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FREP



WPH

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INTRODUCTION

34th Annual FREP/WPH Nutrient Management Conference

Welcome to the 34th Annual Nutrient Management Conference, co-hosted by the Fertilizer Research and Education Program (FREP) and Western Plant Health (WPH). For over three decades, this conference has provided a premier forum for FREP grant recipients to showcase their findings and for industry leaders to share vital insights on irrigation and crop nutrition. Our audience brings together a diverse group of growers, agricultural consultants, researchers, advisors, and students. Since its inception in 1990, FREP has supported California's agricultural sector by investing in research, field demonstrations, and outreach projects designed to optimize irrigation and fertilizer use efficiency. At this year's conference, researchers and industry professionals from around the state will share the newest advancements and research findings in irrigation and nutrient management.

Featured on the agenda are presentations highlighting findings from six projects funded by FREP. The program will also highlight two interactive panel discussions: one examining the recommendations from the Second Agricultural Expert Panel and their implications for Central Valley growers, and another addressing irrigation management challenges across varying cropping systems and irrigation systems common to the Sacramento, San Joaquin, and Imperial Valleys. In addition, the conference offers presentations on the uncertainty of satellite-based estimates of evapotranspiration used in irrigation scheduling, best management practices for stone fruit nutrition, the role of silicon in plant nutrition, updates on the Nitrogen and Irrigation Initiative, and recent regulatory and research developments regarding biostimulants.

Overview of Funded Research

Since 1991, FREP has invested more than \$32 million in over 280 projects dedicated to research, outreach, and demonstration related to nutrient and irrigation management. These projects tackle key management challenges and opportunities across various commodities throughout California (Figure 1).

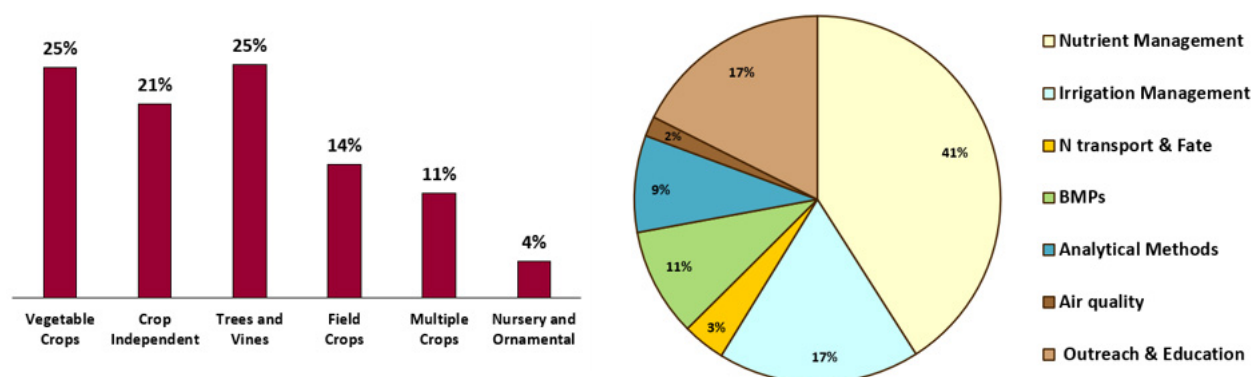


Figure 1. Distribution of commodities (left) and research areas (right) represented in FREP-funded projects.

At present, FREP provides funding for 24 innovative projects designed to enhance irrigation and nutrient management practices in California agriculture. These projects enhance our understanding of grower decision-making, provide valuable technical training, and contribute to a deeper knowledge of nutrient and irrigation management in California crops. The Crop Fertilization Guidelines online portal (cdfa.ca.gov/go/FREPguide) serves as a vital tool generated in part by FREP-supported research. The recommendations offer valuable information on fertilization for the most prevalent irrigated agricultural commodities in the state, depending on the plant growth phase. Numerous crop advisors and producers consult these online guidelines when making fertilizer application decisions.

To explore current and completed FREP-funded projects, visit:

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We are thankful to members of the fertilizer industry for their support in funding FREP projects. Their foresight in creating FREP and their sustained commitment and dedication have been vital to 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 (Co-chair), Dr. Chris Shogren, Dr. Jairo Diaz, Daniel Rodrigues, Gina Colfer, Dr. Sebastian Saa, Dr. Ehsan Toosi, Dan Cook, Dr. Franklin Gaudi, Devin Clarke, and David McEuen.

In addition, we thank the members of the Fertilizer Inspection Advisory Board for their continued support of the FREP program: Gary Silveria (Chair), Christopher Gallo (Vice Chair), Greg Cunningham, Jake Evans, David McEuen, Melissa McQueen, Andrew Larson, Tracy Starich, and Tucker Salles.

We are grateful to WPH and especially President and CEO Renee Pinel, as a continued supporter and valuable partner in organizing and hosting our annual conference.

**SUMMARIES OF
CURRENT FREP
PROJECTS**

“Crop Nutrient Minute” Video Series

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Introduction

The Irrigated Lands Program (ILP) 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 can fulfill their CE requirements. This project includes seven 30-minute videos that will be posted on the CURES website and linked to FREP’s Continuing Education course page for self-certified growers to access and earn CEUs for maintaining their INMP certification. The videos will also supplement the new Certified Crop Adviser (CCA) online training and facilitate CCAs in obtaining CEUs. The videos cover seven crops including almonds, citrus, pistachios, processing tomatoes, wine grapes (high tonnage), strawberries and lettuce. This CURES educational video series focusses on California’s major acreage crops and is accessible to Central Valley and Central Coast growers and crop advisors.

Objectives

- 1 Compile irrigation and nitrogen management information on seven major acreage crops in the Central Valley and Central Coast.
- 2 Develop and produce seven, 5-minute videos in both English and Spanish for the “Crop Nutrient Minute” video series.

- 3 Develop and produce seven 30-minute videos in both English and Spanish that expand on “Crop Nutrient Minute” video content for Continuing Education uses.
- 4 Post “Crop Nutrient Minute” videos online and conduct outreach.
- 5 Apply for CEU credit for “INMP Continuing Education” and CCA trainings, post videos online, fulfill sponsor requirements and conduct outreach.

Description

Video content is being developed by the Project Leaders, University of California Cooperative Extension (UCCE) specialists and University of California (UC) personnel in each of seven crop categories. The foundational information for the videos is the 4R principles (Right time, Right place, Right amount, and Right product) developed by FREP and the UC for California crops. Video content also includes information on soil health, nitrogen processes in the soil, leaf sampling, crop nutrient tracking and efficient irrigation practices, as well as tips gained from crop advisors, UCCE specialists and UC personnel who work with the crops featured in a specific video. Scripts for each of the seven 30-minute videos are written by the project leaders and cooperators using information gathered from the CDFA Crop Nutrient Guidelines and findings from past FREP-funded research. The videos are modeled off a FREP-funded 4R video produced for walnuts. Each draft script is 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 are filmed using CURES, UC and PCA/CCAs with crop-specific footage recorded in the field. Animation and art are used to illustrate technical information.

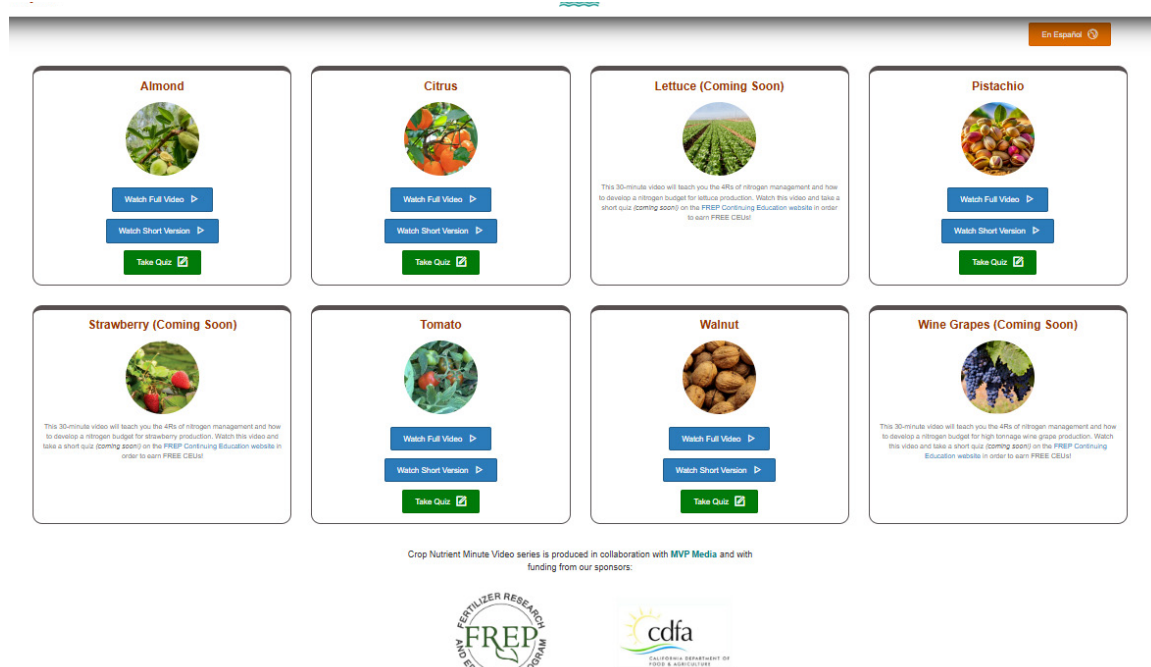


Figure 1. 30-minute and 5-minute videos for 8 crops on the CURES Nitrogen Management webpage.

Videos are 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 condenses the content to create the 5-minute “Crop Nutrient Minute” series. Both sets of videos can be viewed on the CURES Nitrogen Management webpage (www.curesworks.org/nitrogen-management/, see Fig 1 above) or streamed from the CURES Crop Nutrient Minute 4Rs Series YouTube video playlist: www.youtube.com/playlist?list=PLx4qPv3N7x-ZqF_nqqbw5jXWCI8LYsWMRE. The succinct 5-minute videos focus briefly on the fundamentals and cover crop-specific tips and techniques to properly implement the 4Rs. They are designed to be quick and easily accessible references for crop information while in the field.

Outreach is being 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 are available to show 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. Flyers are distributed at crop field days, conferences and events (see Figure 2).



Figure 2. Flyer advertising the Crop Nutrient Minute video series and opportunity to earn free CE credits

Once approved to offer CEUs, the finished 30-minute videos are posted on the CURES website and linked to CFDA's Continuing Education (CE) webpage (www.cdfa.ca.gov/is/fldrs/frep/continuing_education.html) as part of the Self-Study Video Course List. The CE courses enable participants in the Irrigation and Nitrogen Management Training Program to watch, learn and earn their required credits to remain eligible for self-certifying INMP Worksheets. CDFA, crop industry organizations and water quality coalitions are encouraged to send out email blasts, postcards and/or blog posts informing growers and crop advisors of the online courses. Quiz questions are developed and included with each crop video, in compliance with current INMP CE requirements (5 questions per 30 minutes). The mandatory quizzes are automatically graded, results recorded, and Certificates of Completion sent to growers who pass.

Results and Discussion

Project success is being measured through view counts and audience engagement. The total number of video views are tracked quarterly. These videos allow more growers to complete their CEUs, which are tracked and recorded through the INMP Self-Certification Program. In the long-term, project success will be measured by measurable reductions of nitrate in Central Valley and Central Coast groundwater over the next few decades. There are many programs and educational efforts being made 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.

Conclusion

The research-based information delivered to growers and crop advisors by this project supports 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 land-owners/operators in the Central Valley and 2,000 on the Central Coast who are affected by requirements to improve nitrogen and irrigation application practices for reducing salt and nitrate discharges to ground and surface water. Giving growers access to an easily accessible, more efficient source of information will advance the knowledge of proper nitrogen stewardship and, over time, may improve overall groundwater quality in California.

Furthermore, this project serves as a conduit to transfer the latest information on efficient nitrogen fertilizer applications and the practices that can minimize or prevent movement of nitrate to groundwater developed by FREP, UCCE and UC. Some new information is likely to come from interviews with Certified Crop Advisors, agronomists and farm advisors who have crop-specific tips, techniques or other knowledge gained through their work in the field.

Much knowledge has already been developed through UC, UCCE and FREP projects to improve nitrogen efficiency and needs to be disseminated to growers and crop advisors who would benefit from the information. This project provides another option for communicating this information using media that is popular with an increasing number of growers and crop advisors.

Acknowledgements

CURES thanks CDFA FREP for supporting this project and on behalf of growers statewide. CURES acknowledges the project leaders and thanks cooperators for their time reviewing scripts and filming videos: Katherine Jarvis-Shean, Ph.D. (UCCE), Phoebe Gordon, Ph.D. (UCCE), Jacqueline Vasquez Mendoza (UCCE), Franz Niederholzer, Ph.D. (UCCE), Zheng Wang, Ph.D. (UCCE), Michael Cahn, Ph.D. (UCCE), Andre Biscaro, M.S. (UCCE), Doug Amaral, Ph.D. (UCCE), George Zhuang, M.S. (UCCE), Richard Smith (UCCE), Gabriele Ludwig, Ph.D. (Almond Board of California), Casey Creamer (California Citrus Mutual), Orvil McKinnis (Westside San Joaquin River Watershed Coalition), Michael Wackman (San Joaquin County and Delta Water Quality Coalition), Bruce Houdesheldt (Sacramento Valley Water Quality Coalition), and Caitie Diemel (East San Joaquin Water Quality Coalition). Additional thanks to CURES dedicated staff: Courtney Jallo, Maureen Thompson, Eva Dwyer, Monica Quezada, Alany Valle; and, to Matt Martin with MVP Media.

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

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Introduction

Sudan grass is an important forage crop in California's low desert production systems, particularly in Imperial Valley. Because the crop grows rapidly under hot desert conditions, growers often apply large amounts of irrigation water and nitrogen fertilizer to maximize yield. However, excessive inputs can reduce water use efficiency (WUE), nitrogen use efficiency (NUE), increase production costs, and contribute to nitrate losses that may affect the ecosystem and the quality and safety of the forage crop. Findings presented here are based on the first two harvests of the 2026 season.

Objectives

- 1 Determine the optimum level of N and methods of fertilizer delivery for luxury or steady-state nutrient consumption of sudan grass with optimum hay biomass and quality.
- 2 Assess hay yield and economic benefits of the N fertilization practices with efficient use of fertilizer N or crop biomass per lbs of N applied (NUE).
- 3 Assess N leaching from sudan grass fields as affected by irrigation types and fertilizer delivery systems available in crop root zone for uptake.
- 4 Develop a robust extension program and effectively communicate to growers, agricultural scientific community and interested groups on best irrigation and N management for environmental protection, crop quality, yield, and economic considerations.

Description

Experimental Overview

The study evaluated three irrigation levels (80%, 100%, and 120% evapotranspiration replacement) and three nitrogen fertilizer programs (50 lb N/ac, 80 lb N/ac, and 50 lb N/ac applied in split applications) using a split-plot design with four replications. The 3 irrigation levels are deficit (3,000 gallons), full irrigation (3,500 gallons), and excess irrigation (4,000 gallons) applied per irrigation, respectively. All plots received 100 lb N/ac as a pre-plant application to ensure uniform establishment. Crop performance was evaluated through biomass production, Normalized Difference Vegetation Index (NDVI) measurements, nitrate recovery, tail water nitrate, soil pH, and resource efficiency indicators.

