would contain the precedential requirements.

Without the Region-specific requirements being adopted, the update and implementation of a training program could not be conducted.

While the three Conditional Waiver extensions were unanticipated, we do expect that an Ag Order, including the ESJ precedential requirements, will be adopted on September 28, 2023. Our confidence in this stems from Regional Board Member's direction that staff not bring additional extensions forward for consideration and the significant Ag Order developmental milestones that have occurred throughout 2023, including the release of an Administrative Draft WDR in April and a Tentative Order in July. Once the Ag Order is adopted, the training materials will require updates to align with the region-specific requirements and training sessions for growers will follow shortly thereafter. To accommodate this revised timeline, this project has requested and been approved for a 1-year no cost extension through December 31, 2024.

One project task that was able to progress independently of the pending Ag Order status is the Spanish translation of the recently updated CDFA FREP Irrigation and Nitrogen Management Training for Grower Self-Certification presentation material and associated workbook. Currently, these training products are undergoing translation and are slated for completion in September 2023. Subsequent to the adoption of an Ag Order for the Los Angeles Region, any necessary updates will be incorporated into the translated materials.

Anticipated completion for all translation and training program updates is expected at the end of 2023, with the project's primary focus in 2024 being the implementation of training workshops for growers in both English and Spanish.

ACCOMPLISHMENTS

While training sessions were temporarily put on hold as a new Ag Order is being developed and requirements are under consideration, we are actively advancing the translation of training program materials to serve Spanish-speaking audiences. We expect to finalize the Spanish translation of the recently updated CDFA FREP Irrigation and Nitrogen Management Training for Grower Self-Certification presentation material and its accompanying workbook by September 2023.

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 Nicole Nunes with CDFA FREP.

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

Project Leaders

Ms. Charlotte Gallock, P.E.
Manager of Water Resources
Kings River Conservation District
4886 E. Jensen Avenue
Fresno, CA 93725
cgallock@krcd.org

Dr. Ken Cassman
Senior Agronomic and Soils Advisor
823 Oceanside CA 92058
kgc1consulting@gmail.com

Mr. Ken Miller
Technical Program Manager SSJV
MPEP Program
Formation Environmental
1631 Alhambra Blvd, Ste 220
Sacramento, CA 95816
kmiller@formationenv.com

Cooperator

Dr. Daniel Geisseler
Assoc. Nutrient Mgmt CE Specialist
UC Davis
One Shields Avenue
Davis, CA 95616
djgeisseler@ucdavis.edu

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 Southern San Joaquin Valley Management Practice Evaluation Program (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: a) incorporate results in an update of Geisseler (2016, 2021), b) 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, and c) 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 (https://agmpep.com/tools/calc-y2r/). These results are also presented in Table 1. Results from Phase 2 are not yet available.

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.

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., pistachios 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.

CONCLUSIONS

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 and 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.

REFERENCES

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

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

Geisseler, D. 2021. Nitrogen Concentrations in Harvested Plant Parts – Update 3/2021.

ACKNOWLEDGEMENTS

This project was funded (in part) by a grant from the California Department of Food and Agriculture's Fertilizer Research and Education Program (FREP) and the Fertilizer Inspection Advisory Board.

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

Project Leader

Ali Montazar
Irrigation and Water Management Advisor
UCCE Imperial County
1050 East Holton Road
Holtville, CA 92250
Phone: (442) 265-7707
amontazar@ucanr.edu

Cooperators

Daniel Geisseler
Nutrient Management Specialist
Dept. of LAWR, UC Davis
One Shields Ave., PES Building,
Davis, CA 95616
Phone: (530) 754-9637
djgeisseler@ucdavis.edu

Michael Cahn
Irrigation and Water Resources Advisor
UCCE Monterey County
1432 Abbott Street
Salinas, CA 93901
Phone: (831) 759-7377
mdcahn@ucanr.edu

Jaspreet Sidhu
Vegetable Crops Farm Advisor
UCCE Kern County
1031 South Mount Vernon Ave.,
Bakersfield, CA 93307
Phone: (661) 868-6222
jaksidhu@ucanr.edu

INTRODUCTION

Water and nitrogen (N) management in carrots is critical for increasing efficiency of crop production by decreasing costs and nitrate leaching losses. To maximize yield and quality, carrots need a sufficient level of N in the soil. Matching N fertilizer applications with carrot N uptake, and water applied with crop water requirements can optimize N and water use efficiency, as well as crop yield and quality. This study was conducted to develop knowledge and information on improving and promoting adoption of management practices that optimize N and irrigation water use efficiency in the desert carrot production system.

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 (CM) tool for water and N management in carrots.

DESCRIPTION

The study was conducted over one crop season (October 2022 - March 2023) at the UC Desert Research and Extension Center in Holtville, California. The experiment consisted of three N fertilizer strategies (N1, N2, N3) under two irrigation regimes (I1, I2). The trial was arranged in a randomized complete block with split plot arrangement over four replications. Each sub-plot included 12 beds of 40-in. width and 60 ft. long (40 ft × 60 ft). Ten lines of Choctaw fresh market cultivar were seeded in each bed. Solid set sprinkler was used to irrigate the trial throughout the season. The field has a silty loam soil texture at the top 2 ft. and sandy loam below 2 ft. depth.

The water applied to the irrigation treatments was monitored throughout the irrigation events using magnetic flowmeters on a 30-minute basis (Fig. 1). Actual soil nitrate content (NO_3-N) and total N percentage in tops and roots were determined monthly through laboratory analysis. Preplant and post-harvest soil samples were taken from six depths (1-6 ft.). At other sampling dates, soil was collected from the top three depths (1-3 ft.). A composite soil sample was analyzed from each layer for NO_3-N content. The amount of irrigation water and N application rates were determined using the CM irrigation and nitrogen decision management tool.

Figure 1. Magnetic flowmeters and data store and transfer equipment to monitor water applied to the trial.

Canopy images were taken on a weekly to a 15-day basis utilizing an infrared camera (NDVI digital camera) to quantify crop canopy coverage over the crop seasons. Plant measurement was carried out on 40-plant samples collected randomly per plot and determinations of fresh and dry weights of roots and foliage were made on a regular monthly basis during the seasons. The plant measurement was conducted on 100-plant samples per plot at harvest.

RESULTS AND DISCUSSION

Water and nitrogen applied.

A preplant N fertilizer with monoammonium phosphate was broadcasted at a rate of 280 lbs./ac over the entire trial area. Urea Ammonium Nitrate (UAN-32) was injected into the sprinkler system to supply the remainder amount of the N for each nitrogen treatment. The N and irrigation application rates varied from 145 to 217 lbs. N/ac and from 23.6 to 29.7 in., respectively (Fig. 2).

Impact of water and N management on nitrogen uptake.

Nearly 50% of the total N in carrots are taken up during a 50-day period, 80-130 days after seeding (Montazar et al. 2021a). The highest N accumulation rates at harvest were associated with the N2 treatment under the I2 irrigation regime (273 lbs. ac^{-1}) and the N3 treatment under the I1 irrigation regime (281 lbs. ac^{-1}) (Fig. 3). However, nitrogen application rates had no statistically significant effect on total N uptake (roots and tops) and the N accumulated in roots. The N application rate had a clear and scientifically significant effect on increasing aboveground foliage (tops), which could be a reason for greater nitrogen uptake at the higher rate of N applied.

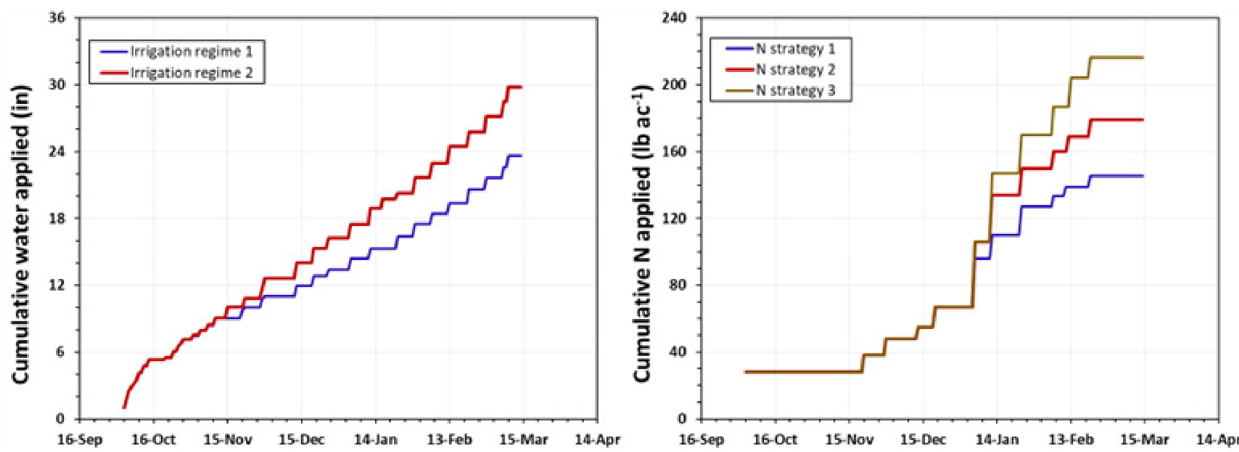


Figure 2. Cumulative water and N applied in each of the irrigation regimes and N strategies.

The results provide evidence (p=0.01) for an overall effect of the interaction of irrigation regime and nitrogen management strategy on the total N accumulation in carrots (roots and tops) even though the irrigation regime as an individual driver had no significant effect on the N accumulation (neither the total nor tops or roots). The 25% over irrigation couldn't have a considerable impact on leaching nitrate within a silty loam soil type. A higher amount of excessive water through a more aggressive over irrigation scenario (for instance 150% ET or greater) could influence the N uptake differently.

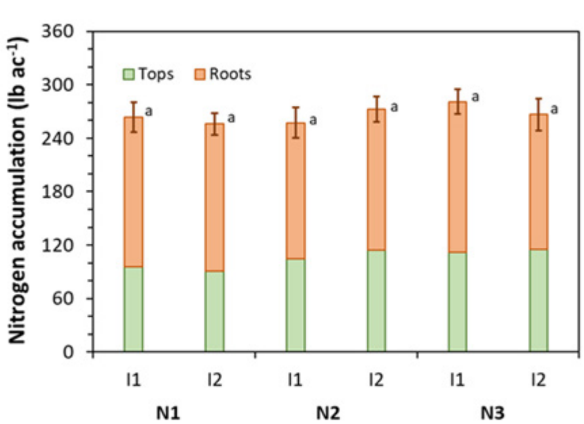


Figure 3. Mean nitrogen uptake distribution in carrot roots and tops affected by water regimes and nitrogen application rates. The bars demonstrate the standard error of root yield values. Fresh root yields with different letters significantly differ ($p < 0.05$) by Tukey's test.

Impact of water and N management on carrot fresh roots. Although no statistically significant impacts were found from both irrigation and N application rates on the fresh root yield, N application statistically affected root yield (Fig. 4). The findings suggested an insignificant difference of fresh root yields impacted by the interaction of irrigation regime and N strategy within the range of application. Different results could be obtained in a field that is irrigated more than the I2 treatment (> 125% of CM recommendation), has a low residual nitrate content or/and has a sandy textured soil.

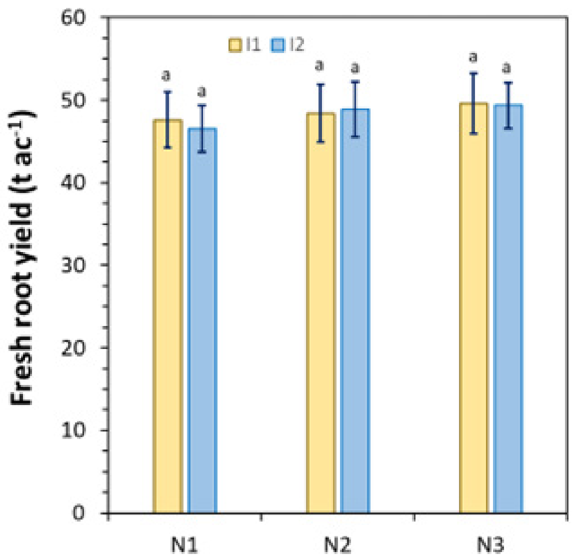


Figure 4. Mean fresh carrot root yields as affected by water regimes and nitrogen application rates. The bars demonstrate the standard error of root yield values. Fresh root yields with different letters in each season significantly differ ($p < 0.05$) by Tukey's test.

CONCLUSIONS

In the low desert of California, 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 (Montazar et al. 2021b).

The findings of this study suggested that N application rates greater than 145 lbs. ac^{-1} do not have a significant impact on carrot root yield in a well-managed irrigated field. However, the fact that more N was taken up in the crop than applied for the N1 and N2 treatments would suggest that the residual nitrate in the soil from the past season contributed to the N nutrition of the crop. Higher N rates are likely necessary in over-irrigated carrot fields (receiving more than 125% of Crop ET), or fields with a low residual nitrate content.

REFERENCES

Montazar, A.; Geisseler, D.; Cahn, M. (2021a). Spatial Variability of Nitrogen Uptake and Net Removal and Actual Evapotranspiration in the California Desert Carrot Production System. Agriculture, 11 (8), 752.

Montazar, A.; Geisseler, D.; Cahn, M. (2021b). New Knowledge-Based Information Developed to Enhance Water and Nitrogen Use Efficiency in the Desert Fresh Market Carrots. Progressive Crop Consultant, September/ October 2021, 8-13.

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 UCCE Imperial County and UC DREC staff.

Certification and Distance Learning for Fertigation

Project Leader

Charles M. Burt
Chairman
Irrigation Training and Research Center (ITRC)
Cal Poly State University
San Luis Obispo, CA 93407-0740
(805) 748-3863
cburt@calpoly.edu

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, is already available for free download.
   - Spanish material will be developed.
2. Prepare approximately 21 training modules to be developed; 11 will be in Spanish.
3. The laboratory exercises will 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) narrated the Spanish videos and PowerPoints.

All the modules have been completed. The list is as follows, along with the URLs for You Tube.

Language	Video	Type	Chapter(s)	Group	Video Title	YouTube link
English	Video 1	Lecture	1	Fertilizer, Soil, and Plant Nutrition and Environmental Concepts	Overview	https://youtu.be/hywgsfFA-8Y
English	Video 2	Lecture	19		Basic Fertilizer Chemistry and Vocabulary	https://youtu.be/dbIGAC8JFgA
English	Video 3	Lecture	8, 9		N and the Environment	https://youtu.be/ccLZI_I_XTw
English	Video 4	Lecture	6		Basic Soil Principles	https://youtu.be/xS-iAtejfnE
English	Video 5	Lecture	16, 10		Crop Fertilizer Requirements	https://youtu.be/WasPud7aeWE
English	Video 6	Lecture	15		Testing of Plants Soil and Water	https://youtu.be/6jQy45I8HDs
English	Video 7	Lecture	11		Fertilizer Labels Characteristics and Usage	https://youtu.be/pdtkCwxIX9
English	Video 8	Lecture	8		Nitrogen Conversions	https://youtu.be/tR64vME64iA
English	Video 10	Lecture	6		Irrigation System Uniformity and Efficiency	https://youtu.be/QBGMY3IDfFI
English	Video 11	Lecture	2		Safety	https://youtu.be/MXC7J3rME2I
English	Video 22	Lecture	7	Field Practices	Fertigation for Specific Methods	https://youtu.be/MdsZZf8rWx8
English	Video 12	Lab	3		Purging Media Tanks of Chemicals	https://youtu.be/dPvtNynLhnc
English	Video 13	Lab	7, 18		Calibration, Titration, and Travel Time	https://youtu.be/OtSZObWIxWY
English	Video 14	Lab	3		Varying Venturi Injection Rates	https://youtu.be/1_ZyKo4WGgo
English	Video 9	Lab	8, 18	Specific Problems and Solutions	Volatilization of ammonia from irrigation water	https://youtu.be/ECNVi4DVuxw
English	Video 15	Lecture	19		Chemigation for Soil Infiltration Problems	https://youtu.be/rBdqJTukfCI
English	Video 16	Lab	5		SO2 Generators	https://youtu.be/Mg_ThaRp1Kc
English	Video 17	Lecture	18		Chemigation for Drip System Maintenance	https://youtu.be/yO_xCI1iq3A
English	Video 18	Lab	11		Incompatibility of Different Fertilizers	https://youtu.be/6AJnn_SA8pI
English	Video 19	Lecture	4	Injectors	Proportional Injection	https://youtu.be/fc-Mi9omwO0
English	Video 20	Lab	3		Fertilizer and Chemical Injection Devices	https://youtu.be/XpxkkoYo3eA
English	Video 21	Lab	3		Calibration of Fertilizer and Chemical Injectors	https://youtu.be/ewOUzgA4bCI
Spanish	Video 1-S	Lecture			Visión general	https://youtu.be/GzOff6vomUo
Spanish	Video 2-S	Lecture			Química y Vocabulario Básico de Fertilizantes	https://youtu.be/tg1F0zTywBI
Spanish	Video 3-S	Lecture			Manejo del nitrógeno y medio ambiente	https://youtu.be/cPDEyWj_01Q
Spanish	Video 4-S	Lecture			Principios básicos del suelo	https://youtu.be/PJmBb6HPRN4
Spanish	Video 5-S	Lecture			Requisitos de fertilizantes de los cultivos	https://youtu.be/XHBIc6siAvw
Spanish	Video 6-S	Lecture			Análisis de plantas, suelo y agua	https://youtu.be/yILvsZRimS0
Spanish	Video 7-S	Lecture			Etiquetas, características y uso de fertilizantes	https://youtu.be/PE8hdDLmIzQ
Spanish	Video 8-S	Lecture			Conversiones del nitrógeno	https://youtu.be/8tjse7FjNyE
Spanish	Video 9-S	Lab			Volatilización de Amoníaco del Agua de Riego	https://youtu.be/nODbjWgD0mA
Spanish	Video 10-S	Lecture			Uniformidad y eficiencia del sistema de riego	https://youtu.be/rsryxkkH29Q
Spanish	Video 11-S	Lecture			Seguridad	https://youtu.be/bkjCGkIs4rQ
Spanish	Video 12-S	Lab			Tiempo Requerido Para Purgar Productos Químicos de los Tanques de Filtración	https://youtu.be/rj16zeqG1Yk
Spanish	Video 13-S	Lab			Calibración, Titulación y Tiempo de Viaje	https://youtu.be/2ZmfOwzU_cM
Spanish	Video 14-S	Lab			Variación de Tasas de Inyección de Químicos Cuando se Utiliza un Venturi	https://youtu.be/XLNS5tIMR4U
Spanish	Video 15-S	Lecture			Quimigación para problemas de infiltración del suelo	https://youtu.be/YjRVxxOAq0E
Spanish	Video 16-S	Lab			Generadores de SO2	https://youtu.be/CgHqGJ6Qrpg
Spanish	Video 17-S	Lecture			Quimigación para el mantenimiento del sistema de goteo	https://youtu.be/tNmZhMZmxc8
Spanish	Video 18-S	Lab			Incompatibilidad de Fertilizantes Diferentes	https://youtu.be/eMrcd5aMJPg
Spanish	Video 19-S	Lecture			Inyección proporcional	https://youtu.be/5-WMwAZftSI
Spanish	Video 20-S	Lab			Dispositivos de Inyección de Fertilizantes y Productos Químicos	https://youtu.be/kT2GF_pwG7c
Spanish	Video 21-S	Lab			Calibración de Inyectores Químicos	https://youtu.be/WEltByWA80I
Spanish	Video 22-S	Lecture			Fertirrigación para Métodos Específicos de Riego	https://youtu.be/oQ33xifACwA