Results and Discussion

Biomass Response to Irrigation and Nitrogen

Irrigation effects

Irrigation was the primary factor affecting biomass production throughout the study. The first harvest reflected crop response primarily to irrigation because all plots had only received the pre-plant fertilizer application. During the first harvest, biomass increased substantially when irrigation increased from 80% to 100% ET, while additional irrigation to 120% ET provided only a small yield increase. The highest yields were observed under the 100% and 120% ET treatments, demonstrating that severe water deficits reduced productivity. Biomass production increased significantly as irrigation increased from 80% to 100% ET (Table 1). Yield under full irrigation (100% ET) was approximately 33% greater than under deficit irrigation. However, increasing irrigation beyond full crop requirements provided only a small additional yield benefit. Biomass under 120% ET was only 3.6% greater than under 100% ET, demonstrating diminishing returns from excess irrigation.

The second harvest confirmed this trend. Biomass increased from 15.6 t/ac at 80% ET to 18.4 and 19.9 t/ac under 100% and 120% ET, respectively. Although maximum yield occurred at 120% ET, the gain beyond full irrigation was relatively small, indicating diminishing returns from additional water application. Biomass increased with irrigation, but differences among nitrogen treatments were not significant. These results suggest that irrigation was the primary factor influencing biomass production. Applying 80 lb N/ac did not significantly improve yield when compared with the 50 lb N/ac treatments, indicating opportunities to improve nitrogen-use efficiency through reduced fertilizer inputs (Table 3).

Table 1: Sudan grass forage biomass from first and second cuttings		
Irrigation level (ET)	First cut (t/ac)	Second cut (t/ac)
80	10.2a	15.6a
100	13.6b	18.4ab
120	14.1b	19.9b

Means followed by same letter within the column are not significantly different from each other at $\alpha = 0.05$

Nitrogen Effects

Unlike irrigation, nitrogen fertilizer rate had little effect on biomass production. Similar yields were obtained from the 50 lb N/ac and 80 lb N/ac treatments, and no significant irrigation $\times$ nitrogen interaction was observed. These results suggest that Sudan grass can maintain productivity under moderate nitrogen inputs and that higher fertilizer rates may not be economically justified.

Crop Growth Monitoring Using NDVI

Normalized Difference Vegetation Index (NDVI) effectively reflected differences in crop growth among irrigation treatments (Figure 1). NDVI increased from 0.629 under 80% ET to approximately 0.74 under both 100% and 120% ET treatments, indicating improved canopy vigor and crop development as water availability increased.

A moderate positive relationship ($r = 0.554$) was observed between NDVI and biomass production, suggesting that NDVI may serve as a useful, non-destructive indicator of forage yield. Nitrogen treatments had minimal influence on NDVI, reinforcing the conclusion that irrigation was the dominant driver of crop growth in this study.

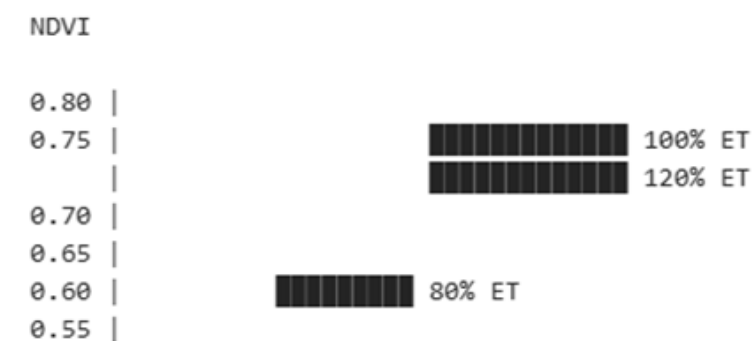


Figure 1: Mean crop NDVI under different irrigation levels (80, 100, and 120)

Nitrogen Recovery, erodibility, and Environmental Implications

One of the major objectives of the project is to reduce nitrogen losses from production fields while maintaining profitable yields. Analysis of nitrate recovery within the soil profile revealed significant differences among irrigation treatments (Table 2). There were no significant differences in $\text{NO}_3\text{-N}$ within soil depths of 0-1, 1-2, 2-3, and 3-4 ft depth. The 80% ET treatment retained the highest overall nitrate concentration within the sampled profile (22 ppm), while nitrate recovery declined under 100% and 120% ET treatments, suggesting that $\text{NO}_3\text{-N}$, under the latter 2 treatments may have moved down (leached) beyond 4 ft of the soil profile (profile beyond the sampled zone). Excess irrigation may therefore increase the risk of nitrate leaching and groundwater contamination. Because nitrogen rates (within the tested rates) have limited effects on yield, irrigation management appears to be a more important factor in controlling nitrogen losses under these conditions.

Table 2: soil N-recovery (soil depth), tail water and soil pH

Irrigation level (ET)	$\text{NO}_3\text{-N}$ (ppm)	$\text{NO}_3\text{-N}$ (ppm) in tail water	pH
80	22a	33a	8.11a
100	10b	34a	8.03b
120	12ab	33a	7.99b
<i>p-value</i>	<i>0.0494</i>	<i>0.0874</i>	<i>0.0318</i>

Efficient irrigation scheduling can help retain nutrients within the crop root zone while reducing environmental risks. While irrigation has moved fertilizers added to tail water (erode), there was no significant difference between irrigation levels (Table 2) and the number of added fertilizers. All irrigation treatments moved NO_3 through irrigation water to the tail water.

Soil pH Response

Soil pH remained relatively stable and alkaline across all treatments and remained within an alkaline range (Table 2) typical of Imperial Valley soils. Soil pH remained relatively stable across treatments, ranging from about 8.0 to 8.1. Although differences were statistically significant, their practical agronomic importance was minimal, indicating that irrigation management had little effect on soil chemical conditions during the study period. The slight decline in pH with increasing irrigation is unlikely to influence crop productivity or nutrient availability under the conditions of this study.

Water and Nitrogen Use Efficiency:

Water Use Efficiency (WUE)

Using second-harvest biomass because irrigation effects were statistically significant and irrigation amounts were defined as 3,000, 3,500, and 4,000 gallons per irrigation events, for 80, 100, and 120 ET, respectively:

WUE was highest at 100% ET (5.26 t/ac per 1,000 gallons of water), slightly greater than 80% ET (5.20), and higher than 120% ET (4.98). Although 120% ET produced the highest biomass yield, the additional water applied generated only a small increase in production (Table 3). As a result, irrigation beyond full crop requirements reduced water-use efficiency.

Table 3: WUE and NUE of Sudan grass forage under irrigation and Fertilizer treatments

WUE			
Irrigation Level (ET)	Water applied (1000 gal)	Biomass (t/ac)	WUE (t/ac per 1000 gal)
80	3.0	15.6	5.20
100	3.5	18.4	5.26
120	4.0	19.9	4.98
NUE			
Nitrogen Treatment	N Rate (lb/ac)	Biomass (t/ac)	NUE (t biomass/lb N)
N1	50	19.36	0.387
N3 (Split)	50	18.10	0.362
N2	80	16.46	0.206

Nitrogen Use Efficiency (NUE)

NUE was greatest under the 50 lb N/ac treatment (0.387 t biomass/lb N) and the 50 lb N/ac split application (0.362 t biomass/lb N). The conventional 80 lb N/ac treatment had the lowest NUE (0.206 t biomass/lb N) (Table 3). These results indicate that applying additional nitrogen above 50 lb N/ac did not increase biomass sufficiently to justify the extra fertilizer input. Together, these findings support an irrigated production system that emphasizes efficiency rather than maximum input use. Irrigation near 100% ET and moderate nitrogen rates produced strong yields while maximizing resource-use efficiency.

Reduced Risk of Forage Rejection

Excess nitrogen fertilization can increase nitrate accumulation in Sudan grass tissue (Bachie, et al, 2025). High nitrate forage may be rejected by buyers or discounted in the marketplace because of livestock health concerns. Maintaining consistent forage quality is often as important economically as maximizing yield.

Economic and Environmental Significance

The results suggest substantial opportunities to improve farm profitability. Since lower nitrogen rates produced yields comparable to the conventional fertilizer program, growers may be able to reduce fertilizer costs without affecting production. Similarly, the small yield increase obtained from 120% ET irrigation may not justify the additional water, labor, and pumping costs associated with over-irrigation. Irrigation near 100% ET is therefore likely to provide the most favorable balance between productivity and input costs. Environmental benefits are equally important.

Efficient irrigation reduces the potential for nitrate movement below the root zone, protects groundwater quality, and conserves scarce water resources. Improved nitrogen-use efficiency also reduces the likelihood of fertilizer losses and nitrate accumulation in forage while supporting more sustainable production practices. Our findings further support policies and management programs that promote ET-based irrigation scheduling, soil moisture monitoring, moderate nitrogen applications, and routine evaluation of WUE and NUE. Such practices can help improve both farm profitability and environmental stewardship across the low-desert agricultural region.

Conclusions

Results from the first two harvests indicate that irrigation management has a greater influence on Sudan grass productivity than nitrogen fertilization rate. Biomass production increased markedly between 80% and 100% ET, while additional irrigation beyond full crop water requirements produced only modest gains. Similarly, nitrogen rates above 50 lb N/ac did not significantly increase biomass production.

The highest WUE occurred at 100% ET, while the highest NUE occurred at 50 lb N/ac. NDVI successfully reflected treatment differences and showed promise as a practical crop monitoring tool. Soil nitrate data indicate that excessive irrigation may increase the risk of nitrate movement beyond the crop root zone and across the fields. Current evidence supports irrigation near 100% ET combined with moderate nitrogen applications as the most effective strategy for sustaining Sudan grass productivity, improving resource-use efficiency, enhancing economic returns, and reducing environmental risk in low-desert production systems. Additional harvests and forage-quality data will be incorporated into final recommendations as the project continues.

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Optimizing Nitrogen Fertilizer Concentration in Vegetable Transplant Production

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Introduction

California's \$7.68 billion vegetable crop industry is dependent on the use of vegetable transplants for efficient plant establishment (CDFA 2021). To produce high-quality transplants, nutrients are supplied as water soluble fertilizer through irrigation systems. Fertilizer is a low-cost input for vegetable transplant production, allowing growers to over-apply nutrients without large financial losses. Over-application of nutrients can cause poor shoot growth, decreased root growth, or disease susceptibility in vegetable transplants. In addition, excessive fertilizer application can have negative environmental impacts.

Currently, nitrogen (N) fertilizer application recommendations for vegetable transplant production are extremely broad (ex. 60-600 ppm N), and they do not have specific guidelines for the diverse range of vegetable transplants produced in California. For example, extension publications have general recommendations, such as providing "more" N for solanaceous crops, and "less" for cucurbit crops. Therefore, we evaluated N uptake of the top five vegetable transplant crops produced in California to provide clear nutrient application recommendations.

Objectives

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

Description

We applied 50, 200, and 400 ppm N to 5 vegetable transplant crops: broccoli, celery, leaf lettuce, processing tomato, and romaine lettuce. We ran the trial twice for each crop, collecting data on canopy cover, evapotranspiration, dry mass, and percent nutrient content. Originally, we intended to use transpiration and percent nutrient content to calculate a recommended fertilizer concentration.

However, due to technical difficulties with lysimeters, this was not a reliable method. Instead, our conclusions focus on the 3 N concentration treatments and their impact on vegetable transplant growth.

We shared the results through the UC Nursery and Floriculture Alliance newsletter, and we will continue to share the results through other Cooperative Extension outlets and events. The results of this study could potentially minimize nitrogen use in vegetable transplant nurseries. This could have a positive impact on water quality and minimize input costs for vegetable transplant nurseries. We will conduct follow-up conversations with vegetable transplant nurseries to determine if they decreased their fertilizer application rate.

Results and Discussion

The 200 and 400 ppm treatments had similar dry weights in Trials 1 and 2 for all 5 crops. Dry weights were significantly lower in the 50-ppm treatment, compared to the 200 and 400 ppm treatments in Trials 1 and 2 for broccoli and celery. We found no difference in dry weights between any treatments in Trial 2 romaine lettuce, Trial 2 processing tomato, and Trials 1 and 2 leaf lettuce. Based on this data, the recommended fertilizer application rate for all crops except leaf lettuce is 200 ppm N.

Our results differ from 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., 1991a; Masson et al., 1991b). For processing tomato transplant production, our results are within the range reported by other researchers (Garton and Widders, 1990; Liptay and Nicholls, 1993; Masson et al., 1991a; Masson et al., 1991b; Melton and Dufault, 1991; Vavrina et al., 1998; Weston and Zandstra, 1989). For celery production, our recommended 200 ppm N differs from previous research that found that celery transplant dry shoot biomass was maximized at 350 (Tremblay and Senecal, 1988) or 400 ppm N (Masson et al., 1991a; Masson et al., 1991b). For leaf lettuce, previous research finds that N concentrations up to 1,000 ppm benefit dry weight in lettuce transplants (Vetrano et al. 2020). There are no results in the literature to compare this to because no researchers have reported nutrient concentrations of romaine lettuce specifically.

Overall, our recommendation of 200 ppm N for vegetable transplants is lower than the recommended rates provided from previous research. This could be due to the large differences between each fertilizer treatment and relatively few treatments compared to other studies. That said, our results indicate that the overall benefit of applying >200 ppm N has little to no benefit in vegetable transplant development.

Table 1. Mean values for vegetable transplant crop experiments for trials 1 and 2. Different letters within the same column and for individual crops indicate significant differences ($p < 0.05$) in the mean values of different fertilizer treatments.

Trial	Treatment (ppm N)	Aboveground Dry Weight (g)	Root Dry Weight (g)	Leaf Count	% N Tissue Content	% P Tissue Content	% K Tissue Content
Broccoli Trial 1	50	1.44b	0.27a	21.4b	6.21a	0.54a	2.83a
	200	3.30a	0.32a	36.6a	6.12a	0.63a	3.26a
	400	3.47a	0.23a	35.4a	5.85a	0.51a	2.74a
Broccoli Trial 2	50	0.46b	0.21a	20.0a	4.23a	0.30a	2.03a
	200	1.09a	0.18a	23.8a	6.74b	0.48b	1.87a
	400	1.08a	0.18a	24.8a	8.19c	0.72c	1.93a
Lettuce Trial 1	50	0.38b	0.07a	79.0a	4.39a	0.32a	4.16a
	200	0.96a	0.02a	75.8a	5.21b	0.50b	4.27a
	400	1.19a	0.00a	79.8a	5.56b	1.63c	4.11a
Lettuce Trial 2	50	0.02a	0.0a	37.0a	3.96b	0.49b	4.84a
	200	0.0a	0.0a	40.0a	5.49a	0.69a	5.32a
	400	0.04a	0.0a	41.6a	5.77a	0.70a	5.44a
Celery Trial 1	50	0.37a	0.16b	39.6a	2.66a	0.56b	3.26b
	200	1.03b	0.12ab	39.6a	5.40b	0.92a	4.94a
	400	0.95b	0.06a	40.0a	6.52c	0.92a	5.41a
Celery Trial 2	50	0.63b	0.45b	86.0a	3.97a	0.21a	2.15a
	200	1.71a	0.57a	111.4b	5.21b	0.44b	2.50b
	400	1.78a	0.49ab	105.4b	5.71c	0.85c	3.04c
Tomato Trial 1	50	0.77b	0.34a	24.0b	2.02a	0.32a	2.00a
	200	1.77a	0.32a	34.6a	6.08a	1.02a	2.77b
	400	1.83a	0.29a	35.0a	8.10a	1.04b	4.29c
Tomato Trial 2	50	0.23a	0.10a	31.6b	3.98b	0.25b	2.16a
	200	1.20a	0.07a	37.4a	5.71a	0.40b	2.19a
	400	0.73a	0.36a	36.6ab	5.85a	0.72c	2.56a
Romaine Trial 1	50	3.17b	0.11b	33.2b	2.79a	0.50a	4.90b
	200	3.36a	0.06a	39.4a	5.60b	0.90b	6.81a
	400	3.45a	0.04a	40.0a	6.83c	1.17c	6.22a
Romaine Trial 2	50	0.31b	0.13b	39.2b	3.96b	0.49b	4.84a
	200	0.64ab	0.11a	48.8a	5.49a	0.69a	5.32a
	400	0.83a	0.10a	48.4a	5.77a	0.70a	5.44a

Conclusions

Based on the data collected, fertigating vegetable transplants with 200 ppm N optimizes root, shoot, and leaf growth. Vegetable transplant growth rates do not benefit from additional fertilizer. Applying N at a concentration of 400 ppm would decrease fertilizer use efficiency, create higher input costs, and encourage nutrient runoff for little to no benefit in transplant growth.

Acknowledgements

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

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Introduction

The 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 loss¹. While, on average nitrate (NO_3^-) leaching is reduced in systems using organic inputs, the variability in N loading is high, highlighting the need to account for the heterogeneity across systems and landscapes¹. For instance, long-term N balance research by Collaborator Brennan showed that compost use in an organic vegetable rotation led to $>100 \text{ kg N/ha/yr}$ that was either lost or stored in the soil below 30cm^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 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 pathway³. 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 byproducts⁴.

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 Conduct a greenhouse experiment to understand how increasing rates of compost application influence leaching of different N species (inorganic and organic N).
- 2 Generate and analyze data on N availability, losses and retention across a diversity of farms to inform model development.
- 3 Calibrate and validate a crop-ecosystem model, Ecosys, for lettuce production in the Central Coast of California.
- 4 Develop and test scenarios of compost application rates and timing across contrasting soil types to quantify N dynamics and losses to develop guidance on how to apply compost to support both productivity and N losses.
- 5 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

We have now completed the greenhouse column experiments testing the effect of increasing compost additions on leaching of DON and inorganic N from contrasting soil types, a sandy loam (>40% sand) and a clay loam (<20% sand) (Obj. 1), analyzed ammonium (NH_4^+), nitrate (NO_3^-), and DON from 28 fields across the Central Coast across three time points, transplant, mid-season, and harvest (1120 samples total) (Obj. 2), determined soil texture and carbon (C) and N in mineral associated organic matter (MAOM) across the 28 field sites, and conducted deep coring from the long term site and subsequently analyzed total C, N, texture, pH, and CEC. This helped shed light on whether N surpluses documented in Brennan's work were leached or stored deeper in the soil profile and these data are being leveraged to calibrate the Ecosys model (Obj. 3 & 4). Further, we executed surveys with the farmers managing the 28 field sites to collect management data from the past 5 years (Obj. 2). This allowed for determination of how management and soil variability can modulate DON loss from organic amendment applications and will help validate the Ecosys model to see if it is performing adequately on varying soil types (Obj. 3 & 4).

Finally, during the grant we have presented our preliminary findings at many farmer outreach and public workshop events, as well as the FREP Conference in 2025 (Obj. 5).

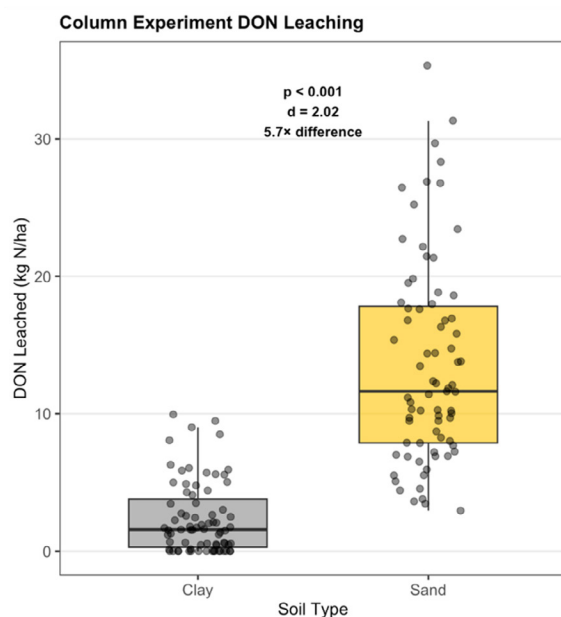


Figure 1. DON leached (kg N/ha) in column experiments by texture.

Results and Discussion

Results from the column experiments suggest that, when management is kept the same across soil types, pathways of N loss differ between soil textures. Sandier soil leached significantly more DON compared to higher clay soils ($p < 0.001$) with about six-fold more DON being lost from the sandy loam soil (Figure 1). Overall, DON accounted for 21% of total N leached in the column experiments (Figure 2). There was no significant relationship between compost application rate and DON leaching.

To understand DON production and downward mobility and characterize DON leaching risk across 28 lettuce fields, we used two complementary metrics. We assessed total DON accumulation using the change in DON (Δ DON) across 60 cm from transplant to harvest to understand how much DON was in the system (Figure 2 B1). We then assessed the Δ DON across the deeper depth interval of 30 cm – 60 cm from transplant to harvest to understand if DON was moving toward groundwater (Figure 2 B2). DON accumulated across 60 cm depth and accounted for 26% of total soil change across the entire profile (Figure 2 B1). Further, Δ DON decreased from transplant to harvest across the deeper soil profile (30 – 60 cm) and accounted for 26% of total N depletion losses (Figure 2 B2).

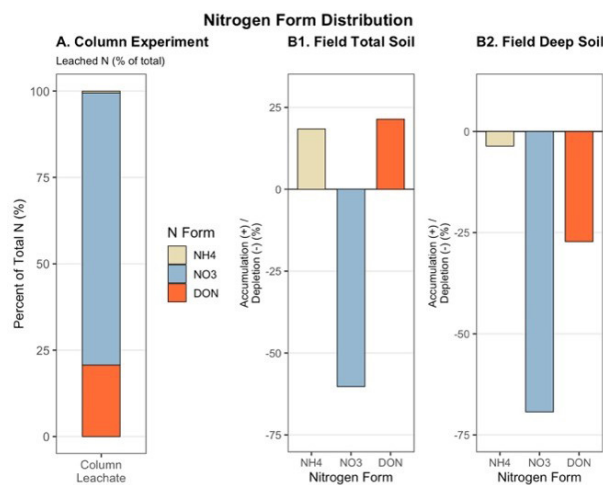


Figure 2. Illustrates nitrogen form distribution across both the column experiment and field sites

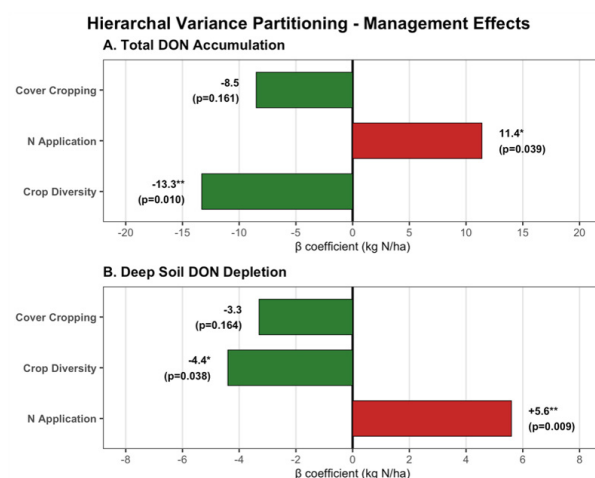


Figure 3. Hierarchical variance partitioning analysis for both DON leaching risk metrics, with beneficial effects (reduced accumulation/deep-depletion) shown in green and detrimental effects in red for specific management practices.

These results confirm significant DON leaching, consistent with van Kessel et al. (2009), who found DON accounted for 26% of leaching losses.

Interestingly, across the 28 fields spanning a texture gradient, no effect of texture was found on both metrics of Δ DON, however, management practices were significant in explaining the variation in Δ DON. According to hierarchical variance partitioning we found that management explains 2x and 32x more variation than texture for deep Soil DON depletion and total DON accumulation, respectively, with management significantly explaining variance ($p=0.045$) in Δ DON across the 60 cm at significance level of $\alpha=0.1$ and the 30 – 60 cm depths ($p=0.069$).

Among the management practices surveyed, two emerged as the primary predictors of variation for both total DON accumulation and deep soil DON depletion: crop diversity ($p = 0.010$ and 0.038 , respectively) and N application rates ($p = 0.039$ and 0.009 , respectively), with cover cropping showing a marginal directional effect ($p = 0.161$ and 0.164 , respectively) (Figure 3). Tillage intensity and frequency did not have a significant effect on Δ DON. Further, MAOM-N emerged as the second strongest predictor ($\alpha=0.1$) after management, with significant effects on both metrics ($p = 0.053$ and 0.057), indicating that greater MAOM-N is associated with reduced total DON accumulation and deep soil DON depletion.

Finally, cover cropping significantly increased the MAOM-N pool ($p = 0.005$), revealing an important potential indirect pathway: cover cropping both directly reduces DON leaching risks and enhances the MAOM-N pool, which itself reduces leaching risks. This will be further explored using a structure equation model to elucidate causal relationships between management and texture and DON loss.

Calibration of the Ecosys model has been difficult to achieve given the complexity of the model. Running through one of the long-term trial treatments, we were getting unreasonably high N leaching outputs. However, we have isolated some issues with the weather data from the CIMIS stations near the long-term trial which could have resulted in the unexpected outputs. We are continuing to calibrate the model for all 5 treatments at the long-term trial to understand how management impacts N species cycling and losses over the long term.

Accomplishments

We have finished all objectives except for analysis of the modeling results and will continue with the modeling through the end of the year. We are drafting a manuscript for submission to Agronomy Journal on the column and field results which should be submitted by December.

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

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Introduction

Effective irrigation and N management are crucial to maximizing lettuce yield while reducing environmental impacts, particularly in light of water quality regulations and water conservation demands in California's low desert. Little Gem lettuce, with its compact growth habit, is well suited to drip-irrigated production; however, information on its irrigation and N requirements under desert conditions is limited. Previous studies have demonstrated the potential of CropManage (CM) to improve irrigation and N management for other desert lettuce types, but its recommendations need to be evaluated for Little Gem production. This study evaluated Little Gem lettuce under different irrigation and N levels to determine biomass and N uptake responses and assess whether inputs above CM recommendations provide additional benefit. The goal was to develop practical information for improving water and N management in drip-irrigated Little Gem lettuce production.

Objectives

Provide data and information on crop water use and crop N uptake in desert lettuce.

- 1 Develop recommendations on best N and water management practices in desert lettuce.

- 2 Adapt the CM decision support tool for water and N management in desert lettuce.

Description

The field experiment was conducted at the UC Desert Research and Extension Center in Holtville, CA, on sandy clay loam soil. Little Gem lettuce was planted on November 13, 2025, with eight rows grown on 80-in-wide beds and irrigated throughout the season using three subsurface drip tapes per bed. The study evaluated three N treatments (N1, N2, and N3), representing 80%, 100%, and 150% of CM-N recommendations, respectively, under two irrigation treatments: I1, representing 100% of CM-recommended irrigation, and I2, representing 150% of the CM-recommended irrigation. Irrigation was the main-plot factor and N management the subplot factor in a randomized complete block design with a split-plot arrangement and four replications.

Crop canopy development was monitored weekly using NDVI imaging. Soil nitrate was monitored through laboratory analysis and soil nitrate quick tests were conducted approximately every 10 days, with results incorporated into CM for in-season N management. Soil matric potential was monitored at depths of 6, 12, 18, and 24 inches using Watermark sensors, and applied irrigation water was measured using Seametrics flowmeters.

At crop maturity, biomass yield and plant N uptake were determined for each subplot. Biomass yield was estimated using 15 randomly selected heads and final plant population. Six additional plants per subplot were composited, dried at 60°C to constant weight, ground to 1 mm, and analyzed for total N by dry combustion to determine plant N uptake. Biomass yield and N uptake were analyzed using the GLIMMIX procedure in SAS 9.4, accounting for the split-plot experimental design. Effects were considered significant at $p < 0.05$.



Figure 1. Little Gem lettuce field trial at the UC Desert Research and Extension Center during the 2025–26 growing season. Applied irrigation water was measured using magnetic flowmeters connected to a datalogger, with measurements automatically recorded and integrated into the CM platform for irrigation monitoring and management.

Results and Discussion

Mean biomass yield ranged from 19.8 to 28.8 t/ac across irrigation × N treatments (Fig. 2a). Under CM-recommended irrigation (I1), biomass increased from 22.6 t/ac at N1 to 28.8 t/ac at N2, a 28% increase, but declined to 19.8 t/ac at N3. Thus, I1N2, representing 100% of both CM-recommended irrigation and N, produced the highest numerical biomass yield. Under I2 (150% of I1), biomass increased from 23.5 t/ac at N1 to 26.0 t/ac at N2 and 27.4 t/ac at N3. Despite these numerical differences, biomass was not significantly affected by irrigation ($p = 0.363$) or N treatment ($p = 0.089$), and the irrigation × N interaction was also not significant ($p = 0.060$; Table 1).

Nitrogen uptake showed a stronger response to N management, ranging from 98.1 to 164.4 lb N/ac (Fig. 2b). Under I1, N uptake increased from 98.1 lb/ac at N1 to 164.4 lb/ac at N2, a 68% increase, but declined to 104.3 lb/ac at N3. Under I2, N uptake was 100.5, 119.6, and 102.1 lb/ac at N1, N2, and N3, respectively. N treatment significantly affected crop N uptake ($p = 0.0014$), whereas irrigation had no significant effect ($p = 0.208$). The irrigation × N interaction was not significant ($p = 0.058$; Table 1).

Considering biomass and N uptake together, the CM-recommended combination (I1N2) produced the highest numerical biomass yield (28.8 t/ac) and N uptake (164.4 lb N/ac) (Fig. 2). Increasing N from the CM recommendation (N2) to 150% of the recommendation (N3) under I1 did not provide an additional benefit; biomass and N uptake were numerically 31% and 37% lower, respectively. Similarly, increasing irrigation to 150% of the CM-recommended amount (I2) did not significantly increase either biomass or N uptake (Table 1). These results indicate that additional irrigation or N beyond CM recommendations provided no demonstrated improvement in crop performance under the conditions of this study.