Other key points for this project include:

1. There has been a change in leadership in the Irrigation Association (IA), and the decision by the IA was to not adopt any new certification training programs. Therefore, Cal Poly ITRC will initiate its own certification training program, as it has done with other topics.
2. Various organizations will be contacted to see if they are interested in providing Continuing Education Units (CEUs) for those who successfully pass various segments of the training.
3. The intent is to have the program running by February, 2024.

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.

ACKNOWLEDGEMENTS

This work has been entirely supported by FREP.

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

Project Leader

Michael Cahn
Irrigation and Water Resources Advisor
UC Cooperative Extension, Monterey County
1432 Abbott St, Salinas, CA 93901
831-759-7377
mdcahn@ucanr.edu

Cooperators

Aliasghar (Ali) Montazar
Irrigation and Water Resources Advisor
UC Cooperative Extension, Imperial & Riverside Counties
1050 East Holton Road
Holtville, CA 92250-9615
442-265-7707
amontazar@ucanr.edu

Daniele Zaccaria
Irrigation Water Management Specialist
LAWR/Hoagland
One Shields Avenue, Davis, CA 95616
530-219-7502
dzaccaria@ucdavis.edu

Brenna Aegerter
Vegetable Crop Advisor
UC Cooperative Extension, San Joaquin County
2101 East Earhart Ave, Suite 200
Stockton, CA, CA 95206-3924
209-953-6114
bjaegerter@ucanr.edu

Khaled M. Bali
Irrigation Water Management Specialist
Kearney Agricultural Research & Extension Center
9240 S. Riverbend Ave.
Parlier, CA 93648
559-646-6541
kmbali@ucanr.edu

Gabriel Youtsey
Chief Innovation Officer, UCANR
2801 Second Street, Davis, CA 95618
530-750-1314
gdyoutsey@ucanr.edu

Gerry Spinelli
Production Horticulture Advisor
Cooperative Extension
9335 Hazard Way, Suite 201
San Diego, CA 92123
530-304-3738
gspinelli@ucanr.edu

Mae Culumber
Nut Crops Farm Advisor
UC Cooperative Extension Fresno County
550 E. Shaw Avenue, Suite 210-B
Fresno, CA 93710
559-241-7526
cmculumber@ucanr.edu

Michelle Leinfelder-Miles
Delta Crops Resource Management Advisor
2101 E. Earhart Ave., Ste 200
Stockton, CA 95206
209-953-6100
mmleinfeldermiles@ucanr.edu

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 vegetable and berry crops, and more recently Central Valley crops including alfalfa, almond, walnut, pistachio, and processing tomato.

CM is used by growers, farm managers, consultants, governmental and non-profit agencies. With the addition of new crops and features grower adoption of CM has steadily increased during the past 10 years. 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 explores and implements strategies 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 is 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 continue to be developed including adding tutorial articles to the CM knowledge base (help.cropmanage.ucanr.edu), an e-newsletter that introduces new features and announces training opportunities to CM users, one-on-one help is offered to users through contacts from the CM hotline or the CM "feedback" link.

Revenue generation for sustaining CM continues to be explored at UCANR including subscription and donation-based models. Automated reporting capabilities may be added which could 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 greatly simplifies data entry for farming operations that want to adopt CM on a large scale.

ACCOMPLISHMENTS

Outreach

CropManage was introduced at eight grower and industry meetings held on the Central Coast, Central Valley, and in Arizona and Colorado. In-depth, hands-on workshops were also conducted in Stanislaus, Fresno, Santa Cruz, and Santa Clara counties. 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. An additional 4 instructional articles were published in the help section of CM (help.crop-manage.ucanr.edu) and an e-newsletter was distributed to CM users at the beginning of 2023 that provided updates about new features and training opportunities.

Expanding use of CropManage and increasing potential for revenue generation

Use of CropManage increased by 36% compared to the previous year, recording as many as 3000 events per month during the growing season. CropManage user accounts have also increased by about 34% compared to last year and now the application has almost 4000 registered users. This increase was presumably an aggregate effect of outreach efforts made during the last two years of the project, as well as the addition of new commodities and features that have made the decision support tool more relevant to grower needs as well as easier to use. For example, the user-interface was redesigned to facilitate task management, identifying upcoming, incomplete, and completed tasks on a single screen.

Collaboration has continued with the private company, GeoVisual Analytics, to integrate CM recommendations into their farm management software (SeedGreen) using the application programming interface (API) available in CM. Additionally, GeoVisual is developing a simple application for smart phones that irrigators and farm managers can use to access CM recommendations and record applied water volumes and fertilizer amounts for a major produce company in the Salinas Valley.

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

ACKNOWLEDGEMENTS

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

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

Project Leaders

Bob Hutmacher
UC Coop. Ext. Spec.; UCD Plant Sci. Dept
rbhutmacher@ucdavis.edu

Daniel Putnam
UC Coop. Ext. Spec.; UCD Plant Sci. Dept.
dhputnam@ucdavis.edu

Cooperators

Sarah Light
Univ. CA Coop. Ext. Farm Advisor, Yuba and Sutter Counties

Nicholas Clark
Univ. CA Coop. Ext. Farm Advisor, Fresno, Kings,Tulare Counties

Daniel Geisseler
UC Coop. Ext. Specialist, UCD Land, Air and Water Resources Dept.

UCD Plant Sci. Dept.
Jorge Angeles
Chris De Ben (SRA)
Maya Hotz (Jr. Spec.)

Geoffrey Koch
PhD Graduate Assistant, UCD Land, Air and Water Resources Dept.

Companies providing Seed or Transplants:
Kayagene Corp., Woodland, CA (Dr. Christopher Hahn); Cultivaris Corp., Encinitas, CA (Dr. Josh Schneider); Phylos Biosciences (Dr. John McFerson); Zera Farms, Ventura, CA (Dr. Matt McClain); Beacon Hemp, Petaluma, CA (Dr. Nick Stromberg)

Company Providing Chemotyping and Quality Analytical Services:
Alkemist Laboratories, Garden Grove, CA (Dr. Bryan Fine)

OBJECTIVES

1. Evaluate for two biotypes of industrial hemp (autoflower/short-season, full-season photoperiod-sensitive types) grown for essential oils (CBD, others) and the impacts of fertilizer N application amount on N uptake and removal, yield under SDI irrigation.
2. Assess impacts of N management practices on THC and CBD in harvested products.

DESCRIPTION

Trials were conducted at the UC-ANR West Side REC (WSREC) in Fresno County (clay loam soil), and UC Davis Farm (UCD) in Yolo County (fine sandy loam). Pre-plant soil samples were collected and analyzed to assess residual soil NO_3-N, P and K. Sub-surface drip irrigation lines were installed 8-10 inches deep, two lines per bed, 30 inches apart on 60 inch beds. For 2021 growing season, two autoflower (AF) cultivars ("Maverick" and "Alpha Nebula") and two full-season, photoperiod-sensitive (PPS) cultivars ("Scarlett" and "The Wife") were used.

In 2022, due to multiple issues regarding seed and transplant availability, we direct-seeded plantings for both AF ("Maverick" and "Rincon" and "Alpha Nebula") and full-season ("Early Wu" and "Cookie Crush") cultivars. Seed companies provided Certificates of Analysis for expected THC levels, and cultivars were selected based on potential for acceptable THC content. The first AF seeded plantings in 2021 were not successful in producing an acceptable stand of plants at either location. Different types of planters were used for a second round of direct seed plantings of AF cultivars with acceptable stands of plants achieved with these plantings at both sites. In 2022, both the AF and full-season types of plants were planted from seed. Plantings were established (through emergence) using sprinklers (WSREC) or surface drip (UCD), afterwards SDI irrigation was used. In-line fertilizer injection units were used to establish five fertilizer levels for each study, with applied N across five treatments ranging from 0 to ~ 120 lbs N/acre for AF cultivars vs 0 to ~ 210 lbs N/ac for full-season cultivars. Exact application amounts are shown with cola yield data (Table 1 and 2). Time to harvest differed markedly between AF types (estimated 70-80 days emergence to harvest for CBD) vs full-season types (110-130 days for PPS types). Based on differences in ultimate size of plants, growth duration, and optimal planting densities, we ran these two nitrogen (N) trials as completely separate field trials. Plant densities used were approximately 17,000 plants/ac for AF varieties (smaller plants) and about ¼ of those populations for PPS cultivars.

RESULTS AND DISCUSSION

The AF varieties begin first cola (flower buds) development about 3 to 4 weeks earlier than PPS types in these studies. For purposes of running N fertilizer response trials, we adjusted irrigation water application amounts to also reflect the difference in plant size and canopy cover between the smaller AF cultivars versus PPS cultivars, resulting in about 50-plus percent lower total applied water for AF cultivars due to a reduced irrigation water amount (lower crop coefficient) and shorter duration of growth. Some N treatment impacts were observed on parameters such as plant canopy width, height, total plant fresh and dry weights (data not shown) in both AF and PPS type cultivars with increasing N applications, as might be expected when beginning stored soil N is low to moderate. For brevity, however, we will focus on cola yield responses. Harvests were in September (AF) and October (PPS) in 2021, late August/September (AF) and late-September/October (PPS) in 2022. Total dry matter and colas were separated at harvest, with samples ground for THC, CBD and plant component part N content. Pre-plant soil residual NO_3-N (lbs/ac) in upper 3 feet of soil averaged 38 lbs N (WSREC-2021), 27 lbs N (WSREC-2022), 47 lbs N (UCD-2021), and 52 lbs N (UCD-2022).

In both field trial years (Tables 1, 2), cola yields in AF cultivars were more responsive to increasing N application levels at WSREC than at UCD, with large increases in cola yields at WSREC from T1 up through T3 N application level (about 60 lbs N/acre). In AF cultivars at WSREC there was no significant response to increases in N beyond 60 or 90 lbs N/acre fertilization rate. There was little or no response to applied N rates with AF varieties at the UCD site with the Alpha Nebula cultivar in both 2021 and 2022 studies, but a slight increase at the T3 (60 lbs N/acre) and higher rates with Maverick cultivar in 2021 (Table 1) and Maverick and Rincon cultivars in 2022 (Table 2) when compared to lower N applications. In full-season cultivars in 2021 (Table 1), at both sites and cultivars, there was a cola yield response to increasing applied N fertilizer from the T1 to T3 level of applications (more consistent across sites than observed with AF types), with a more variable yield response to increases in applied N in T4 and T5 treatments. Cola yields in general were more responsive to increasing applied N (up through T3 levels) at WSREC site than at UCD site (Tables 1, 2).

Table 1. Cola (flower bud) dry weight yields (lbs/acre) as a function of nitrogen treatments for Autoflower (AF) cultivars (upper group) and Full-Season (PPS) cultivars (lower group) in 2021 at UCD and WSREC. Mean separation analyses shown for each site and cultivar, different letters indicating N treatment differences, 5% level. Plants in AF trial were direct seeded, those in PPS trial were transplants in 2021.

Trial Site	Cultivar name	Cola yields (all colas >3" length on main stem and branches) (lbs/acre)				
		Within growing season N application level				
	AF types	**T1 (0 lbs/ac)**	**T2 (15lbs/ac)**	**T3 (50 lbs/ac)**	**T4 (75 lbs/ac)**	**T5 (110 lbs/ac)**
UCD	Maverick	1399 b	1395 b	1595 a	1561 a	1507 ab
	Alpha Nebula	1166 a	1144 a	1099 ab	954 b	1137 a
		T1 (0 lbs/ac)	**T2 (30lbs/ac)**	**T3 (60 lbs/ac)**	**T4 (90 lbs/ac)**	**T5 (120 lbs/ac)**
WSREC	Maverick	1676 b	1899 ab	2186 a	2344 a	2407 a
	Alpha Nebula	1532 b	1682 b	1971 ab	2126 a	2034 a
	PPS types	**T1 (0 lbs/ac)**	**T2 (45 lbs/ac)**	**T3 (85 lbs/ac)**	**T4 (135 lbs/ac)**	**T5 (170 lbs/ac)**
UCD	The Wife	975 c	1192 bc	1469 ab	1818 a	1896 a
	Scarlett	1536 b	2102 a	2018 a	2104 a	2142 a
		T1 (12lbs/ac)	**T2 (55 lbs/ac)**	**T3 (110lbs/ac)**	**T4 (165 lbs/ac)**	**T5 (220 lbs/ac)**
WSREC	The Wife	885 c	1230 b	1589 ab	1812 a	1762 a
	Scarlett	712 b	860 b	1075 ab	1179 a	1269 a

Table 2. Cola (flower bud) dry weight yields (in lbs/acre) as a function of nitrogen treat-ments for Autoflowed (AF) cultivars and Full-Season (PPS) in 2022 at UCD and WSREC sites. Mean separation analyses shown for each site and cultivar, different letters indicating differ-ences, 5% level. Plants were direct seeded for both AF and PPS cultivars in 2022.

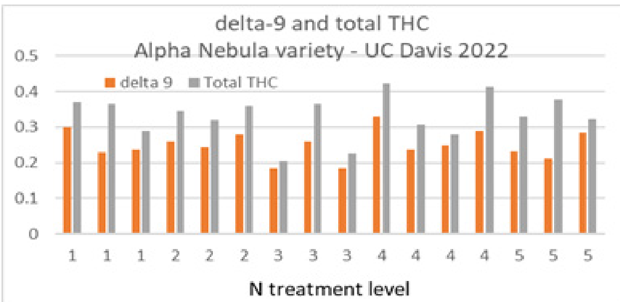
Trial Site	Cultivar name	Cola yields (all colas >3" length on main stem and branches) (lbs/acre)				
		Within growing season N application level				
	AF Types	**T1 (27lbs/ac)**	**T2 (57 lbs/ac)**	**T3 (87 lbs/ac)**	**T4 (117 lbs/ac)**	**T5 (147 lbs/ac)**
UCD	Maverick	1399 b	1395 b	1595 a	1561 a	1507 ab
	Rincon	1747 b	1778 b	1887 ab	1962 a	2001 a
	Alpha Neb	1902 ab	1808 b	1992 a	1728 b	1855 ab
		T1 (0 lbs/ac)	**T2 (30lbs/ac)**	**T3 (60 lbs/ac)**	**T4 (90 lbs/ac)**	**T5 (120 lbs/ac)**
WSREC	Maverick	716 c	1105 b	1519 a	1690 a	1775 a
	Rincon	624 c	908 b	1142 a	1215 a	1219 a
	Alpha Neb	658 c	954 b	1170 ab	1144 ab	1286 a
	PPS Types	**T1 (27lbs/ac)**	**T2 (82 lbs/ac)**	**T3 (137 lbs/ac)**	**T4 (192 lbs/ac)**	**T5 (247 lbs/ac)**
UCD	*Data set not analyzed yet at time of report*					
		T1 (0 lbs/ac)	**T2 (55 lbs/ac)**	**T3 (110 lbs/ac)**	**T4 (165 lbs/ac)**	**T5 (210 lbs/ac)**
WSREC	Early Wu	1455 b	1823 b	2208 a	2246 a	2451 a
	Cookie Crush	1426 c	2013 b	2364 b	2448 ab	2929 a

A partial analysis of N content of hemp plants at harvest time in 2022 at the WSREC site is shown in table 3. Increases in cola N content (lbs N/ac) with increasing N at WSREC site in AF and PPS type cultivars reflected both increases in cola dry weights through T3/T4 levels, and increases in cola N% with increasing N.