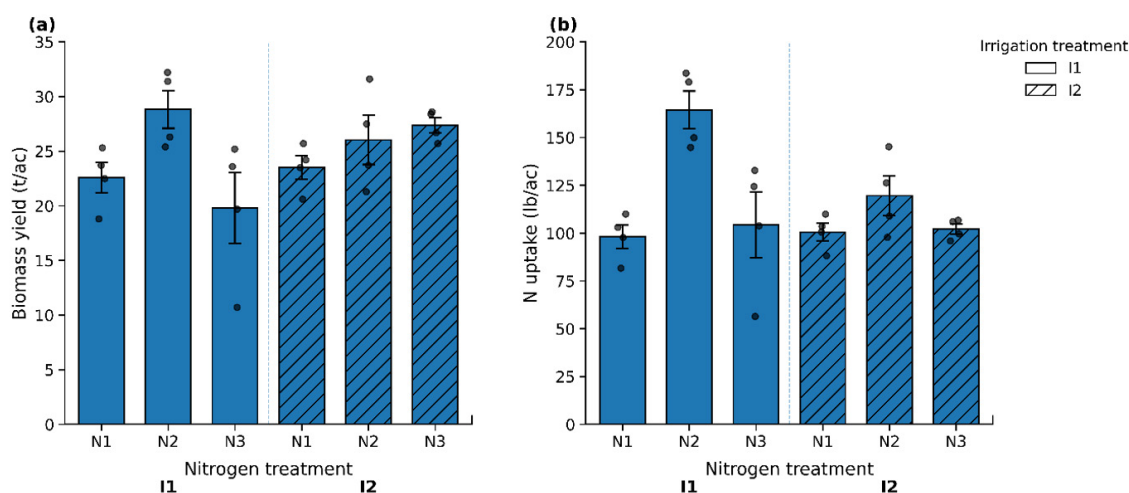


Figure 2. Effects of irrigation and nitrogen treatments on (a) biomass yield and (b) nitrogen uptake of Little Gem lettuce during the 2025–26 growing season. Bars represent means $\pm$ SE ($n = 4$), and points represent individual replicates. I1 and I2 denote irrigation treatments, and N1–N3 denote nitrogen treatments.

These findings are consistent with our previous studies of other lettuce types grown under drip irrigation in the low desert (Montazar, 2024; Montazar et al., 2025), where increasing irrigation or N inputs beyond CM recommendations did not result in corresponding improvements in crop productivity or N use. The consistency of these responses across lettuce types and studies provides further evidence that CM recommendations can provide adequate irrigation and N to support high crop performance while avoiding unnecessary inputs. Although the irrigation $\times$ N interactions for biomass ($p = 0.060$) and N uptake ($p = 0.058$) were close to the conventional significance threshold, they were not statistically significant (Table 1); therefore, the treatment-specific numerical patterns should be interpreted cautiously. Overall, the results provide further support for CM as a practical decision-support tool for improving irrigation and N management in desert lettuce production.

Table 1. Split-plot analysis of variance for biomass yield and N uptake of Little Gem lettuce.

Source of variation	df	Biomass <i>F</i>	Biomass <i>p</i>	N uptake <i>F</i>	N uptake <i>p</i>
Irrigation (I)	1	1.15	0.363	2.56	0.208
Nitrogen (N)	2	2.99	0.089	12.02	0.0014
I $\times$ N	2	3.58	0.060	3.66	0.058

Note: Effects were considered significant at $p < 0.05$. Irrigation was the main-plot factor and nitrogen was the subplot factor in the split-plot randomized complete block design.

Conclusions

The results provide further support for CM-based irrigation and N management for Little Gem lettuce. The CM-recommended treatment (I1N2) produced the highest numerical biomass yield (28.8 t/ac) and N uptake (164.4 lb N/ac). Increasing N above the CM recommendation did not improve crop performance and, under CM-recommended irrigation, resulted in numerically lower biomass and N uptake. N treatment significantly affected crop N uptake but not biomass yield, while irrigation had no significant effect on either response. Overall, CM recommendations supported high crop productivity and N uptake without evidence of benefit from additional irrigation or N inputs, supporting efficient water and N management in desert lettuce production.

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The Role of Irrigation Rate, Irrigation N, and Deep Soil Testing in Broccoli Nitrogen Management

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Introduction

Increasingly stringent water quality regulations are putting pressure on growers to reduce nitrogen (N) inputs and improve N use efficiency. A central challenge is determining how much fertilizer N can be reduced without sacrificing crop yield or quality. Doing so requires accounting for N already available in the production system and understanding how management affects whether that N is available to the crop.

The importance of these N sources differs among crops and production conditions. Broccoli is a deep-rooted crop with a strong ability to scavenge N from the soil profile, and growers often apply less fertilizer N than the crop takes up (Smith et al., 2016). The difference can be supplied by other sources, including residual soil N, N mineralized from crop residues and organic matter, and nitrate in irrigation water. However, the amount of N available from these sources can vary among fields and may be affected by soil conditions and irrigation management. Better accounting for these sources could help growers determine when fertilizer N inputs can be reduced while maintaining yield.

In this study, we evaluated the effects of fertilizer N rate and irrigation rate on broccoli yield, crop N uptake, and soil N dynamics in eight commercial conventional and organic fields spanning a range of seasons, soil textures, preplant soil N levels, and irrigation-water N inputs.

Objectives

The overall goal of this project was to provide guidance on when and by how much fertilizer N inputs can be safely reduced in broccoli by accounting for other sources of crop-available N and understanding the role of irrigation management in making those sources available to the crop.

Specifically, we aimed to:

- 1 Evaluate the effects of N rate and irrigation rate on broccoli yield and aboveground N uptake.
- 2 Assess how N rate and irrigation rate affect soil N distribution and retention through the soil profile.
- 3 Compare these responses across commercial conventional and organic ranches representing a range of soil textures, seasons, preplant soil N availability, and N supplied in irrigation water.
- 4 Evaluate how measured soil N at harvest compares with N balances used as indicators of potential N loss.

Description

We conducted eight controlled on-farm field trials in California's coastal valleys to study the effects of N rate and irrigation management on N dynamics and yield in broccoli production. The experiments took place on commercial ranches between Spring 2022 and July 2025. Fertilizer rates targeted 0 to 150% of the grower's rate, ranged from 0 to 300 lbs N/acre and were applied by hand mimicking grower practice. Irrigation was applied at either the grower-standard (GS) rate or an ET-based rate (ET) recommended by CropManage (Cahn et al., 2015), a free online decision support tool calibrated for local crops and growing conditions. Flow meters tracked water inputs, and measurements included yield, plant N uptake, and preplant, midseason and postharvest soil N concentrations. In Trials 1 and 2, soil N concentrations were measured in the 0–12 and 12–24-inch depth increments, while the other six trials included the 0–6, 6–12, 12–24, and 24–36-inch depth increments. In Trials 6 and 8, the irrigation treatment was lost due to logistical issues.

Table 1: Key characteristics of Trials 1-8. (S = Spring, F = Fall, W = Winter, Conv. = conventional, Org. = organic; Irr. N = irrigation water N concentration).

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8
Season	S '22	F '22	W '23	F '24	S'25	S '24	F '24	S '25
Management	Conv.	Conv.	Conv.	Conv.	Conv.	Org.	Org.	Org.
Topsoil texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Clay loam	Clay loam	Sandy Loam	Fine gravelly sandy loam
Irr. N (ppm)	8	8	13	58	14	18	15	68

Results and Discussion

Across the six trials with both irrigation treatments, ET-based irrigation used 6–18% less water than grower-standard irrigation (GS), without reducing yield (Fig. 1). Yields and N uptake were higher under ET in Trials 1 and 2, and ET retained more N within the root zone in several trials. In Trial 2, maximum yield was reached with 50 lbs N/acre less fertilizer under ET than GS, consistent with greater retention of N within the root zone.

Yield response to fertilizer N varied substantially among trials (Fig. 1). Yield increased with N rate in Trials 1, 2, 6 and 8, but not in Trials 3, 4, 5 and 7. All four trials without a yield response had high preplant soil N in the top three feet of the soil profile, indicating that soil N was an important source of crop nutrition. Because broccoli can access N deep in the soil profile, sampling to three feet can help identify fields where fertilizer N rates may be reduced.

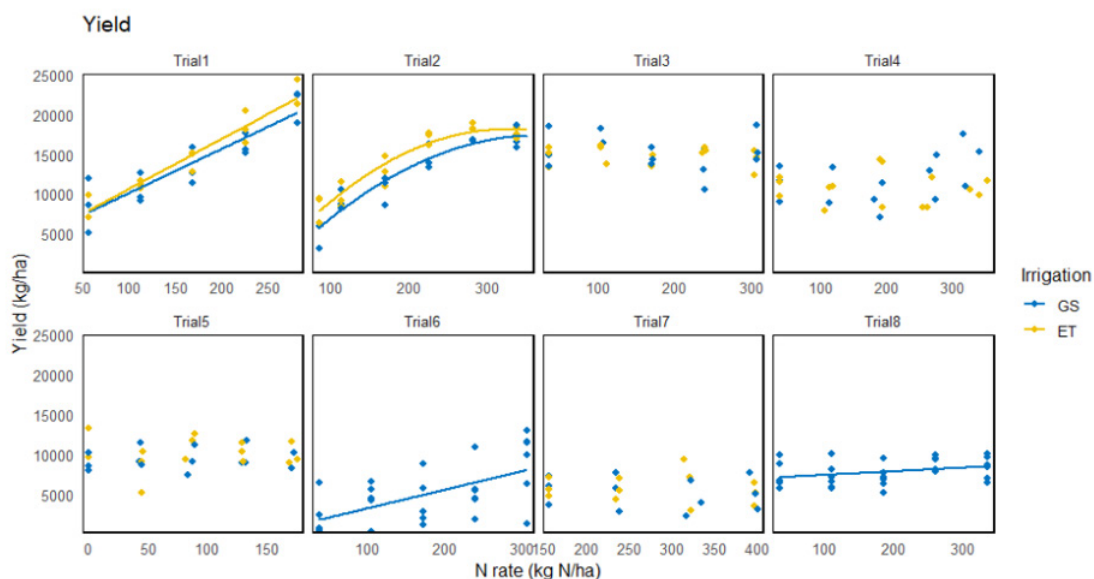


Figure 1. Broccoli yield response to fertilizer N rate under grower-standard (GS) and ET-based irrigation (ET) in eight commercial field trials.

Irrigation-water N was also an important N source, but only when available to the crop. In Trial 8, irrigation water supplied more N than the crop took up yet yield still increased with fertilizer N rate. Irrigation was approximately 80% above ET-based recommendations and much of the water was applied early in the season, before peak crop N demand. These conditions likely moved much of the irrigation-water N below the root zone before the crop could use it. Irrigation-water N can replace fertilizer N only when irrigation rate and timing keep that N available to the crop.

N balances increased with fertilizer N rate in all trials (Fig. 2), but their relationship with postharvest available soil N differed between conventional and organic systems. In conventional Trials 3-5, postharvest soil N to three feet was generally similar to or greater than the N balance.

In organic Trials 6-8, postharvest soil N was much lower than the N balance, even after accounting for expected mineralization of organic fertilizer N. This suggests that N balances may overestimate leaching risk in some organic systems, although we did not measure the fate of N after harvest.

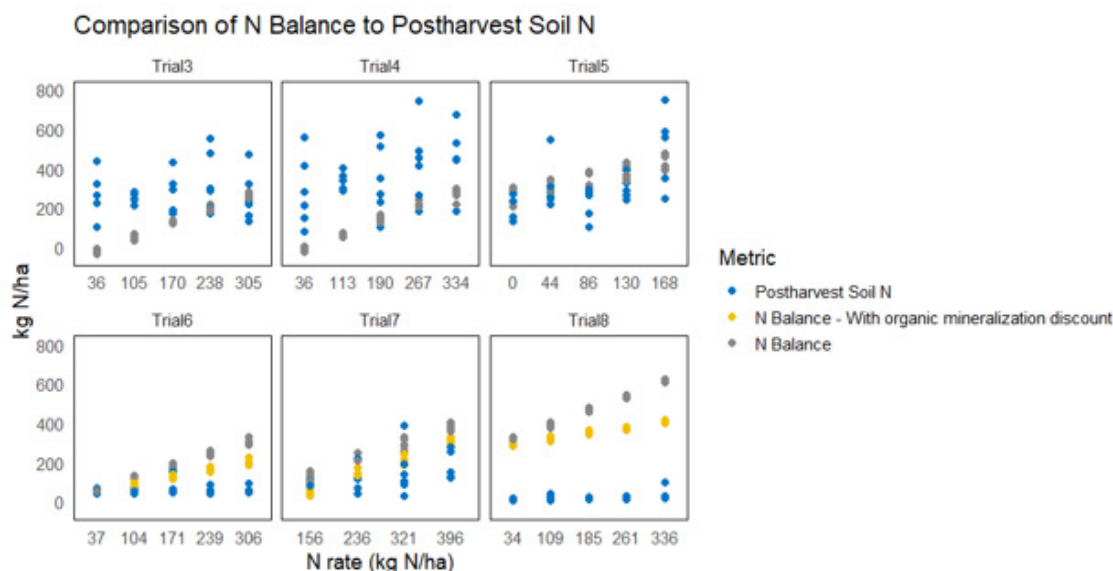


Figure 2. Comparison of N surplus represented by N balance (N applied minus N removed in harvested product) with postharvest available soil N to a depth of three feet in Trials 3–8.

Conclusions

ET-based irrigation reduced water use without reducing yield and retained more N within the root zone in several trials. In one trial, maximum yield was reached with 50 lbs N/acre less fertilizer under ET than GS. In four of eight trials, high preplant soil N helped explain the lack of yield response to additional fertilizer, highlighting the value of deep soil sampling when making N rate decisions for broccoli. Irrigation-water N can also replace fertilizer N, but only when irrigation rate and timing keep that N available to the crop. Finally, postharvest available soil N in the organic trials was much lower than indicated by N balances, suggesting that N balances may overestimate leaching risk in some organic systems.

Acknowledgements

We thank participating growers for support in the management of the trials and are grateful for financial support from CDFA-FREP. This work would not have been possible without contributions from graduate students Shane Egerstrom and Anthony Bella, and undergraduate research assistants Ria Chhabra, Lily Baglin-Bunod, and Allison Mcloughlin. This project was further supported by the Grimm Family Center for Organic Production and Research at Cal Poly San Luis Obispo.

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Facilitating Grower Adoption of Cover Crop Nitrogen Scavenging to Minimize Residual Nitrogen Loss and Comply with the Irrigated Lands Water Quality Protection Program (Ag Order 4.0) on the Central Coast of CA

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Introduction

Intensive specialty crop rotations in the central coast region depend on recurrent nitrogen inputs and often leave a considerable amount of residual nitrogen in the soil, which is highly susceptible to leaching below the root zone, especially during winter rains. Losing residual nitrogen is a missed cost-savings opportunity and can cause water quality impairment, affecting environmental and human health. With good management, residual nitrogen can be reused for subsequent crops, lowering input costs and avoiding water contamination. Cover cropping is one of several soil management practices that can help to recover and recycle nitrogen from crop residue mineralization and excessive fertilizer application through 'nitrogen scavenging'. To help growers quantify and demonstrate the recovery (uptake) of residual nitrogen, USDA-ARS, UCANR, CLGRB and the RCDs of Monterey and Santa Cruz Counties partnered in 2021-2022 to conduct research trials and develop simple methods to quantify the cover crop shoot biomass production and its associated %N (N uptake) and C:N ratio (Brennan and Smith 2023, Brennan 2022). This project is facilitating grower adoption of such methods through education, outreach, 1:1 technical assistance and cost-share for cover crop implementation.

Objectives

- 1 Educate central coast growers on the practical application of a validated method to estimate the biomass and C:N ratio of a winter cereal cover crop, based on simple field-based measurements and observations, to demonstrate residual nitrogen recovery (scavenging) by winter cover crops, in the context of a regional water quality regulation (Ag Order 4.0).
- 2 Facilitate and guide grower adoption of winter cover cropping (with cereal cover crops) and the proposed nitrogen scavenging verification method to reduce residual nitrogen loss and receive full credit for 'nitrogen removal' in the context of Ag Order 4.0's Applied (A) minus Removed (R) nitrogen limits and targets.
- 3 Demonstrate and disseminate the proposed methodology and lessons learned to a broader community of growers and certified crop advisors (CCAs) through outreach events and print materials in multiple languages.