Table 3. Average Nitrogen Content at harvest of partitioned plant parts (Leaf + Stem, all Colas) in lbs N/acre as a function of applied nitrogen treatments for AF and PPS cultivars in 2022 at WSREC site. No statistical analyses have been conducted at time of preparation of report. Plants were direct seeded.

Cultivar	Plant Part	Nitrogen Content at Harvest (lbs N / acre)				
		Within growing season N application level				
PPS Types		**T1 (0 lbs/ac)**	**T2 (55 lbs/ac)**	**T3 (110 lbs/ac)**	**T4 (165 lbs/ac)**	**T5 (210 lbs/ac)**
Early Wu	Leaf + Stem	41.4	58.2	97.2	118.7	112.5
	All Colas	45.4	64.0	76.6	84.0	99.0
Cookie Crush	Leaf + Stem	54.6	87.9	123.0	132.8	148.0
	All Colas	45.9	66.7	77.3	85.4	107.5
AF Types		**T1 (0 lbs/ac)**	**T2 (30 lbs/ac)**	**T3 (60 lbs/ac)**	**T4 (90 lbs/ac)**	**T5 (120 lbs/ac)**
Maverick	Leaf + Stem	18.7	28.5	46.7	64.8	57.4
	All Colas	33.5	48.7	71.1	76.1	86.6
Rincon	Leaf + Stem	18.9	25.3	44.2	44.3	51.1
	All Colas	30.1	40.6	63.0	63.9	71.7
Alpha Neb	Leaf + Stem	19.1	33.8	53.6	56.0	57.2
	All Colas	29.2	47.6	65.5	64.7	69.0

Figure 1 shows limited THC and CBD data from ground primary colas of AF cultivar “Alpha Nebula” at 2022 UCD site across N treatments. From limited THC, CBD data analyzed, we have not seen consistent responses to applied N levels, suggesting that with this range of N and environmental conditions, cola THC and CBD levels are more a function of cultivar than of plant tissue N status.



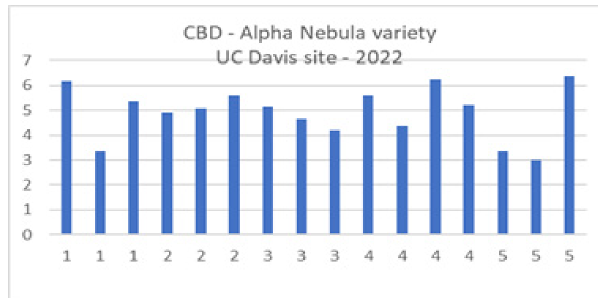


Figure 1. CBD, delta-9 THC and total THC concentrations at harvest time in colas of Auto-flower cultivar “Alpha Nebula” as a function of nitrogen treatment levels (1 through 5) at UC Davis nitrogen trial site in 2022. X-axis values with the same N treatment number are replicate samples.

ACKNOWLEDGEMENTS

This industrial hemp multi-year N management trial is supported by the California Department of Food and Agriculture’s Fertilizer Research Education Program (CDFA-FREP). Donations of hemp transplants and seed for conducting the trials from multiple companies and the donated services for THC and CBD analyses from Alkemist Labs have been incredibly valuable donations to assist with this project, and we wouldn’t be able to do the study without this assistance. We are also grateful for the hard work and great attention to detail provided by our field research staff, 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

Project Leaders

Toby O'Geen
Professor and Cooperative Extension Specialist
atogeen@ucdavis.edu

Scott Devine
Post-Doctoral Researcher
smdevine@ucdavis.edu

Helen Dahlke
Associate Professor
hdahlke@ucdavis.edu

Isaya Kisekka
Associate Professor
ikisekka@ucdavis.edu

Thomas Harter
Professor and Cooperative Extension Specialist
thharter@ucdavis.edu

Majdi Abou Najm
Associate Professor
mabounajm@ucdavis.edu

Shulamit Shroder
Department of Land, Air and Water Resources, University of California, Davis
One Shields Avenue, Davis CA 95616
sashroder@ucanr.edu

INTRODUCTION

Agricultural management of floodwaters (Flood-MAR) is of broad interest in California as a tool to recharge aquifers. There are concerns to be analyzed before this practice can be safely implemented, such as contamination of groundwater by leaching soil nitrate (NO_3). This modeling exercise hypothesized that Flood-MAR will enhance NO_3 leaching vs. no Flood-MAR (business-as-usual). We hypothesized early Flood-MAR timing will leach less NO_3 than late Flood-MAR timing, due to lower rates of mineralization when soils are cooler. Mineralization generates NO_3 from soil organic matter decay. Additionally, frequency of Flood-MAR pulses (shorter interval between water applications) may leach less NO_3, due to less time for mineralization between Flood-MAR applications. Finally, NO_3 leaching risk is offset partially by denitrification in finer textured soils with longer periods of saturation and anaerobic conditions.

OBJECTIVES

This research evaluated contrasting seasonal timing and frequency of Flood-MAR as strategies to minimize NO_3 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. Findings were tested in the field on semi-arid, coarse textured soils through an evaluation of the effect of cover crops on NO_3 leaching during Flood-MAR.

DESCRIPTION

RZWQM modeling included 33 Central Valley soils representing distinct particle-size classes (termed here Coarse, Loamy and Fine) and five different 37-year climate records obtained from CIMIS, 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. Simulations extended to a depth of 150 cm. Leaching values represent the NO_3 flux at the bottom boundary of this simulation domain. 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 simulations, Flood-MAR was practiced during the 10-wettest water years of each 37-year climate record, applying 600-cm additional water via Flood-MAR. In a Flood-MAR year, four 15-cm water applications were made in either January or March, using a 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^{-1} after 37-years of the business-as-usual scenario (Fig. 1).

This is because in-situ precipitation during the wet years, when Flood-MAR is expected to be practiced, removed most residual NO_3 through deep percolation. This is true even in the finest textured soils, which are most difficult to leach due to high 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 (Fig. 1 & 2). Additional nitrate leaching risk increased in dry climates, because lack of precipitation allowed for residual NO_3 accumulation across growing seasons.

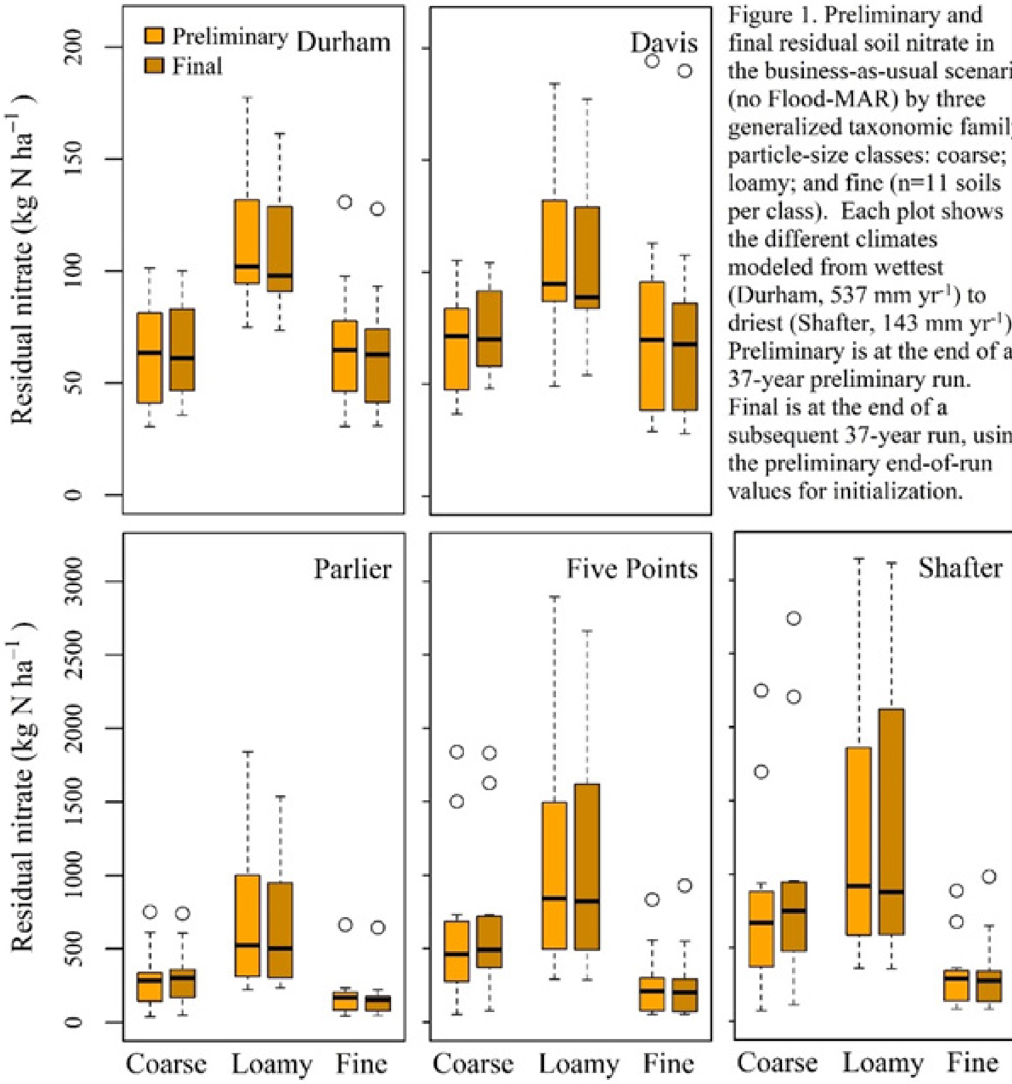


Figure 1. Preliminary and final residual soil nitrate in the business-as-usual scenario (no Flood-MAR) by three generalized taxonomic family particle-size classes: coarse; loamy; and fine (n=11 soils per class). Each plot shows the different climates modeled from wettest (Durham, 537 mm yr^{-1}) to driest (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.

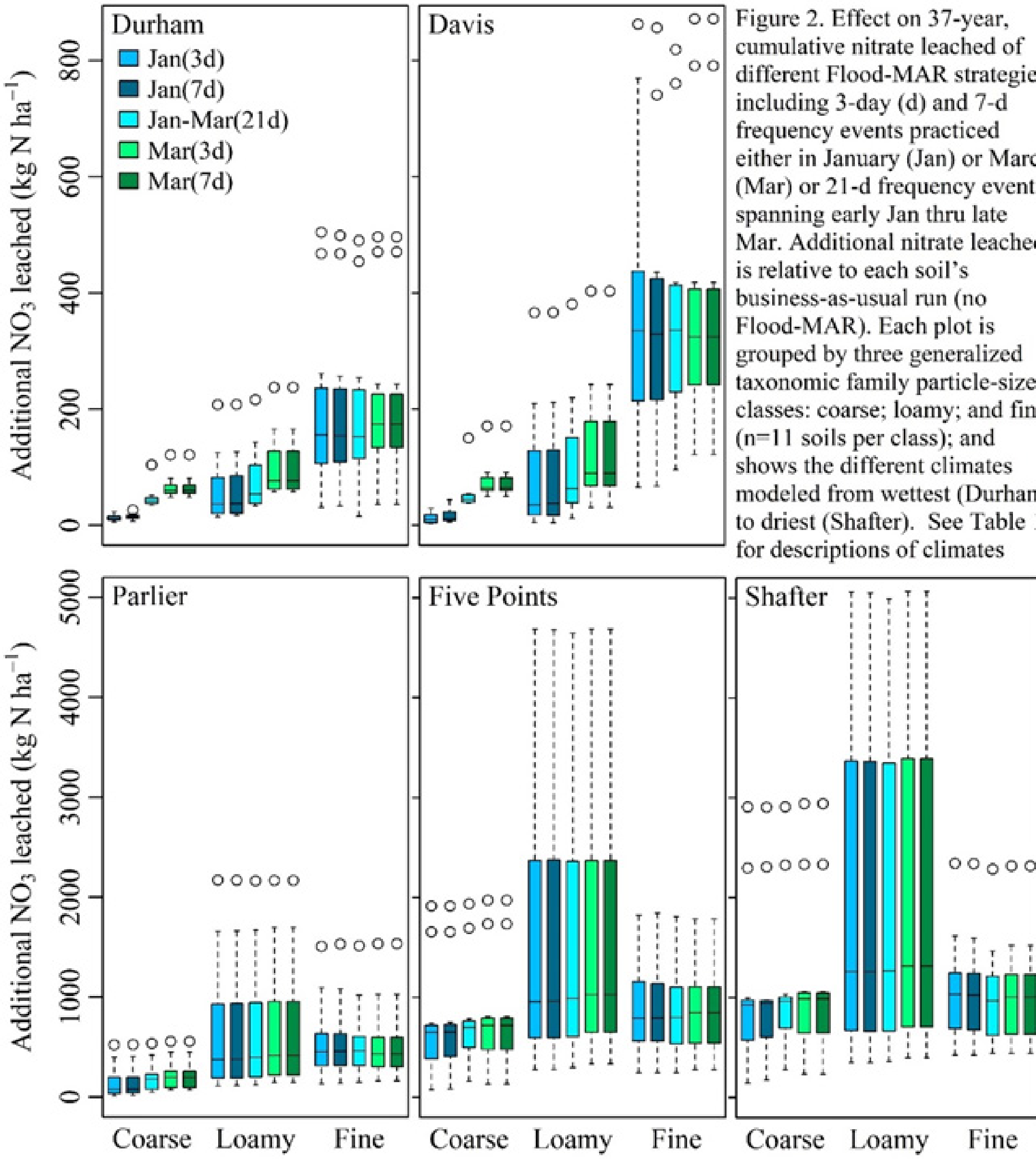


Figure 2. Effect on 37-year, cumulative nitrate leached of different Flood-MAR strategies, including 3-day (d) and 7-d frequency events practiced either in January (Jan) or March (Mar) or 21-d frequency events spanning early Jan thru late Mar. Additional nitrate leached is relative to each soil's business-as-usual 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

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 (Fig. 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. 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 to leach residual NO_3, such that the additional NO_3 leaching risk from Flood-MAR is typically lower in coarse soils compared to loamy soils.

Field trials on coarse soils were slightly higher than modeling results but demonstrate low NO_3 leaching during Flood-MAR (Fig. 3). Cover crops had no detectable effect on NO_3 leaching. Similar to the modeling experiment, the oxidation-reduction potential was not low enough in these coarse textured soils to facilitate denitrification.

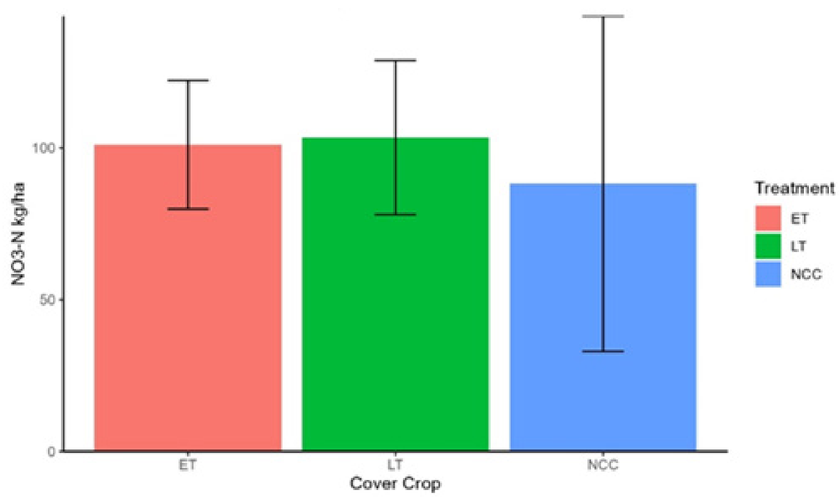


Figure 3. Average amount of nitrate leached in cover crop treatments during Flood-MAR on a coarse textured soil at the Kearney Agricultural Research and Extension Center. ET = early cover crop termination; LT = late termination and NCC = no cover crop treatment.

ACKNOWLEDGEMENTS

This research is supported by CDFA-FREP.

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

Project Leaders

Deborah Nares
CA Senior Manager
American Farmland Trust (AFT)
455 Capitol Mall, Suite 410
Sacramento, CA 95814
(831) 769-6385
dnaresparedes@farmland.org

Kee Xiong
Deputy Director
Asian Business Institute and Resource Center (ABIRC)
7035 N Fruit Ave.
Fresno, CA 93711
(559) 402-0067
kee@fresnoabirc.org

Misael Sanchez
Bilingual Outreach and Water Resource Specialist
Cachuma Resource Conservation District (CRCD)
920 E Stowell Road, Santa Maria, CA 93454
(805)868-4013
irrigation.crcd@gmail.com

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, many whom 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 small-scale diversified vegetable production, coupled with historical uneven distribution of services across ethnic and racial groups prevents California agriculture from realizing its nutrient management and irrigation efficiency potential.

OBJECTIVES

Given the above-mentioned issues related to lack of TA this project aims to:

1 Increase nutrient management and irrigation efficiency TA and information distribution for underserved farmers and 2) Increase management efficiencies and adoption of sustainable nutrient management and irrigation efficiency practices.

DESCRIPTION

The objective of this project is being carried out through outreach and relationship building strategies to understand and better serve Southeast Asian and Latino growers and farm workers in the Central Coast, Southern California, and San Joaquin Valley in the primary languages of the audience, Hmong and Spanish. Eleven on-farm tailgates are being delivered each focused on providing technical information to growers and demonstrating efficient fertilizer selection, application, and timing; adoption of compost application, cover cropping, and mulching; and compliance with nutrient management, depending on RWQCB jurisdictions from which growers and farm workers are attending. These 11 tailgates are collectively reaching 165 growers which 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 that can assist growers in development of Nitrogen Management Plans.

In an effort to compliment the nutrient management assistance, basic bookkeeping and business health training is being provided to growers through a partnership with the Asian Business Institute and Resource Center (ABIRC). These trainings will cover record keeping for general business health with an emphasis on cost and benefits in soil management practices. These trainings are carried out in the Fresno region with Hmong growers and in the Santa Maria region with Latino growers, delivered to a minimum total of 80 growers over the course of the project. To further expand outreach on these topics, 15 radio broadcasts are being organized in Spanish and Hmong in coordination with Radio Bilingue and Hmong Radio, respectively. These broadcasts will also discuss basic concepts in farm business and soil health, share local technical and financial assistance available and will announce local farmer events in the regions AFT is working.

Translation of carefully curated resources are being selected to offer into Spanish and Hmong and a preliminary list of existing resources will be shared that may include resources such as FREP's Nitrate Quick Test guide, FREP's Soil Test Sampling guide for phosphorous and potassium and FREP's Sampling for Soil Nitrate Determination. 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

In 2022 AFT staff organized 3 farmer tailgate meetings with partners ABIRC in Fresno and with Cachuma RCD in Santa Maria. In Fresno, the topic was in response to farmer concern 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 (SRCD) and the Natural Resource Conservation Service (NRCS) in Fresno were available for follow up implementation assistance. This event was conducted in English with interpretation to Hmong and Spanish to be able to reach farmer communities that have been historically underrepresented and under resourced.

The Santa Maria farmer tailgate meeting was focused on soil health and irrigation efficiencies where AFT partnered with the Cachuma Resource Conservation District (CRCD) to demonstrate 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 conducted in Spanish with a group of small-scale diversified vegetable and strawberry farmers.

In 2023 there were 2 tailgate and business skills events organized in response to farmer needs related to bookkeeping for nutrient management & organic farming systems and market opportunities. One was in Fresno in partnership with ABIRC and AGQ labs and the other was in Merced in partnership with CCOF and Daily Harvest. In both events, local TA providers were invited to participate and share resources in Spanish to support planning and implementation of soil health practices, financial assistance and explore various market channels. 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. It has also been a way for AFT to learn firsthand where there is need for culturally appropriate outreach efforts in Spanish and Hmong to be able to provide long lasting relationships within 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

Project Leader

Oli Bachie
UCCE Imperial County Director and Agronomy and Weed management advisor, Imperial, San Diego, and Riverside Counties
1050 East Holton Road, Holtville, CA 92250
Phone: (442) 265-7700
obachie@ucanr.edu

Collaborators

Ali Montazar
Irrigation and Water Management Advisor
UCCE Imperial County

Brooke Latack
Livestock advisor
UCCE Imperial County

INTRODUCTION

The low desert, particularly the Imperial Valley, is the major Sudan grass producing region of California. Sudan grass, being a C4 grass thrives in the low desert, where maximum summer daily temperatures often exceed 115°F. While insufficient N is a common yield-limiting factor, most growers of the low desert apply excessive amounts of N in their efforts of maximize Sudan grass crop yield. Although, Sudan grass responds very well to Nitrogen (N) fertilizers, higher levels of N in its tissue results in high tissue concentration of N in hay and becomes toxic to livestock or leaches out of the fields and cause environmental pollutions. Leaching of N out of the crop root zone can be exacerbated by high irrigation water. In the meantime, N availability may also depend on irrigation water to move to root zones for crop uptake. Higher amounts of tissue N concentration in Sudan grass hay are unacceptable for export, hence diminishing hay market value. There is little guide to growers in the determination of optimum N fertility for Sudan grass. This research was aimed at developing best management N and irrigation management strategies for optimum yield and quality Sudan grass hay production in the low desert. The study is being conducted at the UCANR Desert Research and Extension Center (DREC), in Holtville, California. This is a preliminary report of major aspects of yield and forage quality results of the study to date. It must be noted that this report is to serve as a preliminary indication of our findings with no statistical separation of treatment effects.

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.
2. Lay out strategies that reduce N loss from agricultural crop fields and 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 N fertilizer inputs, improve marketability of hay production, and maximize grower's economic benefit while reducing loss from Sudan grass production systems due to quality.

DESCRIPTION

The trial was conducted at the UC DREC. Three fertilizer rates (sub plots) consist of (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 100 lbs N / acre at successive cuttings. The three irrigation strategies (main plots) are:), (1) 80% ET, (2) 100% ET, and (3) 120% ET. A split plot design with 4 replications per treatment was used for this study. Initial fertilizers were applied as common pre-plant for initial crop establishment. Sprinkler irrigation was used during initial crop establishment across all treatments and later converted into a furrow irrigation controlled by gated pipes. Preplant soil samples were taken from four depths (0-1, 1-2, 2-3, and 3-4 ft.) from 4 sites each. Samples were composited and analyzed for various soil parameters (Table 1). The soil of the experimental site, which was predominantly silty loam, was generally low for N (except at the topsoil surface) and phosphorus, but high in K and pH (Figure 1). The second-year field site was re-established after crop failure from the first-year experiment.

Table 1. major soil components for pre-fertilizer and pre-plant soil samples at four depths, 0-1, 1-2, 2-3, and 3-4 ft, respectively

Type	Soil Depth				Optimum Levels	
	0 - 12"	12 - 24"	24 - 36"	36 - 48"	Low	High
Total N, *Combustion/%*	0.02	0.01	0.01	0.01	-	-
Org. Matter, *Combustion/%*	0.30	0.18	0.23	0.20	-	-
NO3-N, *OLSEN/PPM*	53.1	12.4	6.3	12.7	25.0	50.0
PO4-P, *OLSEN/PPM*	16.3	7.1	2.0	2.2	10.0	20.0
K, *OLSEN/PPM*	262	157	114	86	80	160
Soil Texture / estimate	Loam; Sl. Lloam	Loam; Sl. Lloam	Loam; Sl. Lloam	Sandy Loam	-	-
pH, *Saturation Paste / Units*	7.98	8.11	8.14	8.04	6.50	7.50

RESULTS AND DISCUSSION

Second year crop growth looked good (Figure 1).

Figure 1. Sudan grass crop appearance on May 9, 2023, after first irrigation treatment (left) and after harvest (right).

Moisture sensors indicated that there were variations in irrigation water availability following irrigation treatments. The 80ET irrigation had relatively less soil water availability (higher soil water potential) over the period and could have some crop water stress. There was better water availability in both the 100ET and 120ET irrigation levels.

Sudan grass was usually harvested when the crop had 10 to 20% flowers, following growers' common practices. A typical Sudan grass production in this region involves 3 to 4 cuttings when the crop is planted in early Spring (March-April). We completed the first cutting for baseline biomass evaluation and two subsequent cuttings so far for the 2023 trial. Mean baseline fresh biomass (averaged over for sample sites) was about 16.5 tons/ac. Sudan grass biomass production over the two cuttings does not seem to vary between fertilizer rates or irrigation treatments (Figure 2). Fresh biomass yield for all N rates is relatively lower for the 100ET than N treatments at the lower or higher irrigation rates.

For the third cutting season, Sudan grass respond better to fertilizers at 100ET or 120ET than when irrigation water was slightly deficient (80%ET). Mean biomass over fertilizer levels suggest that irrigation water may be more critical for biomass production than N levels, at least at the tested N rates (Figure 2).

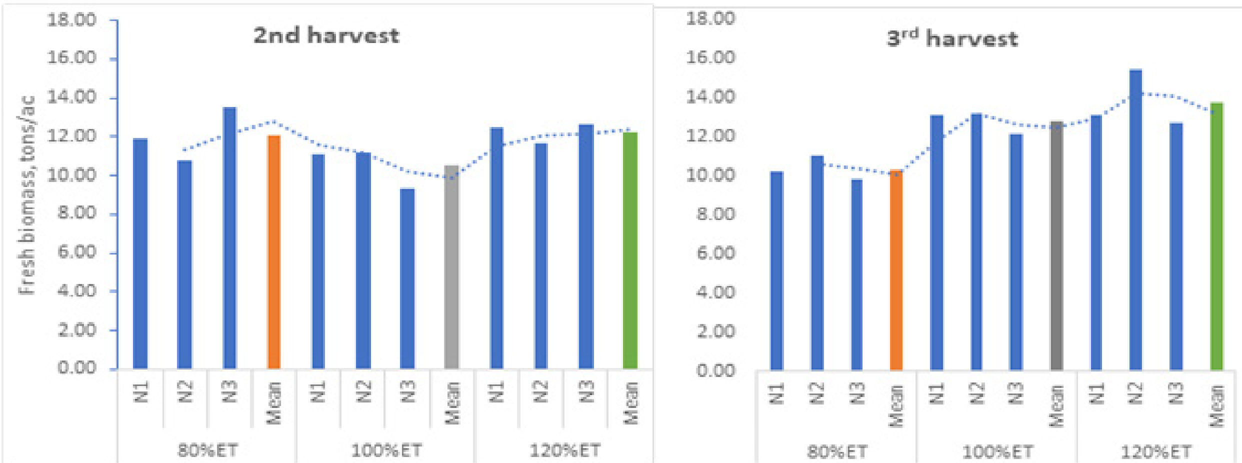


Figure 2: Fresh biomass, tons /ac of crop under 3 fertilizer (N1, N2, and N3) and 3 irrigation rates for the second cutting (left) and third cutting (right)

Nutrient components of Sudan grass did not also vary much among supplemental N levels and or irrigation rates (Table 2). The crop had consistent crude protein, ADF, NDF, Ash, TDN and Prussic acid for almost all treatments. However, there higher nitrate ion (%DM) accumulation for intermediate N level (N2, 80 lbs / ac) under low irrigation rates (80ET) than any of the other fertilizer and irrigation treatments (Table 2). Similarly, intermediate fertilizer level (N2), increased Nitrate-N (ppm) for the 80ET irrigated crop beyond acceptable hay nitrate concentrations (4,979 ppm) than any other treatments (Table 2). It is hard to justify why an intermediate N at low irrigation produces higher crop nitrate ion than the higher or lower fertilization and higher irrigation rates. Relatively low N supply levels, 80 and 100 lbs / ac also enhanced crop nitrate-N concentrations, but not at the highest fertilizer level (Table 2) N levels (80 and 100 lbs/ac) slightly increased and 100 ET irrigations, respectively, but not at the 120lbs/ac.

Table 2: Sudan grass Nutrient Analysis 1 - 7/13/2023

Soil parameter	80%ET			100%ET			120% ET		
	N1	N2	N3	N1	N2	N3	N1	N2	N3
Crude Protein (%DM)	12.9	12.1	13.2	12.7	12.4	12.4	12.9	13.5	13.1
ADF (%DM)	35.3	32.9	31.7	31.3	33.5	32.2	30.8	30.6	31.2
NDF (%DM)	57.1	55.3	56.3	58.4	62.9	57.8	51.1	51.8	58.2
Ash (%DM)	9.8	10.48	9.71	10.3	9.4	9.8	10.69	10.5	10.6
Nitrate Ion (%DM)	0.98	2.2	1.05	1.10	1.06	1.2	1.5	1.7	1.2
Nitrate-N (ppm)	2223	4979	2365	2376	2406	2771	3405	3783	2616
TDN (%DM)	59.6	59.4	59.7	58.7	58	59.3	60.5	60.9	58.5
Prussic Acid	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Experts described hay with nitrate-N concentrations less than 1,200 PPM as generally safe, and hay with concentrations between 1,200 and 2,300 PPM as potentially safe, though problems could occur at this concentration, particularly with pregnant livestock. All samples showed concentrations of nitrate-N above the toxic concentration (>2,300 ppm) except the sample at the lowest irrigation and fertilization rates. While hay quality grades are usually determined primarily by chemical analyses (such as crude protein, acid detergent fiber, neutral detergent fiber, TDN, and mineral analyses) and the prussic acid contents, our findings did not confirm a high nitrate tissue concentration with a presence of prussic acid. Even, samples with the highest nitrate accumulation did not show presence of prussic acid (Table 2). In summary, supplemental fertilizer levels and irrigation water may have effects on biomass accumulation and nutritive quality of Sudan grass and potential effects of fertilizer leachates / erosion to the environment. Nitrate leaching and erosion factors were not sampled at this time but will be incorporated in the upcoming samplings. Relatively lower response of crop biomass to N for the third cuttings at the lower irrigation level may be indicative of water stress and poor transport of fertilizers to crop roots. Increased tissue nitrate concentrations can be due to high fertilizer or higher irrigation rate with increased fertilizer distribution for crop uptake. However, higher tissue nitrate concentration did not result into higher prussic acid accumulation, although it is said to result in increased prussic acid and toxicity to livestock. These findings are just preliminary and can't be conclusive until complete evaluation of the project findings.

ACKNOWLEDGEMENT

Funding for this study is provided by the California Department of Food and Agriculture (CDFA) - Fertilizer Research and Education Program (FREP). The research team gratefully acknowledges the UCCE Imperial County and UC DREC staff for their support in crop establishment, resource management and crop maintenance.

Optimizing Nitrogen Fertilizer Concentrations in Vegetable Transplant Production

Project Leaders

Lorence R. Oki
CE Specialist
University of California, Davis
Department of Plant Sciences, MS6
One Shields Avenue
lroki@ucdavis.edu

Bruno J.L. Pitton
Staff Research Associate
University of California, Davis
Department of Plant Sciences, MS6
One Shields Avenue
bjpitton@ucdavis.edu

Donald J. Merhaut, Ph.D.
Associate CE Specialist, Nursery and Floriculture Crops
University of California, Riverside
Department of Botany and Plant Sciences
donald.merhaut@ucr.edu

INTRODUCTION

California's $7.68 billion vegetable crop industry (CDFA 2021) is dependent on the use of vegetable transplants to increase productivity. Transplant producers commonly supply soluble fertilizer in water to provide sufficient plant nutrients to produce high-quality vegetable transplants that will ensure a successful crop. As fertilizer is a small percentage of total cost, supplying excessive fertilizer to ensure plant health is only a minor financial cost. However, excessive fertilizer can cause environmental problems and 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 nutrient application guidelines for the diverse range of vegetable transplants produced in CA. Extension publications have general recommendations, such as providing more N 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 N without specific guidelines for individual crops.

To provide clarity for vegetable transplant producers, we are evaluating nutrient uptake of the top five vegetable transplant crops in CA to elucidate optimal nutrient concentrations.

OBJECTIVES

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

DESCRIPTION

Experiments were completed with broccoli, leaf lettuce, and processing tomato. Seedlings of each crop were germinated in plug trays on a mist bench before being placed on individual ebb and flood trays for application of nutrient solution. Nitrogen, phosphorus, and potassium (NPK) composition of nutrient solution treatments are in Table 1. Each ebb and flood tray was built on a weighing lysimeter to record daily evapotranspiration. Growing media was refilled to container capacity each day and daily water use was recorded. Plants were harvested after reaching commercial size.

Table 1. Total nitrogen (N), ammonium-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N), phosphorus (P), and potassium (K) concentration of nutrient solution applied to vegetable transplant crops during experiments.

Nutrient concentration in solution (ppm)				
N	NH_4-N	NO_3-N	P	K
50	20	30	11	42
200	80	120	44	166
400	160	240	87	332

At harvest, shoot samples were dried at 55°C for 48 hours. Plant samples from each individual plug tray were kept together and dried in a single paper bag, resulting in a composite plant sample for each plug tray. Dried shoot biomass for each plug tray was recorded and dry shoot biomass samples were analyzed for NPK content.

The nutrient concentration in plant tissue was multiplied by the total biomass harvested from each plug tray to get the total nutrient mass per plug tray. Optimal nutrient concentration for each vegetable transplant crop was calculated as the total nutrient mass in all plant tissue in a plug tray divided by the total plug tray transpiration.

RESULTS AND DISCUSSION

There was no significant difference in shoot dry weight of 'Grazion' leaf lettuce indicating that all treatments were receiving sufficient NPK for growth. Significant difference in shoot dry weight of 'Green Magic F1' broccoli and 'N 6428' processing tomato between the 50 ppm N and the two greater concentration fertilizer solutions indicates that the 200 and 400 ppm N solutions were providing adequate NPK. For the vegetable transplant crops evaluated, plant P and K content for the 50 ppm N treatment was significantly less than the 200 and 400 ppm N treatments, indicating that P and K provided in nutrient solution for 50 ppm N treatments was deficient. For the vegetable transplant crops evaluated, the 50 ppm N treatment had a significantly lower calculated fertilizer concentration of N and P than the 200 and 400 ppm N treatments.

We recommend using the mean of the calculated NPK concentrations of the 200 and 400 ppm N treatments as the optimal fertilizer concentration for leaf lettuce and processing tomatoes. For the broccoli, we recommend using the calculated NPK concentration of the 200 ppm N treatment because shoot biomass was maximized at 200 ppm N.