Description

The project goal is to facilitate grower adoption of winter cover cropping and demonstrate research-validated methods to easily and confidently estimate cover crop biomass, C:N ratio, and associated N uptake, helping growers to quantify and take advantage of cover crop N scavenging to supplement nitrogen inputs for subsequent crops and meet regulatory requirements under the irrigated lands program - Ag Order 4.0 (assuming that the current A-R credits, limits and targets will still be applicable after the conclusion of the current remand process). The project is using outreach, training, and technical assistance to demonstrate and support grower adoption of winter cover cropping for N scavenging on the central coast. Multiple field-scale demonstrations were implemented on commercial fields during winter of 2024 and 2025 and will continue in 2026. Participants receive one-on-one technical assistance, cover crop seed cost-share, and planting guidelines. Soil N concentrations are measured on all fields using the soil nitrate quick test before and after each cover crop cycle. Participating growers are trained on how to collect simple measurements of a cover crop 3-4 months after planting and use a calculator to estimate the amount of nitrogen scavenged. Findings and lessons learned from field trials are being shared with other growers and certified crop advisors (CCAs) in the region through outreach events (field days) at different locations in the Salinas and Pajaro valleys, and guidance documents (accessible in print and electronic formats) that illustrate the protocol and benefits of this practice in the context of Ag Order 4.0. Field days are tailored to growers of different scales, crops and cropping systems, and focus on general education about the Ag Order, practical demonstration of cover crop N scavenging credit quantification and reporting, and broader benefits associated with the use of cover crops for nitrogen management.

Guidance documents will provide a reference on methods for reporting a cover crop N credit under Ag Order 4.0, and considerations for effective management of winter cover crops. These documents will be available in English, Spanish and simplified Chinese script (the written language for Cantonese speakers) to support a wide range of growers on the Central Coast.

Results and Accomplishments

Direct individual assistance to growers:

- Since the beginning of the project 44 participating farming operations have signed up to implement cover cropping (receiving cost-share for seed) and participated in education events and 1:1 training on simple field-based quantification methods to estimate nitrogen scavenging.
- 32 farming operations planted winter cover crops (Merced Rye cereal grass) on 36 different fields in 2024 and engaged in nitrogen scavenging quantification training and practice in early 2025. 27 farms planted winter cover crops in 2025; 18 of them planted Merced Rye, 2 planted Pacheco Triticale, and 7 planted a cereal-legume mix (Merced Rye + Lana Vetch), adding a legume to further boost soil fertility for early spring vegetable crop plantings. The project team decided to allow this flexibility to accommodate grower preferences and needs and given the ongoing uncertainty around new Ag Order 4.0 updates.
- The project team conducted soil nitrate quick tests (SNQTs) to estimate the soil nitrogen levels before and after each cover crop planting and documented the duration (no. of days) of each planting and measured shoot length and Feekes stage to estimate cover crop biomass, C:N ratio and amount of nitrogen scavenged. In 2026 we also took a second SNQT several weeks after cover crop termination (and before any fertilizer N application) on a subset of sites (mostly sites with cereal-legume mix). These results showed that mineralized nitrogen from the cover crop residues started to become available (detected as NO₃-N) 20-25 days after termination and ranged from 4-7ppm NO₃-N even up to 70 days after termination.

Year 1 results (winter of 2024)

n=36	Cover Crop duration (# days)	Cover Crop shoot length (in)	Cover Crop biomass (lb/ac)	Cover Crop C:N ratio (based on Feekes stage)	Soil N before CC (ppm NO ₃ -N)	Soil N at termination of CC (ppm NO ₃ -N)	N Scavenged (lb N/ac)
MIN	74	14.5	1,525	10:1	3.2	0	58
MAX	159	65.1	11,020	33:1	74	15	179
AVG	105.6	38.4	6,276	26:1	19.3	1.2	102.6

Year 2 results (winter of 2025)

n=20*	Cover Crop duration (# days)	Cover Crop shoot length (in)	Cover Crop biomass (lb/ac)	Cover Crop C:N ratio (based on Feekes stage)	Soil N before CC (ppm NO ₃ -N)	Soil N at termination of CC (ppm NO ₃ -N)	N Scavenged (lb N/ac)
MIN	84	26	3,688	11:1	0	0	53
MAX	117	48.9	7,918	42:1	32.2	2	130
AVG	100.6	34.87	5,286	27:1	9.2	1.2	85.1

*cereal-legume cover crops were excluded from the N scavenged analysis

Education and Outreach:

During the past 30 months the project team has:

- Collaborated with central coast ag industry groups, grower and shipping companies and academic researchers to coordinate education and outreach events on cover cropping and nitrogen management.
- Presented at several farming conferences on the multiple benefits of cover crops emphasizing nitrogen recovery and management in the context of Ag Order 4.0 (2024 Latino Farmer Conference, 2026 Eco-Farm conference).
- Hosted a series of educational field days and classroom trainings (in Spanish) on the use of cover crops for nitrogen management with a group of 9 small, diversified farming operations, in partnership with Kitchen Table Advisors.
- Co-hosted and presented at workshops and educational events for growers on the central coast, including: a) 2024 California Marine Sanctuary Foundation's event "Unlocking the Power of Cover Crops: Benefits, Risks and Ag Order Updates" (audience included growers, farm companies, and certified crop advisors); b) 2025 RCDMC workshop for Spanish-speaking growers discussing water conservation, water quality protection and nutrient management aspects of cover cropping (54 attendees, mostly small diversified farming operations); c) 2025 Dole Vegetables, cover crop field day; d) 2025 L.A. Hearne cover crop seed demo field day (attendees included CCAs, growers, consultants, technical assistance providers, and researchers).
- Collaborated with technical advisor Dr. Eric Brennan from USDA-ARS to develop a practical guide and calculator to quantify cover crop nitrogen scavenging.



Figure 1. Cover crop field days hosted by RCD of Santa Cruz and Monterey Counties

Conclusions

Using winter cover crops to recover and recycle end-of-year residual nitrogen for crop production during the following growing season is an advisable practice for several reasons, including input cost savings, water quality protection, soil fertility enhancement and maintaining an active and diverse soil microbiome. Using relatively simple measurements and observations of a cover crop and tracking the days after planting it is possible to confidently estimate the total amount of recovered (scavenged) nitrogen in a field and claim it as a “Removed N” credit in the context of Ag Order 4.0 regulatory compliance. This project provides training and one-on-one technical assistance for growers to adopt this practice and quantify its benefits.

Acknowledgements

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Estimating Mineralization and N Utilization from Banded Compost Applications in Drip Irrigated Sweetpotatoes and Processing Tomatoes

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Introduction

Composts are important sources of nutrients for crops and are increasingly popular to maintain or improve soil health. The contribution of compost to crop-available nitrogen (N) depends on net N mineralization, which is affected by temperature, moisture, soil texture, composition of the composts, and management practices. In Merced County, the application of poultry and dairy manure compost to supply part of the N required by crops is commonly used in sweetpotatoes and processing tomatoes.

California is a major producer of sweetpotatoes, with annual production around 700 million pounds from 18,500 acres. Most of this production occurs on the sandy soils in Merced and Stanislaus Counties. Both organic and conventional growers frequently apply a band of composted poultry manure under the surface drip tape, then supplement fertilizer N through the drip tape during the growing season. Merced County is also a major producer of processing tomatoes, with over 1 million tons annually on about 25,000 acres. Production generally occurs on clay loam soils using subsurface drip irrigation. Compost may be band applied and incorporated in the fall into the bed above the buried drip tape. As with sweetpotatoes, additional N is supplied through the drip system during the growing season.

Previous research found that less than 30% of the total N applied with poultry manure compost is mineralized within six months when incorporated in early April under typical climatic conditions of the San Joaquin Valley. Observations in sweetpotato fields, however, suggest that very high decomposition and N mineralization rates occur, as the compost is no longer visible by the end of the 120-day season. Therefore, we may underestimate N availability from the compost. Consequently, application rates may need further refinement.

Objectives

The objective of the project is to develop N budgets for sweetpotatoes and processing tomatoes in Merced County where the crop nutrient sources include both compost and mineral fertilizers as fertilizer sources. Specific objectives are:

- 1 Determine N release of commonly used manure composts in field trials.
- 2 Investigate the effects of soil texture on N mineralization.
- 3 Determine the accumulation of N in the vines and storage roots of sweetpotato plants throughout the growing season.
- 4 Conduct outreach and develop user-friendly tools for growers and consultants.

Description

This report focuses on trials conducted in sweetpotato fields during the first two years of the project (2024 and 2025). The trials were in commercial fields near Ballico (project sites B1 and B2) and Turlock (project sites T1 and T2). At all sites, the soil texture in the top foot was a loamy sand with total carbon (C) content < 0.5% (Table 1).

Table 1: Soil properties at the trial sites. Samples were collected in spring from the top foot of the profile. Total nitrogen (N) was determined by dry combustion, while pH and electrical conductivity (EC) were measured on a soil water slurry. Values for EC would be approximately three times higher in a soil paste extract. Potassium was extracted with ammonium acetate.

Site	Year	Sand	Clay	pH	EC	Total C	Total N	K	Olsen P
		%	%		dS/m	%	%	ppm	ppm
B1	2024	83.6	3.2	6.7	0.10	0.35	0.037	44.5	9.0
T1	2024	78.0	5.3	6.9	0.20	0.49	0.051	140.4	46.6
B2	2025	83.6	3.2	6.9	1.62	0.31	0.033	90.1	15.9
T2	2025	78.0	5.3	6.7	1.59	0.44	0.047	106.0	41.7

Composts made from poultry manure, steer manure, and almond hulls were surface applied prior to transplanting in a 6-8"-band in the center of the bed, 20" from the plant row, and not incorporated. Surface drip tape was then placed on top of the compost band. The results reported here are from two treatments: (i) control plots without compost and (ii) plots with the growers' compost application rate. In-season fertilizer N was applied through the drip tape. Compost C to N ratios ranged from 11.0 to 15.4 (Table 2). Plots were 3 beds wide (20 ft) and 50 ft long with four replications. Sweetpotatoes were transplanted between May 1st and May 17.

Table 2: Properties of the composts used at the sweetpotato field sites for the 2024 and 2025 season. Total carbon (C) and nitrogen (N) are shown in percent of dry matter (DM) while the application is the measured fresh weight.

ID	Year	Dry matter (%)	Total N (%)	Total C (%)	C to N ratio	Rate (tons/ac)
B1	2024	68.3	0.90	13.9	15.4	3.9
T1	2024	74.1	1.11	15.3	13.8	5.9
B2	2025	66.3	1.42	15.6	11.0	6.9
T2	2025	68.6	1.08	12.7	11.8	5.9

Every three weeks during the growing season, soil samples from the center of the bed were collected from the top 2 ft of the profile from both treatments, then analyzed for ammonium-N and nitrate-N. At the same time, litter bags were removed and analyzed for total dry matter, carbon, and N content. Root and vine biomass samples were collected from beds surrounding the trial in areas where compost was applied, then dried and analyzed for dry matter and total N content. Irrigation water samples were also collected and analyzed for nitrate-N.

At harvest, storage root yield, plant dry matter and N concentration in the vines and roots were determined in all plots. At site B2, however, the vines were mowed before samples were collected.

To address Objective 2, an 18-wk laboratory incubation was set up using the composts from each field trial. The soil for the incubation was collected at site B1. Samples were incubated at 25 °C and ideal moisture content for N mineralization (i.e., 60% of the soil's water holding capacity). At weeks 1, 3, 6, 12, and 18, soil samples were analyzed for ammonium-N and nitrate-N. Net N mineralization of compost N was calculated as the difference between the unamended control and the treated sample at each time step.

Results and Discussion

Analyses of the soil samples taken from the center of the bed in 3-week intervals suggest minimal impact of compost application on plant-available N in the soil. Furthermore, compost treatment had no significant effect on total N in the biomass (roots and vines), or marketable yield at any site (Table 3). The comparison with results from previous research projects suggests that N mineralization from composts is not fundamentally different in the soils and cropping systems of the current project.

Table 3: Total nitrogen (N) in the biomass (vines and storage roots) at harvest and marketable root yield. Marketable yield was determined by commercial harvest equipment. Values in parentheses are standard error of the mean (n=4).

Site	Total N in biomass (lb/ac)		T-test	Marketable yield (lb/ac)		T-test
	No compost	With compost	p -value	No compost	With compost	p -value
B1	192.1 (10.7)	226.1 (26.3)	0.28	48,176 (7,577)	51,786 (7,066)	0.74
T1	101.7 (9.0)	103.0 (4.4)	0.90	28,983 (2,306)	26,347 (4,096)	0.60
B2	NA	NA	NA	32,912 (4,739)	34,357 (1,419)	0.78
T2	155.2 (15.2)	142.7 (14.0)	0.57	26,988 (5,411)	24,249 (1,693)	0.65

NA: data not available

During the 18 weeks of incubation under optimal conditions, between 11 and 18% of the total N in the compost mineralized (Figure 1). Most N mineralized within the first three weeks of incorporation. The N uptake curve followed a sigmoidal (S-shaped) pattern. (Figure 2). Across the four sites, total biomass (vines and storage roots) contained 177 lb N/ac at harvest. The storage roots contained 98 lb N/ac, which accounted for 55% of the total. While the data collected to date do not support the hypothesis that greater N mineralization occurs under the unique production system found in sweetpotatoes, the rapid release of N suggests greater NUE could be achieved with delayed compost application timing. Further research is planned.

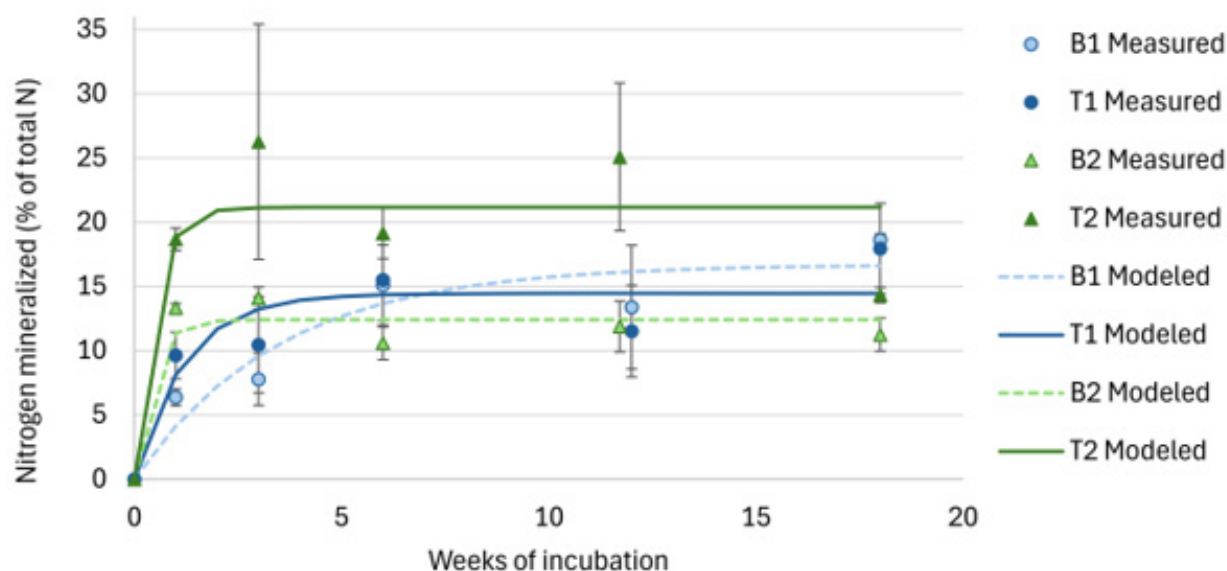


Figure 1: Results of a laboratory incubation of three composts in sandy soil. Data points show an average of observed values at every time point, while trend lines were modeled. Standard error bars are shown.