Table 2. Mean values for vegetable transplant crop experiments. Different letters within the same column and for individual crops indicate significant differences (p<0.05) in the mean values of different fertilizer treatments. Calculated fertilizer concentration is calculated by multiplying shoot concentration by shoot dry weight and dividing by transpiration.

Crop	Applied nitrogen conc. (ppm)	Shoot DW (g)	Transpiration (L)	Shoot N (%)	Shoot P (%)	Shoot K (%)	Calculated Fertilizer Conc. (ppm)[a] Nitrogen	Phosphorus	Potassium
'Grazion' Leaf Lettuce	50	1.66 a	10.046 a	2.1 a	0.36 a	3.2 a	69 a	12 a	109 a
	200	2.77 a	13.764 b	5.6 b	0.86 b	4.5 b	223 b	33 b	173 b
	400	2.00 a	10.757 a	7.2 c	0.89 b	4.4 b	269 b	33 b	164 ab
'Green Magic F1' Broccoli	50	1.44 a	6.293 a	2.4 a	0.35 a	1.9 a	118 a	17 a	96 a
	200	3.30 b	9.409 b	6.3 b	0.74 b	3.4 b	437 b	52 b	232 b
	400	3.47 b	8.975 b	9.5 c	0.60 c	3.6 b	732 c	47 b	277 b
'N 6428' Processing Tomato	50	0.77 a	7.08 a	2.0 a	0.32 a	2.0 a	48 a	8.0 a	48 a
	200	1.77 b	8.11 a	6.1 b	1.02 b	2.8 b	265 b	44 b	121 ab
	400	1.83 b	9.27 a	8.1 c	1.04 b	4.3 b	343 c	44 b	180 b

Recommended NPK concentration of nutrient solution for broccoli was 437, 52, and 232 ppm N, P, and K, respectively. The N concentration is in agreement with previous research that found that broccoli transplant dry shoot biomass was maximized at 350 (Tremblay and Senecal, 1988) or 400 ppm N (Masson et al., 1991b; Masson et al., 1991a). Furthermore, greater yields in the field may be realized with more N applied to transplants because Masson et al. (1991a) found that yield of broccoli in the field was 25-58% greater for transplants with 400 ppm N applied compared to 100, 200, or 300 ppm N. Tremblay and Senecal (1988) identified that 200 ppm K was optimal for broccoli transplants and that agrees with our calculated fertilizer concentration of 232 ppm K.

Recommended NPK concentration of nutrient solution for leaf lettuce was 246, 33, and 169 ppm N, P, and K, respectively. The N concentration we calculated is 154 ppm N lower than the N concentration Masson et al. (Masson et al., 1991b; Masson et al., 1991a) identified in their research. They determined that 400 ppm N increased yield in of lettuce in the field by 16% and increased shoot biomass by 38% as compared to 100 ppm N and it is not clear if 246 ppm N will increase field yield. Previous research recommended >15 ppm P and >24 ppm K for nutrient solutions growing lettuce transplants (Soundy et al., 2001a; Soundy et al., 2001b) which agrees with our recommended P and K concentrations. However, Soundy et al. (2001a; 2001b) grew transplants with only 60 or 100 ppm N and growth may not have been optimized because the plants may not have received sufficient N.

Recommended NPK concentration of nutrient solution for processing tomatoes was 304, 44, and 151 ppm N, P, and K, respectively. The optimal N concentration we calculated was within the range reported by other researchers (Weston and Zandstra, 1989; Garton and Widders, 1990; Masson et al., 1991b; Masson et al., 1991a; Melton and Dufault, 1991; Liptay and Nicholls, 1993; Vavrina et al., 1998). Greater concentrations resulted in increased shoot mass (Masson et al., 1991b), greatest early yields (Masson et al., 1991a), and total yields (Weston and Zandstra, 1989) than lower concentrations. Melton and Dufault (1991) and Vavrina et al. (1998) only tested N concentration up to 225 and 75 ppm, respectively and they may have realized greater yields with more N supplied. Liptay (1993) found that 350 ppm N provided more N immediately available for root growth in the field and resulted in greater root biomass in the field than lower N concentrations.

LITERATURE CITED

CDFA (2021). California Agricultural Statistics Review, 2019-2020, California Department of Food and Agriculture, ed.

Garton, R., Widders, I., 1990. N and P preconditioning of small plug seedlings influences growth and yield of processing tomatoes. Hortscience 25, 655-657.

Liptay, A., Nicholls, S., 1993. Nitrogen supply during greenhouse transplant production affects subsequent tomato root growth in the field. Journal of the American Society for Horticultural Science 118, 339-342.

Masson, J., Tremblay, N., Gosselin, A., 1991a. Effects of Nitrogen-Fertilization and HPS Supplementary Lighting on Vegetable Transplant .2. YIELD. Journal of the American Society for Horticultural Science 116, 599-602.

Masson, J., Tremblay, N., Gosselin, A., 1991b. Nitrogen fertilization and HPS supplementary lighting influence vegetable transplant production. I. Transplant growth. Journal of the American Society for Horticultural Science 116, 594-598.

Melton, R.R., Dufault, R.J., 1991. Nitrogen, phosphorus, and potassium fertility regimes affect tomato transplant growth. Hortscience 26, 141-142.

Soundy, P., Cantliffe, D.J., Hochmuth, G.J., Stoffella, P.J., 2001a. Nutrient Requirements for Lettuce Transplants Using a Floatation Irrigation System II. Potassium. 36, 1071.

Soundy, P., Cantliffe, D.J., Hochmuth, G.J., Stoffella, P.J., 2001b. Nutrient requirements for lettuce transplants using a floatation irrigation system. I. Phosphorus. Hortscience 36, 1066-1070.

Tremblay, N., Senecal, M., 1988. Nitrogen And Potassium In Nutrient Solution Influence Seedling Growth Of 4 Vegetable Species. Hortscience 23, 1018-1020.

Vavrina, C.S., Hochmuth, G., Cornell, J., Olson, S., 1998. Nitrogen fertilization of Florida-grown tomato transplants: Seasonal variation in greenhouse and field performance. Hortscience 33, 251-254.

Weston, L.A., Zandstra, B.H., 1989. Transplant age and N and P nutrition effects on growth and yield of tomatoes. Hortscience 24, 88-90.

ACKNOWLEDGEMENTS

We would like to acknowledge India Simons, Sarah Kim, and Syndelle La Due for their contributions to this research. Funding was provided by California Department of Food and Agriculture Fertilizer Research and Education Program.

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

Project Leaders

Timothy Bowles, PhD
Assistant Professor
UC Berkeley Department of Environmental Science, Policy and Management
130 Mulford Hall
Berkeley, CA 94720-3114
timothy.bowles@berkeley.edu

Bhavna Arora, PhD
Research Scientist, Energy Geosciences Division
Lawrence Berkeley National Lab
One Cyclotron Road, MS 74-327R,
Berkeley, CA 94720
(510) 495-2163
barora@lbl.gov

Eric Brennan, PhD
Research Horticulturist
USDA Agricultural Research Service
1636 East Alisal Street
Salinas, CA 93905,
831-755-2822
eric.brennan@usda.gov

Hannah Waterhouse, PhD
Postdoctoral Scholar
UC Berkeley Department of Environmental Science, Policy and Management
130 Mulford Hall
Berkeley, CA 94720-3114
hwaterhouse@berkeley.edu

INTRODUCTION

The 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 nitrogen (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 properties to improve N use efficiency (NUE) and reduce N loss[1]. 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 the soil below 30 cm[2]. 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].

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 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 and analyze 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

DESCRIPTION

In the second year of the project, we concluded a greenhouse column experiment to test the effect of compost additions on leaching of DON and inorganic N from contrasting soil types, a sandy loam (>40% sand) and a clay loam (<20% sand). Soils were packed into 40 cm high columns with small marbles on the bottom to allow for free drainage of leachate to be collected. Soils were packed to approximate field bulk density values. 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 (0, 7.6, and 22.8 Mg/ha) while other rates had one replicate. Lettuce transplants were planted in the columns. Irrigations occurred once a week and columns were brought to 10% above field capacity each irrigation event. Leachate was collected after each irrigation event and analyzed for ammonium (NH_4^+), nitrate (NO_3^-), DON, and DOC.

After 8 weeks the experiment was concluded and lettuce was harvested, dried, and ground for later determination of plant C and N content. In addition, analyses are pending for total C and N and pH of the compost and soils, and soil texture. In addition to the column experiments, deep coring (0-1m) from the USDA long term trial was conducted in late August 2022 and soils are currently being analyzed for total C and N on an elemental analyzer (Obj. 1). This will help shed light on whether N surpluses documented in Brennan's work were leached or stored deeper in the soil profile and to help calibrate the Ecosys model. Collaborator Brennan is currently assembling data needed to calibrate the Ecosys model for his long-term experiment site. Soil extracts transplant and harvest down to 60cm from 28 fields growing lettuce are currently being analyzed on a liquid elemental analyzer (980 samples in total, Obj. 1). This analysis will allow determination of how soil variability can modulate DON loss from organic amendment applications and help validate the Ecosys model to see if it is performing adequately on varying soil types.

RESULTS AND DISCUSSION

Preliminary results from the column experiments in the sandy loam suggest over the growing season for lettuce, the percentage of N leached as either DON or NO_3^- is similar when compost is added at low and mid-range rates (1.9 Mg ha^{-1} to 15.9 Mg ha^{-1}) (Figure 1). At very high rates of compost addition, the main N leaching pathway is via NO_3^- and DON leaching is comparable or lower to the treatment where no compost was added. Total mean N lost across all irrigations for the entirety of the sandy loam column experiment were variable across compost treatments, with a slightly decreasing trend at the highest compost rates. Comparing the compost treatments that were replicated (0 Mg ha^{-1}, 7.6 Mg ha^{-1}, 22.8 Mg ha^{-1}), no significant differences in NO_3^- or DON concentrations in leachate were found. However, significant differences were found for dissolved organic carbon (DOC) loss between the three compost application rates ($P<0.05$). Leached DOC increased linearly with increasing compost treatments for the first two irrigation events and remained constant across treatments for subsequent irrigation events (Figure 2). The 22.8 Mg ha^{-1} treatment had significantly higher rates of total mean DOC leached (1016.4 ug C/ml) compared to the 0 Mg ha^{-1} treatment (689.70 ug C/ml) with no significant differences between the 22.8 Mg ha^{-1} treatment and the 7.6 Mg ha^{-1} treatment (764.9 ug C/ml) and no differences between the 7.6 Mg ha^{-1} treatment and the 0 Mg ha^{-1} treatment.

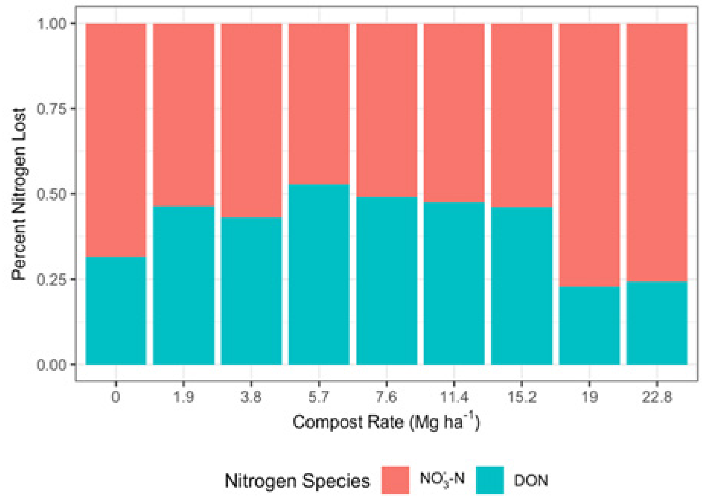


Figure 1: Percent of nitrogen leached as either dissolved organic nitrogen (DON) or nitrate (NO_3-) across compost rate treatments summed over the duration of the sandy loam column experiment.

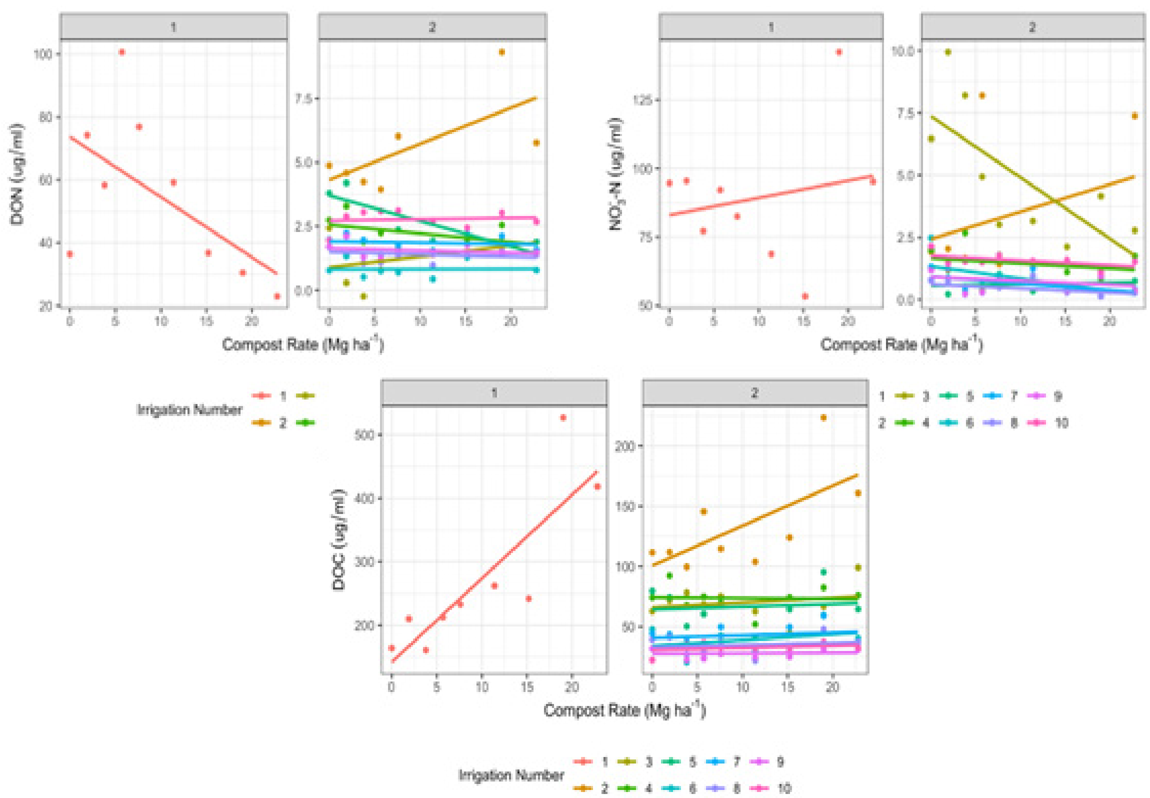


Figure 2: DON, NO_3^- concentrations (ug ml^{-1}) in leachate across compost application treatments (Mg ha^{-1}) for each irrigation event. The first irrigation event is shown in the left facet due to the large discrepancy in values between the first irrigation.

The majority of N leached occurred after a disturbance event (packing of columns) and the first subsequent irrigation event (Figure 2). While NO_3^- values in the leachate after the first irrigation were above the 10 ppm maximum contaminant limit (MCL), subsequent irrigations led to NO_3^- loads below the MCL. After the third irrigation event, DON shifts to becoming the dominant N leaching pathway. Future analysis will examine how soil edaphic properties control N leaching pathways by examining differences between the sandy loam vs clay loam column experiments.

ACCOMPLISHMENTS

Thus far, we have completed two greenhouse column experiments quantifying the N species in leachate lost from the root zone of a sandy loam and a clay loam soil. We are completing data cleaning and analysis for the columns, with the sandy loam column 95% complete. Deep coring down to a meter in the long-term trial (180 samples collected) was completed and 160/180 samples have been analyzed for C and N. We have begun collating data for parameterizing the Ecosys model runs.

LITERATURE CITED

Seufert, V., & Ramankutty, N. (2017). Many shades of gray—the context-dependent performance of organic agriculture. Science Advances, 3(3).

White, K.E., Brennan, E.B., Cavigelli, M.A., Smith, R.F., 2022. Winter cover crops increased nitrogen availability and efficient use during eight years of intensive organic vegetable production. PLOS ONE 17, e0267757.

van Kessel, C., Clough, T., & van Groenigen, J. W. (2009). Dissolved Organic Nitrogen: An Overlooked Pathway of Nitrogen Loss from Agricultural Systems? Journal of Environmental Quality, 38(2), 393–401.

Westerhoff, P. and Mash, H. 2002. Dissolved organic nitrogen in drinking water supplies: a review. Journal of Water Supply: Research and Technology-Aqua 51 (8): 415–448.

ACKNOWLEDGEMENTS

We acknowledge the CDFA FREP Grant program for funding this project. Additionally, we thank Melanie Rodriguez Fuentes and Massa Godbold for their help with conducting the greenhouse experiment and lab analyses.

Developing Tools and Information on Irrigation and Nitrogen Best Management Practices in California's Low Desert Lettuce Production Systems

Project Leader

Ali Montazar
Irrigation and Water Management Advisor
UCCE Imperial County
1050 East Holton Road
Holtville, CA 92250
Phone: (442) 265-7707
amontazar@ucanr.edu

Cooperators

Daniel Geisseler
Nutrient Management Specialist
Dept. of LAWR, UC Davis
One Shields Ave., PES Building,
Davis, CA 95616
Phone: (530) 754-9637
djgeisseler@ucdavis.edu

Michael Cahn
Irrigation and Water Resources Advisor
UCCE Monterey County
1432 Abbott Street
Salinas, CA 93901
Phone: (831) 759-7377
mdcahn@ucanr.edu

INTRODUCTION

The intensive production of lettuce in the low desert region requires high inputs of fertilizer, irrigation water, tillage, and pesticides, and therefore, there is a high potential impact on the water quality of surface water and leaching of nitrate to drainage systems and limited groundwater supplies. The overall purpose of this study is to fully understand the viability and applicability of current N and irrigation management practices in the low desert lettuce production systems. It aims to develop knowledge and information on improving and promoting adaptation of management practices that optimize N and irrigation water use efficiency in low desert lettuce.

OBJECTIVES

1. Provide data and information on crop water use, crop N uptake curve, and net N removal in low desert lettuce.
2. Develop recommendations on best N and water management practices in low desert lettuce.
3. Develop knowledge base information and data to adapt the CropManage (CM) tool for water and N management in low desert lettuce.

DESCRIPTION

The experiment was conducted in four commercial fields in the Imperial and Coachella Valleys consisted of two iceberg lettuce and two romaine lettuce trial fields (Fig. 1). The trial fields 1 and 2 were germinated by drip and sprinklers were used to germinate the trial fields 3 and 4 (Table 1).

Figure 1. A demonstration of two trial fields in the Imperial (a) and Coachella Valleys (b). The water applied was measured using magnetic flowmeter attached to datalogger. The data of water applied was automatically imported and analyzed by CM tool.

Due to logistical limitations, in each of the trial fields an assigned plot with an area of 300 feet by 300 feet was selected and all the measurements were conducted at the assigned plots. Within the experimental assigned area of each field, five sub-areas (each will have an area of 50 feet by 50 feet) were determined for soil-plant samplings and monitoring the entire crop season.

To develop a crop coefficient model based on canopy development, images were taken on a weekly basis utilizing an infrared camera. The fertilizer applied was monitored throughout the crop season. The data of water applied was automatically imported and analyzed by the CM web-based tool (Fig. 1). The actual soil nitrate content and the total N concentration in the plants were determined three times per season through laboratory analysis. Soil samples were collected from three depths (0-10”, 10-20”, 20-30”). In addition, soil quick N test was conducted from the top 10” of the soil in each trial field on a 10-day basis. A comprehensive yield quality data at commercial harvest stage was evaluated including plant population, head weight, biomass, and marketable yield. At harvest, total N, NO_3-N and dry matter concentration of head tissue were also determined.

Table 1. General information of the trial fields.

Trial	Soil texture	Crop	Irrigation method	Wet date	Harvest date
1	Silty clay loam	Iceberg 80-in, 6 row	Drip	29 Oct, 2022	15 Feb, 2023
2	Silty loam	Romaine 80-in, 6 row	Drip	5 Nov, 2022	15 Feb, 2023
3*	Loamy fine sand	Iceberg 40-in, 2 row	Drip	9 Nov, 2022	21 Feb, 2023
4*	Sandy loam	Romaine 40-in, 2 row	Drip	29 Oct, 2022	18 Jan, 2023

*Trial fields 3 and 4 were switched to drip after plant establishment using sprinklers.

RESULTS AND DISCUSSION

Plant density and canopy development: A considerable difference of plant density was observed among the trial fields. The maximum plant density was found at the trial field 1 (iceberg lettuce in 80-in bed) with a mean plant number per acre of 65,340. The minimum plant number was observed at the trial field 4 with a mean plant per acre of 24,830. CM provided a good estimation of canopy % for both the iceberg and romaine trial fields (Fig. 2). The SIMS model's estimations were not as good as CM.

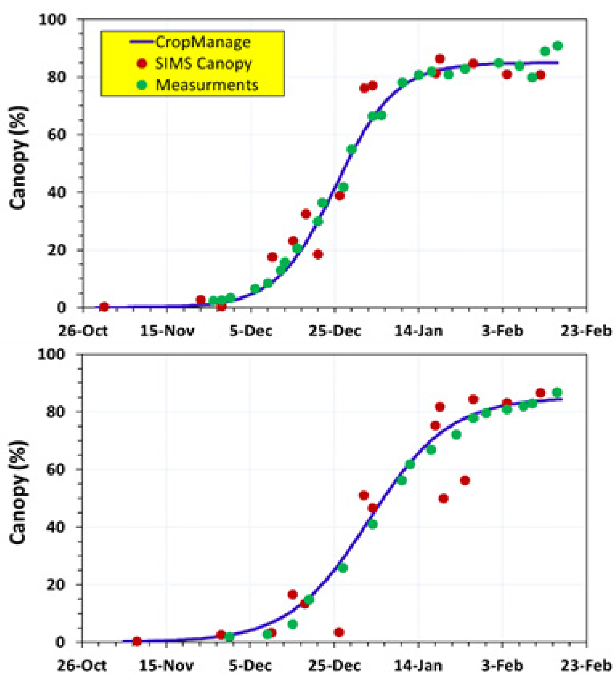


Figure 2. A comparison of measured canopy cover % versus the estimated values by the CM and SIMS models.

Assessment of water and nitrogen applied

Variable water and N application rates were observed at the experimental sites (Fig. 3). Overall, the amounts of water and N applied were greater at the iceberg lettuce fields as well as soil with sandy soil textures. For instance, the seasonal irrigation water was 20.8 inches at the iceberg lettuce field with a loamy fine sand soil (trial field 3) while the value was 16.7 inches at the iceberg lettuce field with a silty clay loam soil (trial field 1).

The trial field 4 (romaine lettuce in a sandy loam soil) received 3.2 inches water more than the trial field 2 (romaine lettuce in a silty loam soil). A substantial difference was found between the N application rates recommended by CM and grower practice at the field trials with sandy soil textures (Montazar, 2023).

Soil NO_3^- N.

Across the four trial fields, the average soil NO_3^-N concentration in the top one foot varied from 17.7 mg kg^{-1} or ppm (trial 4) to 55.5 (trial 2) mg kg^{-1} at post-thinning and ranged between 9.3 mg kg^{-1} (trial 3) and 77.5 mg kg^{-1} (trial 2) at harvest (Table 2). A higher level of plant tissue N% was observed at the trial fields 3 (3.9%) and 4 (3.4%) than the trial fields 1 (3%) and 2 (2.7%).

Mean biomass N and seasonal applied N: Across the trial fields, seasonal N application rates varied from 101 $lbs.ac^{-1}$ in a romaine lettuce field (trial field 2) to 298 $lbs.ac^{-1}$ in an iceberg lettuce field (trial field 3) (Table 2). A wide range of biomass N was found among the trial fields varied from 82 $lbs.ac^{-1}$ in a romaine lettuce field (trial field 4) to 158 $lbs.ac^{-1}$ in an iceberg lettuce field (trial field 1).

CONCLUSIONS

The findings of this study suggested that lettuce growth could be maximized by seasonal N fertilization and irrigation water application rates below the current typical practices even in drip irrigated fields. However, more data from the ongoing replicated trials at the Desert Research and Extension Center may verify this preliminary conclusion. As a free decision-making tool, CM may assist local growers to maximize lettuce production and enhance the efficiency of N and water use.

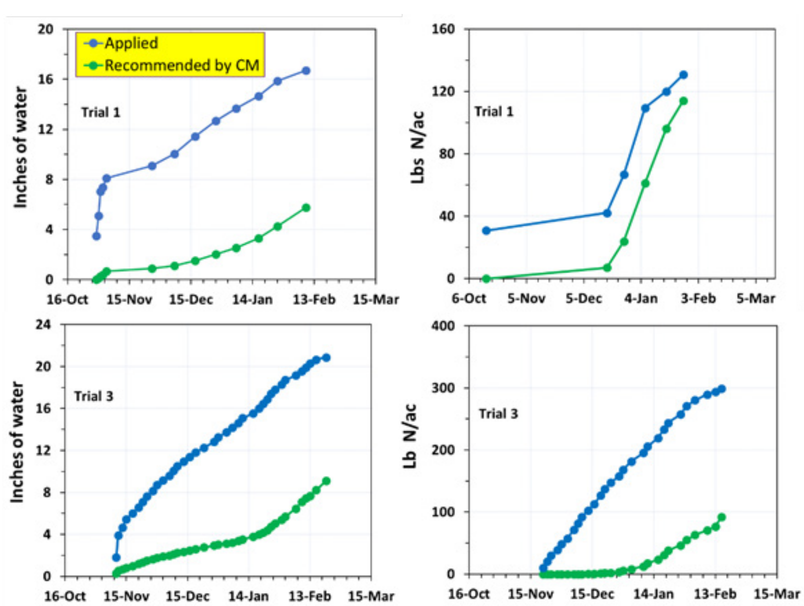


Figure 3. Cumulative water and N applications across the experimental sites.

Table 2. Seasonal N applied, lettuce fresh biomass and N in the trial fields.

Trial field	Soil NO_3-N at post-thinning (ppm) (1-ft)	Seasonal N applied (lbs. ac^{-1})	Mean Lettuce fresh biomass (ton.ac^{-1})	Mean Biomass N (lbs. ac^{-1})	Soil NO_3-N at harvest (ppm) (1-ft)
1	50.1	131	56.4	158	59.3
2	55.5	101	30.6	88	77.5
3	19.8	298	35.1	141	9.3
4	17.7	209	28.4	82	12.2

LITERATURE CITED

Montazar, A. (2023). Irrigation and nitrogen best management practices in the low desert lettuce cropping system. Agricultural Briefs, 26 (1): 2-7.

ACKNOWLEDGEMENTS

Funding for this study was provided by CDFA-FREP. The research team gratefully acknowledges the Cooperating Farmers and the UCCE Imperial County staff.

The Role of Irrigation Management for Improving Nitrogen Use Efficiency for Broccoli Grown with Nitrate-Contaminated Irrigation Water

Project Leaders

Charlotte Decock, Ph.D.
Associate Professor
Cal Poly San Luis Obispo
1 Grand Avenue,
San Luis Obispo, CA 93407
Phone: (805) 756-6360
cdecock@calpoly.edu

Michael Cahn, Ph.D.
Irrigation and Water Resources Advisor
UC Cooperative Extension (UCCE) Monterey County
1432 Abbott Street, Salinas, CA 93901
Phone: (831) 759-7377
mdcahn@ucdavis.edu

Cooperators

Richard Smith, Ph.D.
Farm advisor
UC Cooperative Extension (UCCE) Monterey County
1432 Abbott Street, Salinas, CA 93901
Phone: (831) 759-7357
rifsmith@ucanr.edu

Anthony Bella
Graduate student
Cal Poly San Luis Obispo
1 Grant Avenue,
San Luis Obispo, CA 93407
anthonysbella@gmail.com

Christopher Hight
Lab manager
Bonipak Produce Inc.
1850 W Stowell Rd,
Santa Maria, CA 93458
Christopher.Hight@bonipak.com

Matt Grieshop, Ph.D.
Director at The Grimm Family Center for Organic Production and Research
Cal Poly San Luis Obispo
1 Grant Avenue,
San Luis Obispo, CA 93407
Phone: (805) 540-9527
mgriesho@calpoly.edu

INTRODUCTION

In an effort to reduce nitrogen (N) pollution of ground and surface waters, growers are subjected to increasingly stringent regulation. Given that many irrigation water sources have high N loadings, growers are encouraged to take N inputs from irrigation water into account in their N budgets, a concept referred to as 'pump-and-fertilize' (PAF). Previous research has demonstrated that nitrate-N contained in irrigation water is an effective source of crop nutrition (Cahn et al., 2017). However, attempts by commercial broccoli growers to produce broccoli with nitrate contaminated irrigation water without supplemental fertilizer N have led to severe crop failure, even though the total N input from irrigation water exceeded expected crop N uptake.

For N contained in irrigation water to be available to the crop, it is imperative that the irrigation water stays within the root zone.

Therefore, any efforts to increase N use efficiency (NUE) will be affected by irrigation management. While growers are encouraged to base irrigation rates on projected evapotranspiration (ET) and crop coefficients guided by data from soil moisture sensors, adopting an irrigation practice that keeps water in the root zone can be challenging. Installing soil moisture sensors and the use of decision support tools to guide irrigation practices can be expensive or time consuming. In addition, irrigation water may be applied in excess of crop requirements to address salinity issues. Therefore, there is an urgent need to assess the impact of irrigation management on N dynamics and better quantify the fraction of N contained in irrigation water that is available to the crop. The overall goal of the project is 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. Here, we present results from the first two trials, which took place on fields in the Santa Maria valley with low nitrate concentrations in the irrigation water. The trials serve as a control to assess the impact of irrigation management on N dynamics without high nitrate concentrations in the irrigation water. A total of eight more trials on fields with high nitrate concentration in the irrigation water are scheduled.

OBJECTIVES

The specific objectives of the two trials presented in this executive summary include:

1. Determine if yield will maximize at a lower N rate under ET-based irrigation scheduling compared to the grower standard practice.
2. Assess the effect of irrigation management on aboveground N uptake.
3. Assess the effect of irrigation management on soil nitrate concentrations to 24” depth.

DESCRIPTION

We set up two controlled on-farm field trials in California’s Santa Maria Valley to study the effects of N rate and irrigation management on N dynamics and yield in broccoli production. The two experiments took place from February 12th to May 11th and August 30th to November 21st of 2022. Both fields are mapped as Garey soil series (Mixed, thermic Psammentic Haploxeralfs) with a sandy loam topsoil (USDA Soil Survey) and were planted with broccoli in the previous season. In the first crop cycle, the field consisted of 0.92% SOM, with an average pH of 6.85 and an EC of 4. In the second crop cycle, the field had 0.90% SOM with an average pH of 6.95 and an EC of 3.12. The experimental design included two factors, N rate and irrigation management. Fertilizer N rates in the first trial ranged from 50 lbs N ac^{-1} to 250 lbs N ac^{-1}, with 5 rates at 50 lb N ac^{-1} increments and in the second trial ranged from

75 lbs ac^{-1} to 300 lbs ac^{-1} with 6 different rates. The pre-plant fertilizer rates were 10 gal AN-20 ac^{-1} for all N rate treatments for both experiments, corresponding to an N application rate of 21 lbs N ac^{-1}.

Pre-plant nitrate concentrations were 24 ppm in the first crop cycle and 38 ppm in the second crop cycle. The remaining N budget was split between two in-season applications at 5 and 9 weeks after planting. Fertilizer was applied to the top of the soil along the drip line using a manual backpack sprayer with an hour of irrigation before and after application to move the fertilizer into the root zone and mimic the grower fertigation practice. The two irrigation treatments are referred to as grower standard (GS) and adapted irrigation (AI). The adapted irrigation followed recommendations by CropManage (Cahn et al., 2015), a free online decision support tool based on ET based irrigation scheduling and calibrated for local crops and growing conditions. A manifold was designed to modify irrigation inputs in the AI treatment, and flow meters were installed to monitor the water input in GS versus AI. During the two crop cycles, we measured yield, aboveground plant N uptake, and soil N concentrations in the 0-12″ and 12-24″ depth increments.

RESULTS AND DISCUSSION

In both crop cycles, the AI treatment used lower irrigation rates and showed greater yields and N uptake than the GS treatment. In the first crop cycle, the AI practice used 26% less irrigation water than GS, and 15% less in the second crop cycle. In crop cycle 1, there was a linear response of yield to fertilizer rate (Figure 1A). The slope of the linear model was greater for AI then GS, with AI producing 9 lbs fresh yield per pound of N fertilizer applied more than GS. In crop cycle 2, the response followed a linear plateau model (Figure 1B). The AI treatment had a higher maximum yield and a lower optimal N rate compared to the GS treatments. The optimal N rates were 343 lbs N ac^{-1} for GS and 292 lbs N ac^{-1} for AI, thereby saving 51 lbs N ac^{-1} in fertilizer requirements. The response of total aboveground biomass N was linear for both irrigation practices in both crop cycles. However, the linear models were significantly different for AI vs. GS, with generally greater aboveground biomass N in the AI compared the GS treatment. Soil nitrate concentrations were significantly affected by irrigation management. In the 12-24″ depth increment during the late testing period in cycle 1, mean soil nitrate concentrations were 4.6 ppm for AI and 5.1 ppm for GS, suggesting that more N may have moved below 12″ in the GS treatments. In the cycle 2 early testing period, mean nitrate concentrations were 20.2 ppm for AI and 17.1 ppm for GS in the 0-12″ depth increment, while nitrate concentrations were 20.2 ppm for AI and 22.1 ppm for GS in the 12-24″ depth. This indicates retention of N in the topsoil AI treatment and potential leaching of N into the second foot in the GS treatment.