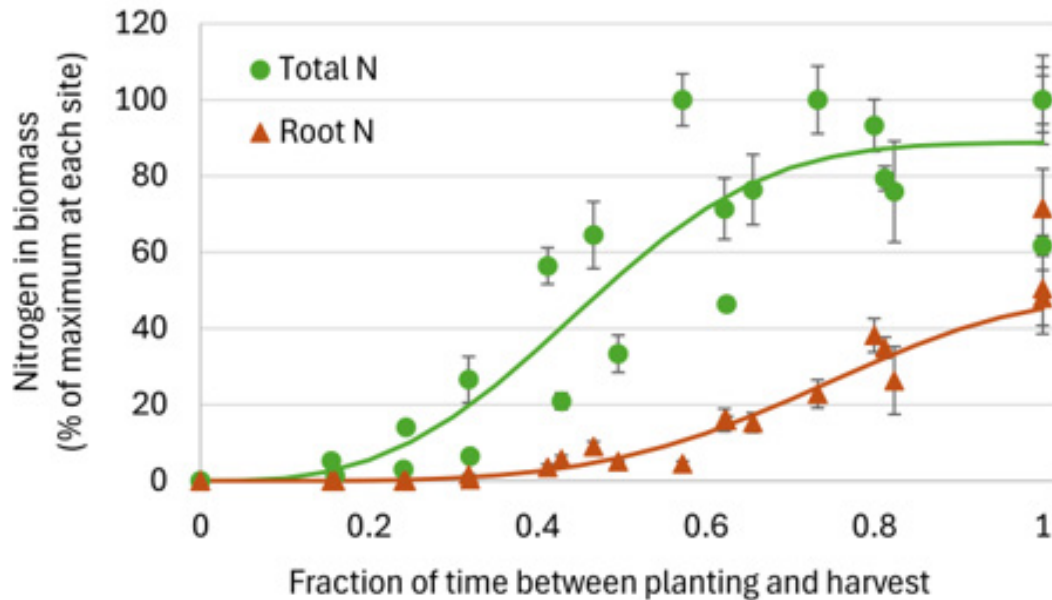


Figure 2: Measured and modeled N uptake in total sweetpotato biomass (roots + vines) and belowground biomass (storage roots). Data points show an average of observed values at every time point, while trend lines were modeled. Standard error bars are shown. The length of the season ranged between 16 and 19 weeks.

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Nitrogen Movement Out of Root Zones in Central Valley Irrigated Lands: a Multi-Scale Management, Monitoring, Modeling, and Outreach Project

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Introduction

To comply with the Central Valley (CV) Irrigated Lands Regulatory Program (ILRP) to reduce nitrate leaching, growers use advanced irrigation and fertigation methods, often guided by decision-support tools like CropManage (CM). ILRP Coalitions assess the efficacy of these practices on 5.2 million acres using specialized models (CV-SWAT and CV-NPSAT) that track water and nitrate movement through soil and groundwater, under the condition that they be continually refined. CV-NPSAT's refinement is funded and ongoing; however, CV-SWAT requires validation against new, more detailed field data. Project leaders have created an extensive Cal Vadose Zone Monitoring Network to study nitrate leaching in key crops, including almonds, oranges, and processing tomatoes.

This project will leverage existing and new data from this monitoring network to ultimately improve the performance of CV-SWAT and encourage the use of decision-support tools like CM.

Objectives

- 1 Evaluate and enhance the performance of CV-SWAT in quantifying the effects of irrigation and nutrient management practices on nitrate leaching.
- 2 Evaluate uncertainty in predicted nitrate leaching through inter-model comparisons (CV-SWAT, APEX, and HYDRUS) and comparisons with field measurements.
- 3 Expand the application of CM by adding data and algorithms for orange, lemon, and mandarin crop types.
- 4 Integrate results from monitoring, management, and modeling efforts to inform outreach to water quality stakeholders at multiple in-person and/or virtual events.

Description

This project workflow (Figure 1) involves integrating data from three study sites, evaluating grower-implemented practices relative to CM's recommendations, validating process-based models, and quantifying the effects of management practices on nitrate leaching.

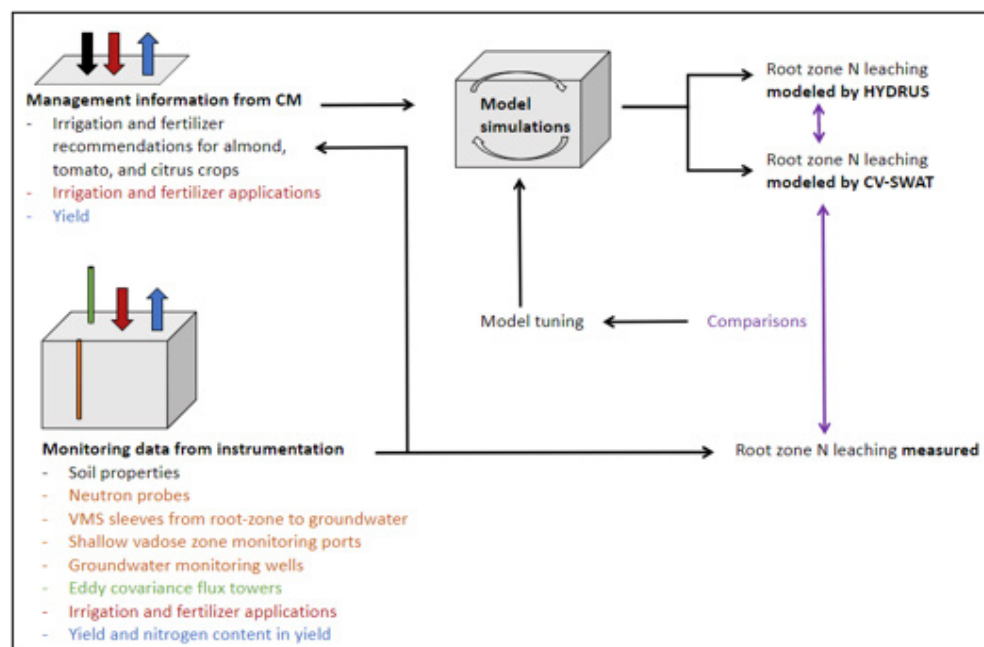


Figure 1. Project schematic integrating management data, monitoring data, and modeling simulations.

This project leverages 3 existing, funded, intensively monitored research sites that are uniquely suited to quantifying nitrate leaching using field-scale mass balance, vadose zone monitoring, and groundwater monitoring. Data collection includes nitrate leaching collected using vadose zone monitoring, evapotranspiration collected using eddy covariance flux towers, irrigation and fertilizer applications, groundwater observation well networks for water levels, neutron probe for soil moisture, soil sampling, and yield (Raij-Hoffman et al., 2024). Using this data, this project is evaluating and verifying CM efficacy in minimizing nitrate leaching while maintaining or improving production. Monitoring and management data is being integrated into CM to derive recommendations that are compared against actual practices. This data is also used to create CV-SWAT modeling scenarios for each site. First, we compare measured leaching against modeled leaching estimates using the “Root-zone Library” of existing, calibrated model scenarios.

Second, we compare measured and modeled water and nitrogen balances using CV-SWAT simulations which are customized to reflect site-specific management practices. Modeling efforts are underway to compare CV-SWAT output with APEX-simulated nitrogen leaching out of the root zone.

Results and Discussion

Monitoring Data Collection. The three-tiered monitoring network was maintained across the Esparto, Bowman, and Booth sites, with continued field-scale, vadose-zone, and groundwater monitoring despite challenging winter conditions and infrastructure issues. At Esparto, monitoring captured hydrologic conditions, including rainfall and ET (Peddinti et al., 2025), vadose-zone processes, groundwater conditions, and changes in the adjacent slough. At Bowman, monitoring included VMS and lysimeter sampling, neutron probe measurements, groundwater well sampling, and post-season and pre-season soil sampling. At Booth, monitoring continued where feasible following vandalism while damaged infrastructure was assessed and recovery options evaluated. A cooperating citrus grower has provided a new, more secure site with excellent conditions for monitoring nitrate leaching across orchards of different ages. Monitoring data, including vadose-zone, groundwater, and soil measurements, were also organized and quality-controlled to support analysis of seasonal hydrologic and nitrate trends.

CropManage Evaluations. Utilization of CM at the 3 study sites is ongoing. The grower managing the almond site uses decision-support technology to automate site-specific irrigation scheduling based on ET and soil moisture, deficit irrigate when appropriate, and implement high-frequency, low-volume fertigation practices. As a result, irrigation water is applied very efficiently and below the current CM recommendation, though drought stress has not historically been observed. To better align CM with grower practices, we conducted canopy cover measurements to locally refine crop coefficients. The annual cropping system at Esparto’s applied water, measured using 6” flow meters installed at this site, was comparable to CM recommendations throughout the growing season.

Similar observations were made at the Bowman almond site. Nitrogen use efficiency was relatively high in both systems and consistent with yield-based N requirement estimates in CM. For the citrus site, an experimental model has been set up for use, while a complementary FREP project aims to improve CM citrus modules.

Root-zone Modeling. Local CV-SWAT models representing each site have been set up to simulate historical management and crop productivity for the annual cropping system and almonds (citrus is forthcoming based on a new site that is currently being established). For the almond site, CV-SWAT currently underestimates crop ET compared to OpenET estimates, but comparisons to eddy covariance data are forthcoming, and uncertainty in ET at this site has been investigated due to water balance anomalies (Jordan et al., 2024). Regarding crop growth, N uptake, yield, and N removed, CV-SWAT aligns with average conditions for the almond fields, though it does not capture the year-to-year variability since a single set of crop model parameters is used. For the annual cropping system, CV-SWAT aligns more closely from year to year as unique crop models are applied for each growing season. The SWAT Calibration Uncertainty Program (SWAT-CUP) is being applied to evaluate whether local model results can be adjusted to better match measured data on moisture content and nitrate concentrations in the vadose zone. Preliminary results show that adjustments to crop model ET parameters and soil properties improved agreement in in-season ET and soil moisture but did not substantially change nitrate leaching estimates or improve agreement in nitrate concentrations. When comparing nitrate leaching estimates from the custom CV-SWAT models and the “Root-zone Library” approach, there tends to be good agreement (see Figure 4b), particularly over multiple growing seasons, highlighting the rigor of the ILRP approach applied to the landscape.

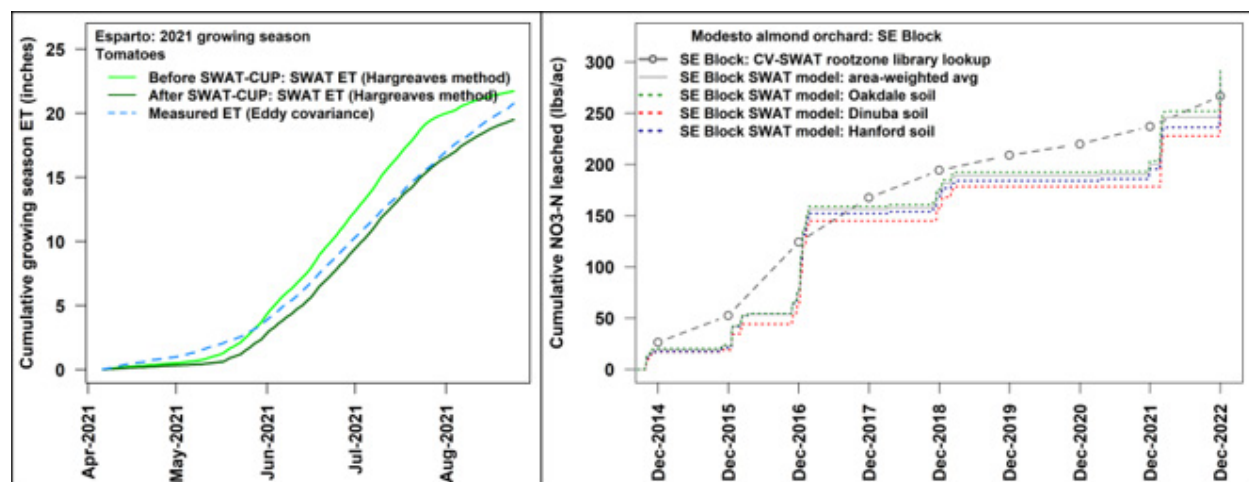


Figure 2. Example of output from a customized CV-SWAT model for an almond block showing a) a nitrogen mass balance over 10 years of production and b) a comparison of cumulative nitrate leaching using the “Root-zone Library” lookup approach.

Conclusions

- Monitoring data confirms that stacking conservation practices (e.g., cover crops, irrigation nitrogen credit) reduce residual soil N at the end of the crop season that could leach in the winter.
- Decision support tools for irrigation and N management can help optimize N management.
- Nitrate leaching from agricultural lands is measurable using mass balance, vadose zone, or groundwater monitoring approaches, but uncertainty varies between approaches, with the highest uncertainty in field mass balance.
- Deep vadose zone monitoring is a very useful tool to continuously monitor the fate and transport of nitrates between the root zone and the groundwater table.
- The new citrus site will provide robust data to improve understanding of nitrate leaching dynamics across orchards of different ages and support root-zone modeling.
- Root-zone models integrating crop x soil x climate x management information can produce robust estimates of nitrate leaching that can be difficult to measure.
- Preliminary results illustrate consistency in nitrate leaching estimates between the ILRP modeling approach and more data- and labor-intensive site-specific modeling.

Acknowledgements

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No-Till Planting of Rice to Conserve Water and Ensure the Sustainability of Rice Systems

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Introduction

The sustainability of California rice systems is being threatened by ongoing rainfall related issues (drought or late rains) with significant reductions in rice area due to them. This has both economic and environmental impacts. Rice systems use a significant amount of water, but there are limited options for reducing water use in California while maintaining an economically viable crop. California rice farmers water-seed rice and evaporation losses are high during the first month of the season. Dry-seeding is the practice of planting rice (broadcasting or drilling) into a dry seedbed (similar to corn). Since there is no reliable rain, fields are flush irrigated two or three times during the first month, after which fields are permanently flooded. However, water use between these two systems is similar (Linquist et al., 2015). One option is to dry-seed into a field that has not been tilled (no-till, NT). One of the purposes of tillage is to dry the soil in order to prepare a good seedbed. With NT, soil moisture in the soil is conserved. In fact, water conservation is one of the big benefits of NT in other cropping systems (Busari et al., 2015). In rice systems, NT is not widely practiced; but given the promise of the NT system for water conservation, it is an important area to investigate. If successful, such a practice will help ensure continued rice production and still provide the other valuable ecosystem services that the rice system provides.