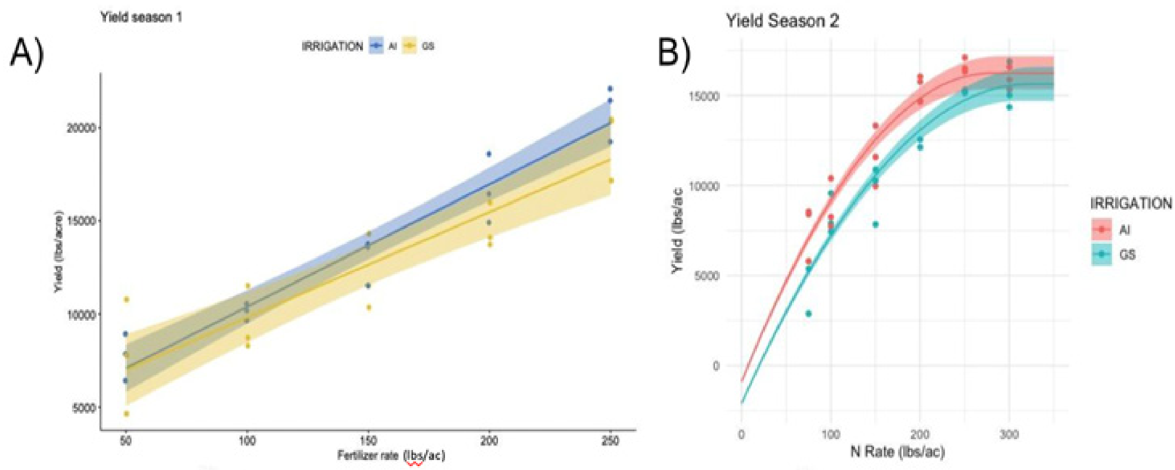


Figure 1. Response broccoli yield (lbs ac^{-1}) to N fertilizer rate (lbs N ac^{-1}) for the grower standard (GS) and adapted irrigation (AI) practice for crop cycle 1 (A) and crop cycle 2 (B). Shading indicates 95% confidence intervals.

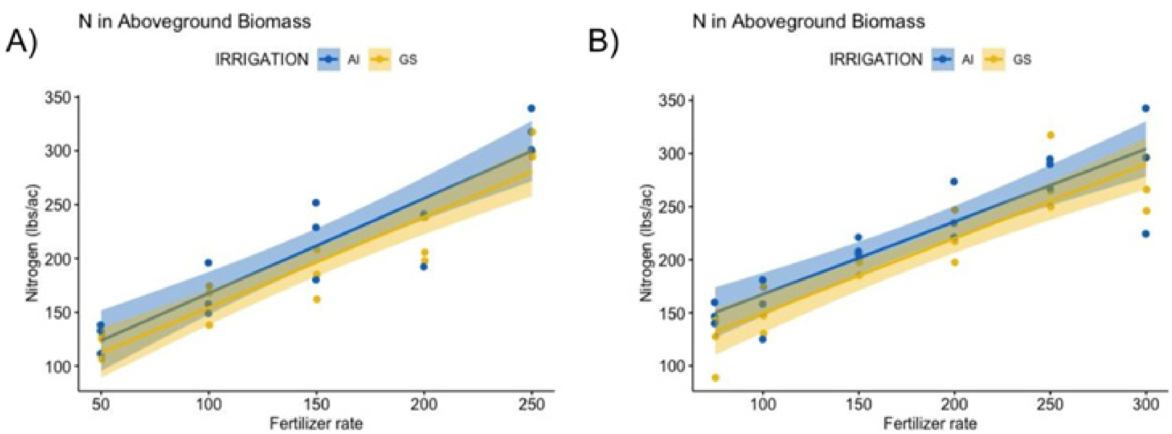


Figure 2 Response of broccoli total aboveground N (lbs/acre) to N fertilizer rate (lbs N ac^{-1}) for the grower standard (GS) and adapted irrigation (AI) practice for crop cycle 1 (A) and crop cycle 2 (B). Shading indicates 95% confidence intervals.

TAKE-HOME MESSAGE

Using ET based scheduling to optimize irrigation rates not only reduced water inputs, but also increased yield and the efficiency of N inputs. Yield was maximized at a rate of 51 lbs N ac^{-1} less than that of the grower standard irrigation practice consisting of 120% ET. Our findings suggest that optimizing irrigation scheduling is one tool growers can use to reduce N rates in efforts to comply with increasingly stringent regulation.

Future trials will assess how irrigation management affects the fertilizer value of irrigation water high in nitrate on conventional and organic ranches.

LITERATURE CITED

Cahn, M., Hartz, T., Smith, R., Noel, B., Johnson, L., Melton, F., 2015. CropManage: An online decision support tool for irrigation and nutrient management. Proceedings of the Western Nutrient Management Conference, Reno, NV, USA, pp. 5-6.

Cahn, M., Smith, R., Murphy, L., Hartz, T., 2017. Field trials show the fertilizer value of nitrogen in irrigation water. California Agriculture 71.

ACKNOWLEDGEMENTS

We thank staff at Betteravia farms for support in the management of the trials and analysis of samples. We are grateful for financial support from FREP for the continuation of this project.

Development of Precision Yield Monitor for Almond and Pistachio

Project Leaders

Patrick Brown
Professor of Plant Sciences
University of California, Davis.
Department of Plant Science
1 Shields Ave. Davis, CA 95616
(530) 304-1390
phbrown@ucdavis.edu

Stavros Vougioukas
Professor of Biological and Agricultural Engineering
University of California, Davis.
Department of Biological and Agricultural Engineering
1 Shields Ave. Davis, CA 95616
(530) 219-9901
svougioukas@ucdavis.edu

INTRODUCTION

Providing uniform water and nutrients to an entire orchard is standard practice but is wasteful. To improve the efficiency of input management, growers must identify and manage field variability. Noble et al. (2018) measured the yield of 4,000-7,000 trees over five consecutive years. The resulting yield map illustrates the extreme variability in yield, with 30% of the orchard yielding more than 6,000 lbs (about 2721.55 kg), while 30% yielded <2,500 lbs. In almond, yield variability is also significant. This project aims to provide the capability for single tree yield monitoring and tree identification at full commercial harvest speed. This precision harvester will immediately provide rationale and context for sub-orchard management and nutrient optimization. The ability to easily measure single tree yield also represents a revolution for research. It will improve the use of remote soil/plant sensors by providing ground truth data and relationship to field variability.

OBJECTIVES

1. Measure yield using laser scanning. A laser scanner will be placed above the conveyor belt of the harvester – after debris has been blown away - and used to measure the flow of the harvested crop volume. The estimated bulk density of the crop will be used to convert volume flow to mass flow, which will be combined with the GPS signal to estimate the yield map.
2. Measure yield using optical and gravimetric methods. Conveyor belts will be modified to include rollers with load cells and a non-contact moisture sensor, thus augmenting volume flow (from Objective 1) with the measured mass flow and water content.
3. Develop and integrate a real-time quality control vision system. A real-time vision system will be developed to estimate valuable parameters such as hull split (for almonds) and trash percentage.

DESCRIPTION

This project aims to provide the capability for single tree yield monitoring and tree identification at full commercial harvest speed. To achieve this goal, the project features a laser scanner and a custom-made conveyor belt system designed to integrate into the terminal section of a conventional commercial harvester. Engineered to operate continuously, the design avoids needing to halt the harvester during crop collection. Additionally, the conveyor belt is outfitted with carefully calibrated sensors, enabling accurate yield estimation for each tree.

Sensing system

The main components and characteristics of the developed system are:

- Conveyor belt with a controllable speed up to 0.9 m/s.
- Four inner load cells to measure the mass flow, max capacity 12 kg.
- Four outer load cells to record the system's weight, max capacity 30 kg.
- Laser Gocator 2690 to read the profile of the almonds with a sub-millimeter resolution.
- Optical encoders to read the belt speed.
- GPS for tree localization
- Vibration sensor to identify when a tree is shaken.
- Radar to register the machine travel speed

Figure 1 depicts the conveyor belt CAD and the actual system.

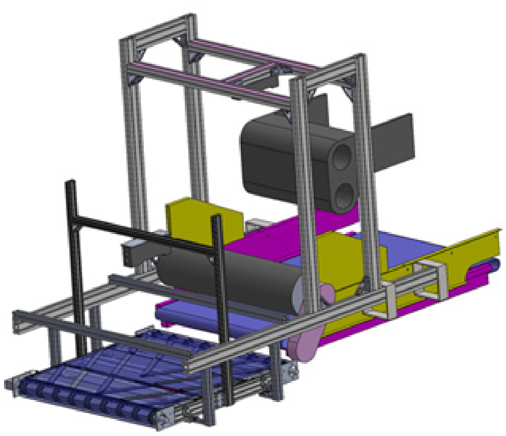


Figure 1. CAD model for the customized conveyor belt (left); actual conveyor belt installed on a TOL machine harvester (right).

Weight estimation

The four inner load cells are designed to record the weight exerted on them as almonds pass over a metal plate beneath the conveyor belt. By combining the load cell readings with the encoder's speed and timestamps, the weight of almonds crossing the metal plate can be estimated as the average between two timestamps. The total weight is then calculated by adding up all the averages. On the other hand, the outer load cells register not only the mass of the almonds but also the mass of the complete conveyor belt.

Volume estimation

The laser is used to estimate the volume of almonds passing under it on the conveyor belt. The laser records the profiles of the almonds; the green points in Figure 2 (left) represent the profile data. An encoder is used to record the belt's speed, which enables the displacement for each profile to be known. The volume can be estimated by combining the laser profile with the encoder readings. Figure 2 (right) provides an example of the resulting point cloud where the volume is calculated.

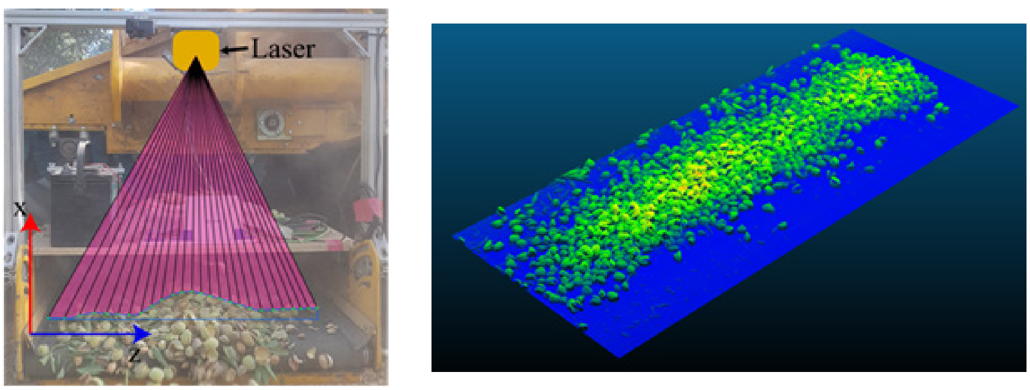


Figure 2. Almond profile reading with a laser (left); result of combining the laser profile and encoder readings (right).

Weight validation

The almonds are collected onto a tarp and weighed using a scale to gather data on the trees for mass or volume estimation. The height of the bucket is also recorded. Figure 3 shows the method for acquiring accurate data.

RESULTS AND DISCUSSION

Initial tests were conducted in the laboratory to assess the accuracy of laser-based weight estimation. The procedure used almonds quantities of 1, 2, 3, 4, 5, 10, 15, 20, and 30 kg and ran the conveyor belt at the speeds of 0.2, 0.4, 0.6, and 0.8 m/s. The laser and encoder data were used to estimate the almond volume crossing the belt. We used weights of 1, 3, 5, 15, and 30 kg to fit a linear model and the remaining weights to validate the model. The speed of the harvester's conveyor belt is around 0.4 (m/s).

Figure 4 presents the relationship between the predicted and actual weight of the almonds at 0.4 (m/s). A comprehensive analysis is shown in Table 1.

Table 1. Summary of the results obtained with the almond weight of 2, 4, 10, and 20 kg. Where R2 is the coefficient of determination, and MAE is the Mean absolute error

Speed (m/s)	R^2	MAE (kg)
0.2	1	0.128
0.4	0.999	0.157
0.6	0.999	0.196
0.8	0.999	0.170

The findings in Table 1 indicate a direct correlation between the estimated weight and the actual weight of almonds. The Mean Absolute Error (MAE) remains below 0.2 kg at all speeds. We conducted a data acquisition campaign at Westwind Farm and Olam Group. The next step is to evaluate and validate the data obtained using the ground truth shown in Figure 3. In addition, the GPS position of the harvester machine will be considered to estimate tree yields.

Figure 3. The almonds are collected in a tarp (left), the almonds are weighted, and the bucket height is registered (right).

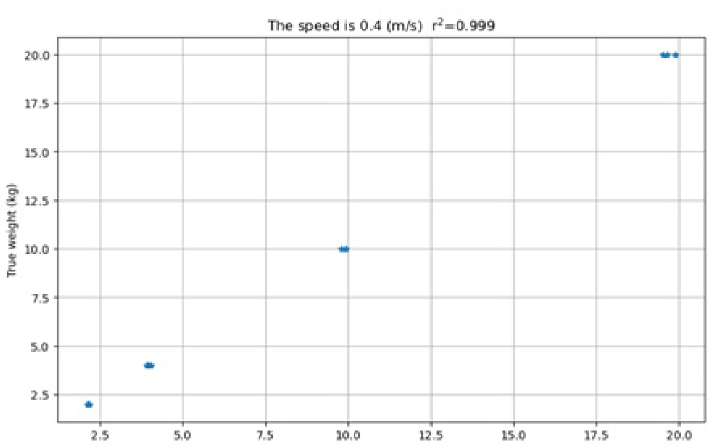


Figure 4. Estimated almond weight (x-axis) versus the actual weight (y-axis) at 0.4 (m/s).

TAKE-HOME MESSAGE

High-resolution lasers can be used to estimate the yield of crops such as almonds moving on a harvesting machine's conveyor belt at commercial speeds. A similar technique can also be applied to crops such as pistachios.

LITERATURE CITED

Noble, AE., TS Rosenstock, PH Brown, J Machta, A Hastings. 2018. Spatial patterns of tree yield explained by endogenous forces through a correspondence between the Ising model and ecology. Proceedings of the National Academy of Sciences 115 (8), 1825-1830

ACKNOWLEDGMENTS

We acknowledge the funding from CDFA-FREP.

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 https://www.cdfa.ca.gov/is/ffldrs/frep/Research.html.You may also contact the program at frep@cdfa.ca.gov.

University of California Nursery and Floriculture Alliance Fertilizers and Plant Nutrition Workshops for Greenhouse and Nursery Growers • Lorence Oki, 20-0963

Development of Nutrient Budget and Nutrient Demand Model for Nitrogen Management in Cherry • Patrick Brown, 19-0954

Achieving Efficient Nitrogen Fertilizer Management in California Wheat • Mark Lundy, 19-0953

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, 19-0950

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

Efficient Water and Nitrogen Management Practices for Mixed Leafy Baby Green Vegetables in the Desert • Charles A. Sanchez, 18-0593

Assessing Drip Irrigation and Nitrogen Management of Fresh Onions Produced in California Low Desert • Jairo Diaz, 18-0592

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

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

Training on Crop Management and Integrated Climate, Soil and Irrigation System Data to Minimize Nutrient Loss and Optimize Irrigation Efficiency • Trina Walley, 17-0489

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

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

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

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

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

Evaluation of Biochar for On-Farm Soil Management in California, 16-0662, Sanjai Parikh

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

Expanding the California Fertilization Guidelines to Support Nutrient Management Decisions for Minor Crops, 16-0610, Daniel Geisseler

Soil biochar amendment to improve nitrogen and water management, 15-0597, Suduan Gao

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

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*

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*

Determination of Root Distribution, Dynamics, Phenology and Physiology of Almonds to Optimize Fertigation Practices • *Patrick Brown, 11-0461*

Nitrogen Fertilizer Loading to Groundwater in the Central Valley • *Thomas Harter, 11-0301*

Assessment of Plant Fertility and Fertilizer Requirements for Agricultural Crops in California • *William Horwath and Daniel Geisseler, 11-0485*

California Certified Crop Adviser FREP Educational Project • *Daniel H. Putnam, 11-0470*

Optimization of Organic Fertilizer Schedules • *David Crohn, 11-0456*

Updating Prior Curriculum for Grades 5-8 • *Judy Culbertson, 11-0454*

Management Tools for Fertilization of the 'Hass' Avocado • *Richard Rosecrance and Carol J. Lovatt, 11-0437*

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

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

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

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

Nitrogen Research and Groundwater • *Renee Pinel, 10-0011*

Chemistry, Fertilizer and the Environment – A Comprehensive Unit • *Judy Culbertson, Shaney Emerson, and Lyn Hyatt, 10-0010*

Adjustable-Rate Fertigation for Site-Specific Management to Improve Fertilizer Use Efficiency • *Delwiche, 10-0004*

Towards Development of Foliar Fertilization Strategies for Pistachio to Increase Total Yield and Nut Size and Protect the Environment - A proof-of-concept project • *Carol J. Lovatt and Robert H. Beede, 09-0584*

Improving Pomegranate Fertigation and Nitrogen Use Efficiency with Drip Irrigation Systems • *James E. Ayars and Claude J. Phene, 09-0583*

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

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

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

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

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

California Certified Crop Adviser FREP Educational Project • *Dan Putnam, 08-0627*

Western Fertilizer Handbook Turf & Ornamental Edition • *Renee Pinel, 08-0007*

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

New Standard for the Effectiveness of Foliar Fertilizers • *Carol Lovatt, 07-0667*

Optimizing Nitrogen Availability in Cherry Growth to Obtain High Yield and Fruit Quality • *Kitren Glozer, 07-0666*

Development of Certified Crop Adviser Specialty Certification and Continuing Education in Manure Nutrient Management • *Stuart Pettygrove, 07-0405*