There are many challenges to developing NT systems. Complicating the challenge are a wide range of potential field conditions before planting, which relates to how fields were managed the previous year. This includes where fields were fallowed in the previous year and tilled (common following drought years) or, where rice was grown, straw may have been left on surface, removed for off-site use or burned. Our goal is to develop the agronomic information required to make these systems viable and sustainable.

Objectives

- 1 Develop robust fertility practices (examining different rates and timings of fertilizer applications).
- 2 Test options to optimize stand establishment (i.e. settings on no-till drills).
- 3 Quantify water inputs to develop a water budget and estimate evapo-transpiration losses.
- 4 Monitor weed populations and develop weed control methods.

In all study years, research occurred at the Rice Experiment Station (RES). In the 2nd and 3rd years, we included on-farm trials. Throughout, we engaged with farmers, CCAs and PCAs through field-days, winter grower meetings and informal meetings.

Description

In 2024 through 2026, we conducted a replicated field experiment at the RES to evaluate three NT drill seeded systems. The treatments were NT drill seeding into three different seed beds: (1) a seedbed that was fallowed and worked the previous year, (2) a seedbed that had rice in the previous year and the straw was removed, and (3) a seedbed that had rice in the previous year and the straw was chopped and left on the surface. These NT systems were compared to a water-seeded conventional control. In all treatments we compared different N rates and different N sources/timing. We also quantified water use in each system. In 2025 and 2026, we had two on-farm trials (one in Colusa County and the other in Butte County) where an N trial (similar to RES) was set up.

Results and Discussion

The 2024 and 2025 results will be discussed (2026 trials have not yet been harvested).

Yield potential and response to N: There were significant differences in yield as a result of both system and N rate. The WS treatment had the highest yield in 2024 and in 2025 the NT Fallow was the highest (Figure 1). The yield potential between WS and NT-Fallow may be similar; however, the annual differences in yields may be due to differences in planting date. For example, 2025 July temperatures were the hottest on record. The NT treatments were all flowering in July which can cause sterility and reduced yields (Espe et al., 2017) while the WS treatment (planted 3 weeks later), flowered in mid-August and avoided that extreme heat. In all cases, the lowest yields were in the strict NT treatments. The optimal N rate to achieve the highest yields in each treatment was 175 for the WS and between 190 and 210 for the various NT treatments.

The higher N requirement for the NT treatment is likely because the urea fertilizer is being surface applied and is more susceptible to N loss.

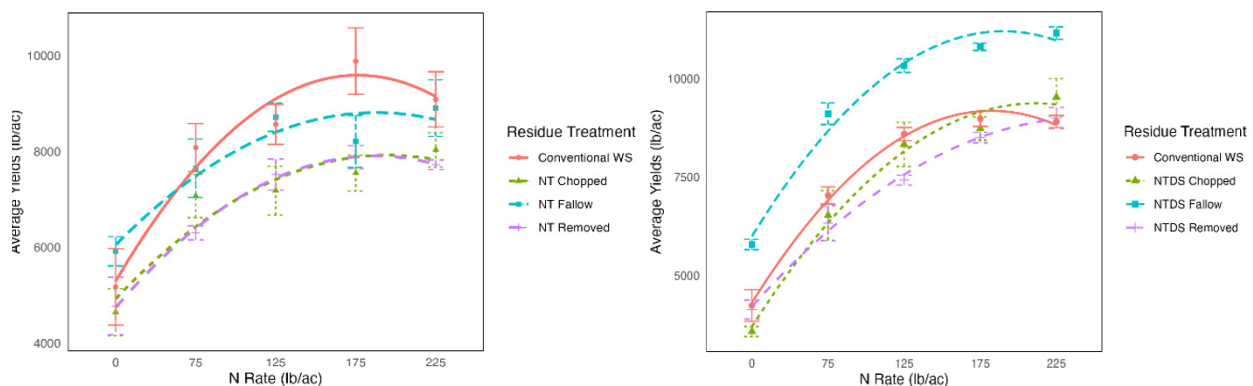


Figure 1. Yield response to N rate in water seeded (WS), Previous year fallow with summer prep stale seedbed (Fallow) and rice the year before with straw chopped and straw removed. Data is for 2024 (left) and 2025 (right).

Response to N source and split: We evaluated four N sources (urea, Anvol, SuperU and manure) and a split N application of N. This was compared to zero N being applied. There was not a significant interaction between systems and N source/management. All N treatments resulted in a significant yield increase, although the yield increase was lowest when manure was applied (Figure 2). For the other N treatments, the yield response was similar among them in both years. This suggests that a single pre-flood application of urea is the best option as it is the cheapest option and requires only one pass (as opposed to a split application).

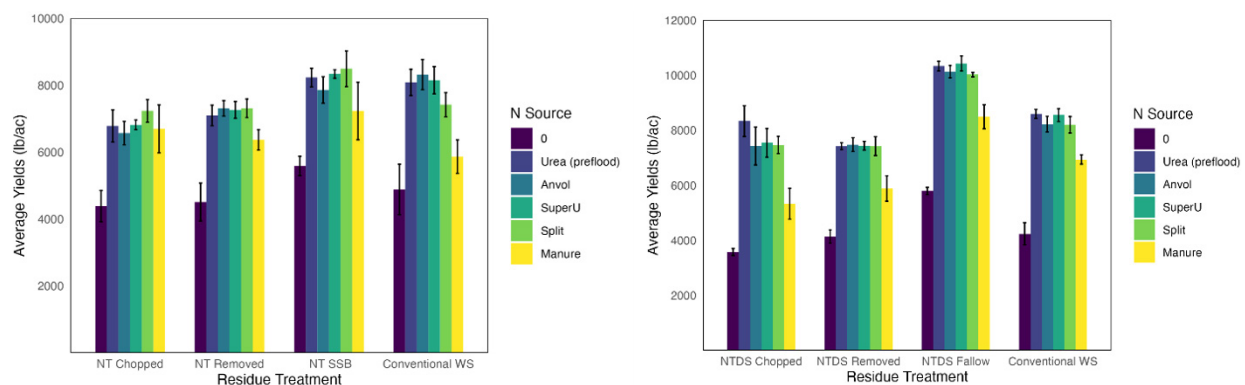


Figure 2. Yield response to varying N sources and management practices (2024 on left and 2025 on right). All N was applied at a rate of 125 lb N/ac.

On-farm trail: In 2025 we had an on-farm trial in Colusa county. The field had been in tomato the previous year. After tomato harvest, a seedbed was prepared similar to the NT-Fallow treatment. Results were very similar to what was seen at the RES. The optimal N rate was 175 lb N/ac and the pre-flood single application of urea provided similar results to the other N treatments, with the exception of the manure treatment which had the lowest yields (Figure 3).

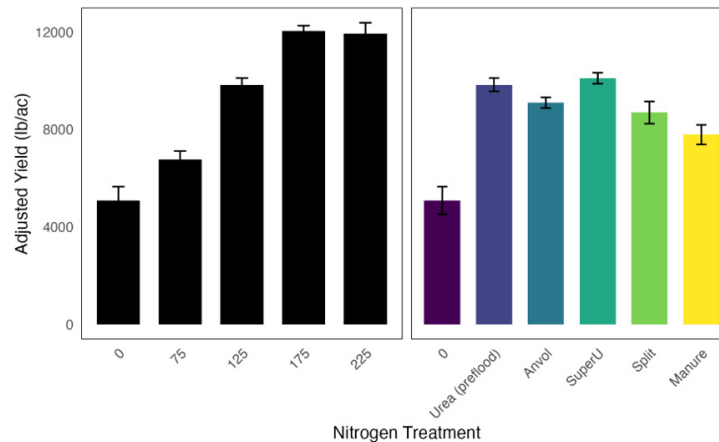


Figure 3. 2025 on-farm (Colusa county) yield response to N rate applied as urea (left) and N source (right). All N was applied at a rate of 125 lb N/ac.

Water savings: Consumptive water use (or ET) was determined for each system. The differences in ET between the NT systems was not significant; however, the NT systems reduced ET by 100 mm (13%) and 58 mm (8%) compared to the water-seeded conventional treatment in 2024 and 2025, respectively (Table 1). Roughly half of the water savings was due to reduce ET during the first month of establishment. In water seeded systems, the fields are flooded during the first month and evaporative losses are very high. The other savings were the result of using existing soil moisture. In NT systems, rice is planted into a soil with some soil moisture. In conventional tilled systems, the soils are tilled and dried in order to make a good seedbed. There is also a small reduction in the amount of irrigation water lost through percolation.

Table 1. Consumptive water use (ET) and percolation for each system. Savings refers to the difference between the NT treatment and the water-seeded (WS) conventional treatment. Differences between NT treatments were not significant. Percolation is an estimate based on average percolation rates for CA rice fields when flooded

Year	System	ET flush period (A to B)	ET drain period (B to C)	ET Post permanent flood (C to harvest)	Season total	Consumptive water use savings	Initial soil moisture	Water savings due to moist soils	Total ET savings	Percolation (0.2mm/day for flood period) **
		Consumptive water use (mm)					Savings due to initial soil moisture			
2024	NT fallow	25.7	39.9	669.4	735.0	49.6	58.6	49.8	99.4	19.4
	NT Chopped	18.4	39.7	669.4	727.5	57.1	50.9	42.1	99.2	19.4
	NT Removed	25.7	32.6	669.4	727.7	56.9	52.0	43.2	100.1	19.4
	CT-WS				784.6		8.82			26.8
	Average NT savings					54.5		45.0	99.6	
2025	NT fallow	24.3	39.1	600.0	663.3	42.1	53.5	6.9	49.0	19.2
	NT Chopped	24.3	27.8	600.0	652.1	53.4	57.2	10.6	64.0	19.2
	NT Removed	24.3	30.0	600.0	654.3	51.1	55.5	8.9	60.0	19.2
	CT-WS				705.4		46.6			26.6
	Average NT savings					48.9		8.8	57.7	

Conclusions

These systems have the potential to conserve water and allow farmers to plant earlier as we had suspected. Our results suggest the yield potential of the NT-Fallow is similar to the conventional water seeded system; however, the strict NT treatments had lower yields. These early findings suggest that strict NT may not be economically viable but the NT following the fallow (NT-Fallow) has promise. Preliminary results show that the N requirement is higher for the NT systems by 15-30 lb N/ac. Applying all the N pre-flood as urea is the best and most economical N management practice.

Acknowledgements

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Improving Nitrogen and Potassium Management in Almond Orchards with Hulls and Shells as a Soil Amendment and Off-Ground Harvest

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Introduction

California almond orchards remove substantial nitrogen (N) and potassium (K) in harvested fruit each year. Most hulls and shells leave the orchard during harvest and processing. Prime hulls have an established feed market, but hull and shell mixtures and shells can have lower-value outlets, especially where processors are distant from dairies. Returning these materials to orchards could recycle nutrients and maintain soil cover, but clear nutrient credits and management guidance are still lacking.

Potassium in almond residues is released rapidly under rainfall and irrigation. Nitrogen cycling is more complex because fresh material has a high carbon-to-nitrogen ratio. Harvest method also matters because on-ground sweeping can remove partially decomposed residues, while off-ground harvest can preserve the surface layer.

This project evaluates changes in soil N and K, residue retention, tree nutrition, and yield. It also examines when nutrient and soil-cover benefits can justify handling, transport, and spreading costs.

Objectives

- 1 Characterize N release and retention and associated K, calcium, magnesium, and sodium dynamics.
- 2 Determine how off-ground harvest affects amendment retention, nutrient cycling, and soil moisture.

- 3 Assess treatment effects on tree nutrition, vegetative growth, and yield.
- 4 Evaluate economic feasibility and practical barriers to grower adoption.

Description

At Westwind Farms near Woodland, a randomized complete block trial compared an unamended on-ground control with hull and shell amended treatments under on-ground and off-ground harvest. Each treatment had four 40-tree plots; approximately 2.8 tons per acre were applied. Measurements included amendment, soil, leaf, moisture, growth, and yield data.

Results and Discussion

Nutrient Release and Soil Distribution

Fresh material contained 0.8% N and 1.95% K, with a carbon-to-nitrogen ratio of 55:1. Potassium concentration declined by as much as 80% within six weeks, confirming rapid K release. By ten months after application, the carbon-to-nitrogen ratio had decreased to 39:1. Amendment N concentration increased after fertigation, showing that the residue layer interacted with applied N as decomposition progressed.

The 2025 soil results showed a continued treatment response. At 0-4 inches on February 21, nitrate-N averaged 59.0 ppm in the control, 98.9 ppm in amended off-ground plots, and 66.1 ppm in amended on-ground plots. At 4-12 inches on August 6, nitrate-N averaged 15.0, 8.1, and 11.0 ppm, respectively. This pattern is consistent with altered nitrate retention and distribution, but it does not directly measure leaching below the root zone.

Exchangeable K at 0-4 inches on February 21 averaged 195.7 ppm in the control, 571.8 ppm in amended off-ground plots, and 516.1 ppm in amended on-ground plots. The amended treatments therefore contained approximately 2.6 to 2.9 times more exchangeable K than the control at this sampling date (Figure 1).

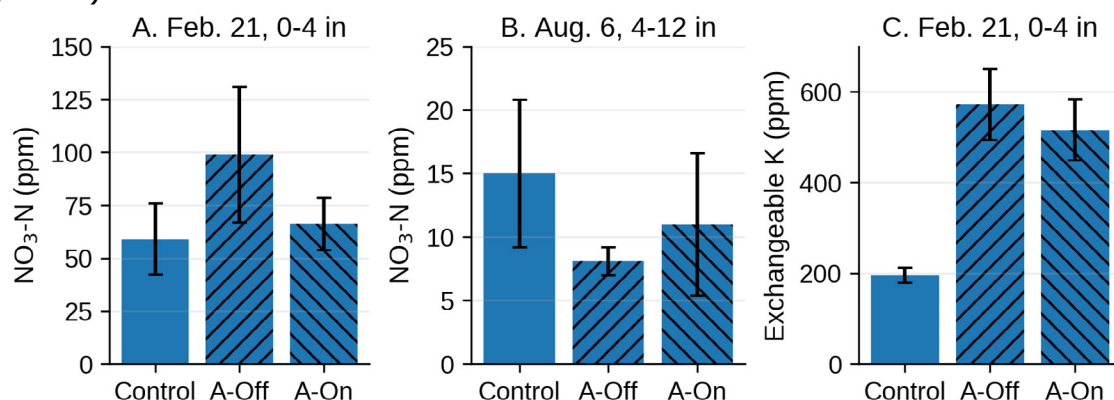


Figure 1. Soil N and K response in 2025. A. Nitrate-N at 0-4 inches on February 21. B. Nitrate-N at 4-12 inches on August 6. C. Exchangeable K at 0-4 inches on February 21. Control = unamended on-ground harvest; A-Off = amended off-ground harvest; A-On = amended on-ground harvest. Bars show means and standard deviations for four plots.

Harvest Method and Residue Retention

Harvest method changed how much amendment remained on the orchard floor. Ten months after application and before harvest, amended on-ground plots retained approximately 1.39 tons per acre, while amended off-ground plots retained 2.28 tons per acre. Off-ground harvest retained about 64% more material. Soil moisture was also consistently higher in amended plots during 2024 monitoring. Preserving the layer retains soil cover and partially decomposed nutrients that can otherwise be disturbed or removed during sweeping.