California Certified Crop Adviser FREP Educational Project • *Dan Putnam, 07-0352*

Development and Implementation of Online, Accredited Continuing Education Classes on Proper Sampling and Application of Nitrogen/ Crop Nutrients • *Renee Pinel, 07-0223*

Evaluation of Humic Substances Used in Commercial Fertilizer Formulations • *T.K. Hartz, 07-0174*

Fertilizer Education Equals Clean Water • *Kay Mercer, 07-0120*

Can a Better Tool for Assessing 'Hass' Avocado Tree Nutrient Status be Developed? A Feasibility Study • *Carol Lovatt, 07-0002*

Development of Practical Fertility Monitoring Tools for Drip-Irrigated Vegetable Production • *Timothy K. Hartz, 06-0626*

Updating Our Knowledge and Planning for Future Research, Education and Outreach Activities to Optimize the Management of Nutrition in Almond and Pistachio Production • *Patrick Brown, 06-0625*

Development of a Model System for Testing Foliar Fertilizers, Adjuvants and Growth Stimulants • *Patrick Brown, 06-0624*

Site-specific Fertilizer Application in Orchards, Nurseriesand Landscapes • *Michael Delwiche, 06-0600*

Fertilization Techniques for Conservation Tillage Production Systems in California • *J Mitchell, 04-0808*

Exploring Agrotechnical and Genetic Approaches to Increase the Efficiency of Zinc Recovery in Peach and Pistachio Orchards • *R. Scott Johnson, Steven A. Weinbaum and Robert H. Beede, 04-0770*

Improving Water-Run Nitrogen Fertilizer Practices in Furrow and Border Check–Irrigated Field Crops • *Stuart Pettygrove, 04-0747*

Fertility Management in Rice • *Chris Van Kessel, 04-0704*

Detecting and Correcting Calcium Limitations • *Timothy K. Hartz, 04-0701*

Soil-Solution Partitioning of Trace Elements in Cropland Soils of California: Estimating the Plant Uptake Factors of As, Cd, and Pb • *Chang, 03-0088*

Potassium Fertility Management for Optimum Tomato Yield and Fruit Color • *Tim Hartz, 03-0661*

Precision Fertigation in Orchards: Development of a Spatially Variable Microsprinkler System • *Michael Delwiche et al., 03-0655*

Increasing Yield of the 'Hass' Avocado by Adding P and K to Properly Timed Soil N Applications • *Carol J. Lovatt, 03-0653*

Improving the Procedure for Nutrient Sampling in Stone Fruit Trees • *R. Scott Johnson, 03-0652*

Reevaluating Tissue Analysis as a Management Tool for Lettuce and Cauliflower • *Timothy K. Hartz, 03-0650*

Environmental Compliance and Best Management Practice Education for Fertilizer Distributors • *Renee Pinel, 03-0005*

Evaluation of Polyacrylamide (Pam) for Reducing Sediment and Nutrient Concentration in Tailwater from Central Coast Vegetable Fields • *Michael Cahn, 02-0781*

Practical Soil Test Methods for Predicting Net N Mineralization • *William Horwath, 02-0653*

Determination of Nursery Crops Yields, Nutrient Content, and Water Use for Improvement of Water and Fertilizer Use Efficiency • *Crum/Stark, 02-0651*

California Certified Crop Advisor • *Evans, 02-0331*

California State Fair Farm Upgrade Project • *Michael Bradley, Joe Brengle, and Teresa Winovitch, 01-0640*

Evaluating the Impact of Nutrient Management on Groundwater Quality in the Presence of Deep Unsaturated Alluvial Sediment • *Thomas Harter, 01-0584*

Crop Nitrate Availability and Nitrate Leaching under Micro-Irrigation for Different Fertigation Strategies • *Blaine Hanson and Jan W. Hopmans, 01-0545*

Development of Lime Recommendations for California Soils • *Miller, 01-0511*

Development of a Leaf Color Chart for California Rice • *Randal Mutters, 01-0510*

Efficient Phosphorus Management in Coastal Vegetable Production • *Timothy K. Hartz, 01-0509*

Development of BMPs for Fertilizing Lawns to Optimize Plant Performance and Nitrogen Uptake While Reducing the Potential for Nitrate Leaching • *Robert Green et al., 01-0508*

Site-Specific Fertilizer Application in Cotton • *Richard Plant, 01-0507*

Effects of Cover Cropping and Conservation Tillage on Sediment and Nutrient Losses to Runoff in Conventional and Alternative Farming Systems • *William R. Horwath et al., 01-0473*

Fertilization Technologies for Conservation Tillage Production Systems in California • *Jeffrey Mitchell, 01-0123*

Long Term Rice Straw Incorporation: Does It Impact Maximum Yield? • *Chris Van Kessel & William Horwath, 00-0651*

Seasonal Patterns of Nutrient Uptake and Partitioning as a Function of Crop Load of the 'Hass' Avocado• *Rosencrance, 00-0621*

Field Evaluations and Refinement of New Nitrogen Management Guidelines for Upland Cotton: Plant Mapping, Soil and Plant Tissue Tests • *Robert Hutmacher, 00-0604*

California Certified Crop Advisor Management Project • *Hank Giclas, 00-0516*

Improving the Diagnostic Capabilities for Detecting Molybdenum Deficiency in Alfalfa and Avoiding Toxic Concentrations for Animals• *Meyer, 00-516*

Ammonia Emission from Nitrogen Fertilizer Application • *Charles Krauter, 00-0515*

Reducing Fertilizer Needs of Potato with New Varieties and New Clonal Strains of Existing Varieties • *Ronald Voss, 00-0514*

Minimizing Nitrogen Runoff and improving Use Efficiency in Containerized Woody Ornamentals through Management of Nitrate and Ammonium • *Donald J. Merhaut, 00-0509*

Location of Potassium-Fixing Soils in the San Joaquin Valley and a New, Practical Soil K Test Procedure • *Stuart Pettygrove, 00-0508*

Effect of Different Rates of N and K on Drip-Irrigated Beauregard Sweet Potatoes • *Bill Weir, 00-0507*

Evaluation of Controlled-Release Fertilizers for Cool Season Vegetable Production in the Salinas Valley • *Richard Smith, 00-0506*

Site-Specific Variable Rate Fertilizer Application in Rice and Sugar Beets • *Plant, 00-0505*

Precision Horticulture: Technology Development and Research and Management Applications • *Patrick Brown, 00-0497*

From the Ground Up: A Step-By-Step Guide to Growing a School Garden • *Jennifer Lombardi, 00-0072*

On-Farm Monitoring and Management Practice Tracking for Central Coast Watershed Working Groups • *Kelly Huff, 00-0071*

Teach the Teachers: Garden-Based Education about Fertility and Fertilizers • *Peggy S. McLaughlin, 00-0070*

Pajaro Valley Nutrient Management Education & Outreach Project• *Win, 99-0764*

Nitrogen Budgeting Workshops • *Jim Tischer, 99-0757*

The Role of Inorganic Chemical Fertilizers and Soil Amendments on Trace Element Contents of Cropland Soils in California • *Chang, 99-0533*

Air Quality and Fertilization Practices: Establishing a Calendar of Nitrogen Fertilizer Application Timing Practices for Major Crops in the San Joaquin Valley • *King, 98-0471*

Evaluating and Demonstrating the Effectiveness of In-Field Nitrate Testing in Drip- and Sprinkler-Irrigated Vegetables • *Marc Buchanan, 99-0756*

Demonstration of Pre-Sidedress Soil Nitrate Testing as a Nitrogen Management Tool • *Timothy K. Hartz, 98-0513*

Efficient Irrigation for Reduced Non-Point Source Pollution from Low Desert Vegetables • *Charles Sanchez, Dawit Zerrihun, and Khaled Bali, 98-0423*

Effect of Cover Crop or Compost on Potassium Deficiency and Uptake, and on Yield and Quality in French Prunes • *Rosencrance, 98-0422*

Winter Cover Crops Before Late-Season Processing Tomatoes for Soil Quality and Production Benefits • *Gene Miyao & Paul Robins, 97-0365 M99-11*

Nitrogen Mineralization Rate of Biosolids and Biosolids Compost • *Tim Hartz, 97-0365 M99-10*

Precision Agriculture in California: Developing Analytical Methods to Assess Underlying Cause and Effect within Field Yield Variability • *Chris Van Kessel, 97-0365 M99-08*

Development of an Educational Handbook on Fertigation for Grape Growers • *Glenn T. McGourty, 97-0365 M99-07*

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*

Interaction of Nitrogen Fertility Practices and Cotton Aphid Population Dynamics in California Cotton • *Larry Godfrey & Robert Hutmacher, 97-0365 M98-04*

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

Development and Demonstration of Nitrogen Best Management Practices for Sweet Corn in the Low Desert • *Jose Aguiar, 97-0365 M98-02*

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

Nitrogen Budget in California Cotton Cropping Systems • *William Rains, Robert Travis, and Robert Hutmacher, 97-0365 M97-09*

Uniformity of Chemigation in Micro-irrigated Permanent Crops • *Larry Schwankl and Terry Prichard, 97-0365 M97-08B*

Development of Irrigation and Nitrogen Fertilization Programs on Tall Fescue to Facilitate Irrigation Water Savings and Fertilizer-Use Efficiency • *Robert Green and Victor Gibeault, 97-0365 M97-07*

Development and Testing of Application Systems for Precision Variable Rate Fertilization • *Ken Giles, 97-0365 M97-06A*

Site-Specific Farming Information Systems in a Tomato-Based Rotation in the Sacramento Valley • *Stuart Pettygrove, 97-0365 M97-05 2002*

Long-Term Nitrate Leaching Below the Root Zone in California Tree Fruit Orchards • *Thomas Harter, 97-0365 M97-04*

Soil Testing to Optimize Nitrogen Management for Processing Tomatoes • *Jeffrey Mitchell, Don May, and Henry Krusekopf, 97-0365 M97-03*

Drip Irrigation and Fertigation Scheduling for Celery Production • *Timothy K. Hartz, 97-0365 M97-02*

Agriculture and Fertilizer Education for K-12 • *Pamela Emery & Richard Engel, 97-0365*

Integrating Agriculture and Fertilizer Education into California's Science Framework Curriculum • *Mark Linder & Pamela Emery, 97-0361*

Water and Fertilizer Management for Garlic: Productivity, Nutrient and Water Use Efficiency and Postharvest Quality • *Marita Cantwell, Ron Voss, and Blaine Hansen, 97-0207*

Improving the Fertilization Practices of Southeast Asians in Fresno and Tulare Counties • *Richard Molinar and Manuel Jimenez, 96-0405*

Management of Nitrogen Fertilization in Sudangrass for Optimum Production, Forage Quality and Environmental Protection • *Dan Putnam, 96-0400*

Fertilizer Use Efficiency and Influence of Rootstocks on Uptake and Nutrient Accumulation in Winegrapes • *Larry Williams, 96-0399*

Survey of Changes in Irrigation Methods and Fertilizer Management Practices in California • *John Letey, Jr., 96-0371*

Development of a Nitrogen Fertilizer Recommendation Model to Improve N-Use Efficiency and Alleviate Nitrate Pollution to Groundwater from Almond Orchards • *Patrick Brown, 96-0367*

On-Farm Demonstration and Education to Improve Fertilizer Management • *Danyal Kasapligil, Eric Overeem, and Dale Handley, 96-0312*

Nitrogen Management in Citrus under Low Volume Irrigation • *Arpaia, 96-0280*

Evaluation of Pre-Sidedress Soil Nitrate Testing to Determine N Requirements of Cool Season Vegetables • *Timothy Hartz, 95-0583*

Development and Promotion of Nitrogen Quick Tests for Determining Nitrogen Fertilizer Needs of Vegetables • *Kurt Schulbach and Richard Smith, 95-0582*

Guide to Nitrogen Quick-Tests for Vegetables with the 'Cardy' Nitrate Meter • *Kurt Schulbach and Richard Smith, 95-0582b*

Western States Agricultural Laboratory Proficiency Testing Program • *Janice Kotuby-Amacher and Robert O Miller, 95-0568*

Avocado Growers Can Reduce Soil Nitrate Groundwater Pollution and Increase Yield and Profit • *Carol Lovatt, 95-0525*

Determining Nitrogen Best Management Practices for Broccoli Production in the San Joaquin Valley • *Michelle Lestrange, Jeffrey Mitchell, and Louise Jackson, 95-0520*

Effects of Irrigation Non-Uniformity on Nitrogen and Water Use Efficiencies in Shallow-Rooted Vegetable Cropping Systems • *Blake Sanden, Jeffrey Mitchell, and Laosheng Wu, 95-0519*

Developing Site-Specific Farming Information for Cropping Systems in California • *G. Stuart Pettygrove, et.al., 95-0518*

Relationship Between Nitrogen Fertilization and Bacterial Canker Disease in French Prune • *Steven Southwick, Bruce Kirkpatrick, and Becky Westerdahl, 95-0478*

Best Management Practices (BMPs) for Nitrogen and Water Use in Irrigated Agriculture: A Video• *Danyal Kasapligil, Charles Burt, and Klaas, 95-0463*

Practical Irrigation Management and Equipment Maintenance Workshops • *Danyal Kasapligil, Charles Burt, & Eric Zilbert, 95-0419*

Evaluation of Controlled Release Fertilizers and Fertigation in Strawberries and Vegetables • *Warren Bendixen, 95-0418*

Diagnostic Tools for Efficient Nitrogen Management of Vegetables Produced in the Low Desert • *Charles Sanchez, 95-0222*

Using High Rates of Foliar Urea to Replace Soil-Applied Fertilizers in Early Maturing Peaches • *R. Scott Johnson & Richard Rosecrance, 95-0214*

Education through Radio • *Patrick Cavanaugh, 94-0517*

Effects of Four Levels of Applied Nitrogen on Three Fungal Diseases of Almond Trees • *Beth Teviotdale, 94-0513*

Use of Ion Exchange Resin Bags to Monitor Soil Nitrate in Tomato Cropping Systems • *Robert Miller, 94-0512*

Nutrient Recommendation Training in Urban Markets: A Video• *Jenks, 94-0463b*

Best Management Practices for Tree Fruit and Nut Production: A Video • *Doerge, 94-0463*

Effects of Various Phosphorus Placements on No-Till Barley Production • *Michael J. Smith, 94-0450*

Nitrogen Management through Intensive on-Farm Monitoring • *Timothy K. Hartz, 94-0362*

Establishing Updated Guidelines for Cotton Nutrition • *Bill Weir and Robert Travis, 94-0193*

Development of Nitrogen Fertilizer Recommendation Model for CaliforniAlmond Orchards • *Patrick Brown and Steven A. Weinbaum, 3-0613*

Extending Information on Fertilizer Best Management Practices and Recent Research Findings for Crops in Tulare County • *Carol Frate, 93-0570*

Western States Agricultural Laboratory Sample Exchange Program• *Miller, 93-0568*

Nitrogen Efficiency in Drip-Irrigated Almonds • *Robert J. Zasoski, 93-0551*

Citrus Growers Can Reduce Nitrate Groundwater Pollution and Increase Profits by Using Foliar Urea Fertilization • *Carol J. Lovatt, 93-0530*

Drip Irrigation and Nitrogen Fertigation Management for California Vegetable Growers: Videotape • *Timothy Hartz, 93-Hartz*

Educating California's Small and Ethnic Minority Farmers: Ways to Improve Fertilizer Use Efficiency through the Use of Best Management Practices (BMPs) • *Ronald Voss, 1993*

Development of Diagnostic Measures of Tree Nitrogen Status to Optimize Nitrogen Fertilizer Use • *Patrick Brown, 92-0668*

Impact of Microbial Processes on Crop Use of Fertilizers from Organic and Mineral Sources • *Kate M. Scow, 92-0639*

Potential Nitrate Movement Below the Root Zone in Drip-Irrigated Almonds • *Roland D. Meyer, 92-0631*

Optimizing Drip Irrigation Management for Improved Water and Nitrogen Use Efficiency • *Timothy K. Hartz, 92-0629*

The Use of Composts to Increase Nutrient Utilization Efficiency in Agricultural Systems and Reduce Pollution from Agricultural Activities • *Mark Van Horn, 92-0628*

Crop Management for Efficient Potassium Use and Optimum Winegrape Quality • *Mark A. Matthews, 92-0627*

Determination of Soil Nitrogen Content In-Situ • *Shrini K. Updahyaya, 92-0575*

Demonstration Program for Reducing Nitrate Leaching through Improvements to Irrigation Efficiency and Fertilizer/Cover Crop Management • *Stuart Pettygrove, 91-0654*

Influence of Irrigation Management on Nitrogen Use Efficiency, Nitrate Movement, and Groundwater Quality in a Peach Orchard • *R. Scott Johnson, 91-0646*

Improvement of Nitrogen Management in Vegetable Cropping Systems in the Salinas Valley and Adjacent Areas • *Stuart Pettygrove, 91-0645*

Field Evaluation of Water and Nitrate Flux through the Root Zone in a Drip/Trickle-Irrigated Vineyard • *Donald W. Grimes, 91-0556*

Nitrogen Management for Improved Wheat Yields, Grain Protein and the Reduction of Excess Nitrogen • *Bonnie Fernandez, 91-0485*

Nitrogen Fertilizer Management to Reduce Groundwater Degradation • *Weinbaum, 91-Weinbaum*