Tree Nutrient Status, Growth, and Yield

Higher soil K was reflected in the trees. July 2025 leaf K averaged 1.60% in the control, 2.07% in amended off-ground plots, and 2.18% in amended on-ground plots. Leaf N showed no consistent treatment response, while leaf calcium and magnesium were modestly lower in amended plots.

August 2025 dry kernel yield averaged 14.1 pounds per tree in the control, 14.3 pounds per tree in amended off-ground plots, and 12.4 pounds per tree in amended on-ground plots (Figure 2). Earlier measurements also showed greater trunk circumference and leaf area in amended plots. However, yield is affected by prior-year production, alternate bearing, bloom overlap, and pollinizer distribution. These results do not establish that K alone caused yield differences. They do show that repeated amendment-derived K did not provide a consistent yield advantage.

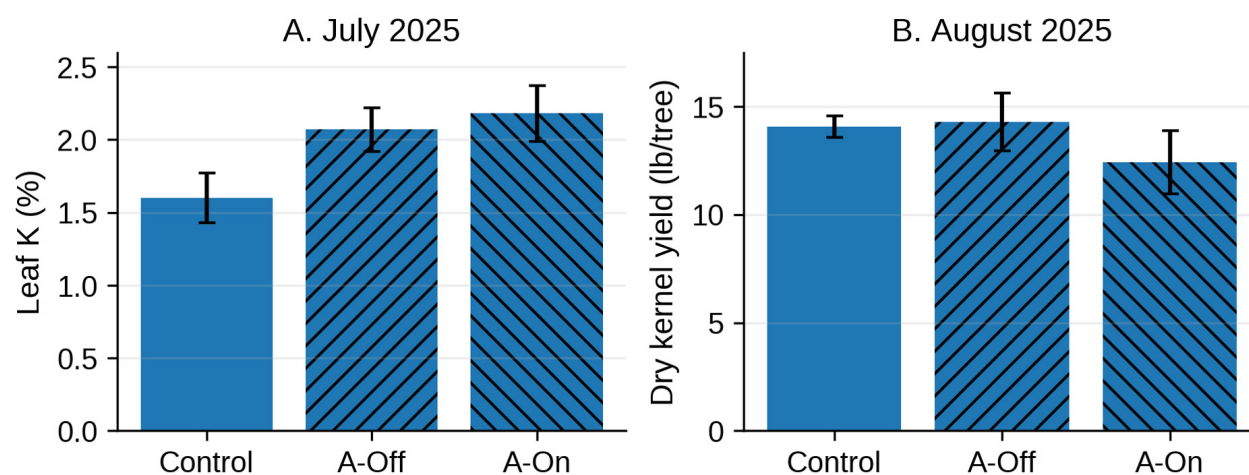


Figure 2. Tree K status and yield in 2025. A. July leaf K concentration. B. August dry kernel yield. Control = unamended on-ground harvest; A-Off = amended off-ground harvest; A-On = amended on-ground harvest. Bars show means and standard deviations for four plots.

Economic Feasibility and Adoption

Related economic analysis examined a shell return pathway. It estimated a fertilizer-equivalent value of approximately \$35 to \$38 per delivered ton of shells based on K content. At 4.5 tons per acre, hauling and spreading at \$25 per ton would cost about \$113 per acre before payment for the material. Nutrient value can therefore offset part of the delivered-and-applied cost, but hauling distance, spreading equipment, material quality, and existing residue markets determine whether the practice pencils out. Statewide shell supply could treat about 14% of bearing almond acreage at this rate, making local targeting and processor-grower coordination important (Khalsa, Zilberman, and Brown, 2026).

The 2026 outreach phase will test these assumptions with growers and agricultural advisors. Draft questionnaires address transportation, spreading, harvest compatibility, material quality, application timing, and confidence in nutrient credits.

Conclusions

- Hull and shell amendments are a substantial K source. Rapid K release increased exchangeable soil K and leaf K. Amendment-derived K should be credited in orchard nutrient budgets rather than added to a full conventional K program.
- The N response is more complex. Higher surface nitrate after spring fertigation and lower nitrate at 4-12 inches in August indicate changed nitrate distribution, but these measurements do not independently demonstrate reduced groundwater leaching.
- Off-ground harvest better preserved the amendment layer. Retaining partially decomposed material can maintain soil cover, moisture, and nutrients that would otherwise be disturbed or removed during sweeping.
- Higher tree K did not consistently improve yield. Growers using hulls and shells should monitor soil and leaf K and reduce supplemental K when orchard status is already sufficient.

The final project year will complete cost-benefit scenarios, deploy the adoption questionnaire, and develop guidance on nutrient credits, rates, timing, and harvest management. The practical goal is to use recycled nutrients where they replace inputs, preserve soil cover, and remain operationally feasible.

Acknowledgements

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Optimizing Potassium (K) Fertilization Management in Almond Orchards

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Introduction

Potassium (K) is the most important nutrient for almond trees after nitrogen. Almonds have an unusually high K demand: a high-yielding orchard removes roughly 168 pounds of K per ton of kernel yield (76 kg/ton), for a total seasonal uptake of 221 to 346 pounds K per acre (248 to 388 kg/ha).

Although K is abundant in most soils, only 1 to 3 percent of the total is available for root uptake at a given time, and soil texture, clay mineralogy, organic matter, pH, and moisture all interact to determine how much is available at any spot in an orchard. This can create large differences in K availability even within a single, uniformly managed block.

Because current testing protocols were not designed to capture this variability, growers have generally relied on a single average soil or leaf test and applied one uniform, often generous, K rate across the whole orchard. With the sharp rise in potash fertilizer prices, this approach is no longer economically sound, and it still does not solve the underlying problem: some parts of an orchard may be over-fertilized while others remain deficient.

This project characterizes how much soil and leaf K vary within almond orchards, identifies what drives that variability, and tests whether affordable sensing tools and improved leaf-sampling protocols can help growers manage K more precisely and cost-effectively.

Objectives

- 1 Characterize the extent of spatial and temporal potassium variability within almond orchards.

- 2 Identify the soil factors most responsible for differences in K availability among and within orchards, and evaluate electromagnetic induction and gamma-ray sensing as tools to guide and improve soil sampling and mapping.
- 3 Describe how leaf K concentration varies within the tree canopy and over the course of the day, and identify the plant physiological factors associated with these differences.
- 4 Develop improved leaf-sampling protocols that more reliably reflect true tree K status.
- 5 Share findings with growers, advisors, and researchers through outreach, training materials, and publications.

Description

The research is being conducted in two commercial almond orchards that differ in soil type: Westwind Farms near Woodland, California, and KG Olam Farms near Madera, California. In each orchard, roughly 125 trees distributed across the block were selected for repeated soil and leaf sampling, with 12 monitored more intensively.

Traditional soil and leaf sampling was combined with electromagnetic induction (EMI) and gamma-ray spectroscopy (GRS) sensors that rapidly characterize soil properties across large areas, allowing the team to target sampling and build higher-resolution K maps. A field trial comparing three K fertilizer rates was established in two areas of Westwind Farms with contrasting soil texture and K status. Leaf samples were also collected at three canopy heights and multiple times of day across two growing seasons. Results are being shared with the almond industry through grower meetings, conference presentations, and upcoming outreach and training materials.

Results and Discussion

Even within a single, uniformly managed orchard, both exchangeable K (EK) and soil solution K (SSK) varied widely from tree to tree. The drivers of this variability differed by site: at Westwind Farms, EK was positively correlated with clay content, calcium, magnesium, cation exchange capacity (CEC), and organic matter, and negatively correlated with boron and sodium, while at KG Olam Farms these same relationships were weak or absent. This confirms that a single soil model, or a single fertilizer recommendation, cannot be applied uniformly across different orchards or even across zones within the same orchard.

Soil texture emerged as the strongest overall driver of K availability: EK tended to be higher in areas with more clay, while SSK was higher in sandier areas. The EMI and GRS sensors, while not a substitute for laboratory testing, helped identify zones of similar soil character that improved the accuracy of K distribution maps, particularly at Westwind Farms.

In the field K-rate trial, the same fertilizer rate raised soil K by different amounts depending on the soil texture and starting K level of the area, reinforcing that a single blanket rate cannot be expected to correct K status evenly across an orchard.

Leaf K sampled in July, the standard timing for almond leaf testing, was highly variable among individual trees at both sites and in both years of sampling, with many trees clustering close to, or below, the widely used critical value of 1.4 percent (Figure 1). This confirms that a single orchard average can mask considerable tree-to-tree variability that matters for fertilization decisions.

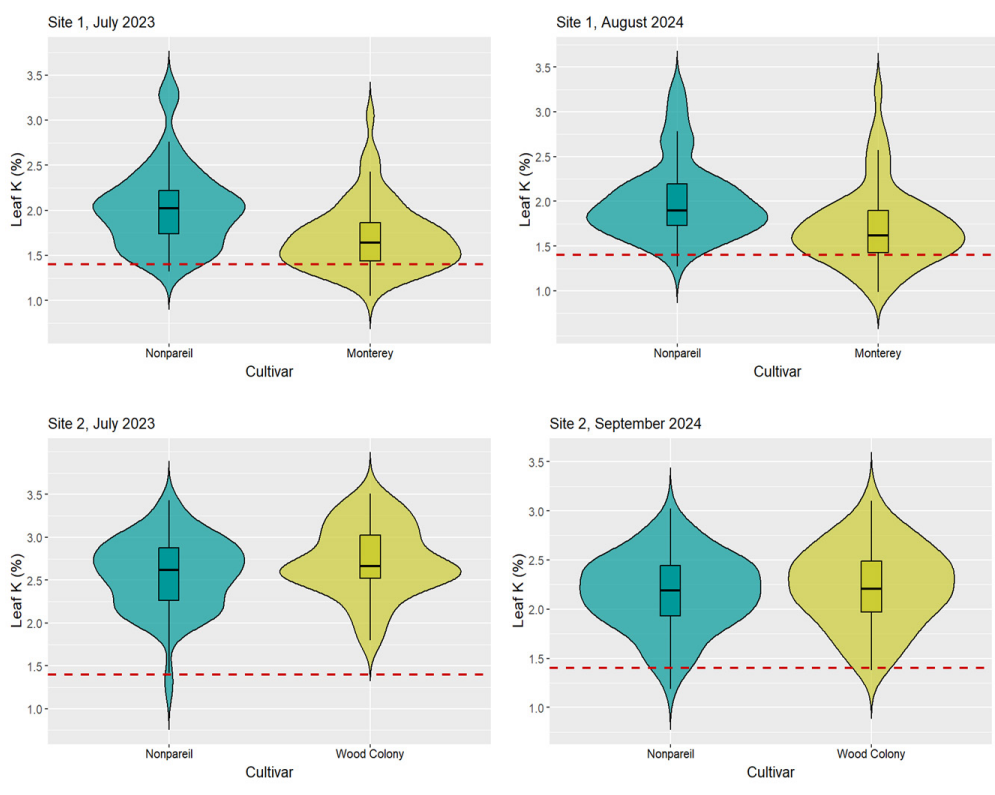


Figure 1. Leaf potassium concentration (%) by cultivar at Site 1 (Westwind Farms) and Site 2 (KG Olam Farms) in two sampling years. The red dashed line marks the 1.4% critical value commonly used to diagnose K deficiency in almond.

Within the canopy, leaf K was consistently highest at the bottom of the canopy and lowest at the top, and tended to decline somewhat from morning to afternoon (Figure 2). The difference associated with just five to six hours of sampling time was large enough to shift a reading meaningfully, underscoring the importance of sampling within a tight, consistent time window. This canopy pattern tracked with differences in leaf water content, osmotic potential, and starch accumulation between top and bottom leaves, although the underlying physiological cause is not yet fully resolved.

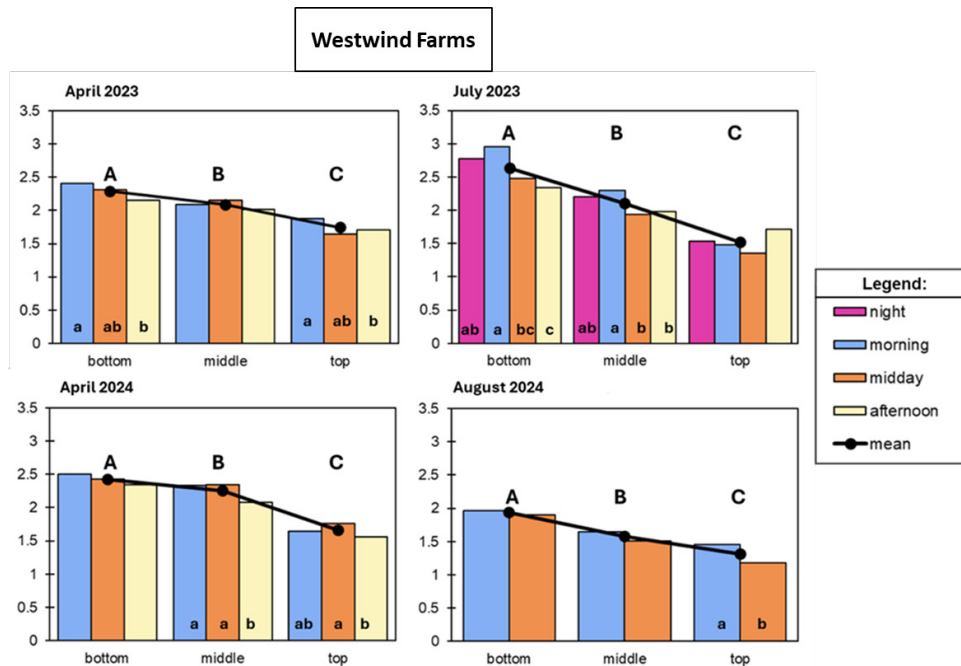


Figure 2. Leaf potassium concentration (%) at bottom, middle, and top canopy positions, sampled at four times of day across four sampling dates at Westwind Farms. Letters denote statistically significant differences among canopy positions within each date (LSD test, $\alpha = 0.05$).

This has a practical implication for growers exploring drone- or satellite-based canopy imagery as a nutrient monitoring tool: those platforms sense mostly the upper canopy, where leaf K runs highest, while standard hand sampling targets lower, non-bearing shoots, where K runs lowest. Growers should be cautious about directly comparing remote-sensing-based K estimates with traditional leaf-testing critical values until the relationship between the two is better defined.

Conclusions

No single soil model, and no single fertilizer rate, fits every almond orchard. Growers and their pest control advisers (PCAs) or crop consultants should expect real, measurable within-orchard variability in K availability, driven mainly by soil texture, and should be cautious about applying one blanket K rate across an entire block.

Pairing traditional soil sampling with affordable sensing tools, such as EMI and gamma-ray spectroscopy, can meaningfully improve the accuracy and cost-effectiveness of K distribution maps and help target soil sampling to where it matters most.

Leaf K testing should be conducted within a narrow, consistent time window and should account for canopy position, since bottom, middle, and top leaves can give meaningfully different readings on the same day. Growers adopting drone- or satellite-based canopy monitoring should be aware that these tools primarily capture the upper canopy, where leaf K runs higher than in the lower canopy targeted by standard hand sampling.

Together, these findings support a shift away from single, orchard-wide K applications toward site- and zone-specific K management. The team plans to refine these protocols and continue grower outreach through the remainder of the project.

Acknowledgements

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A Science-Based and Interactive Website for Nutrient Management in Organic Crop Production

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Introduction

Nutrient management in organic systems is complex and can be challenging because organic growers predominantly apply nutrients with organic inputs, such as composts, organic fertilizers, and cover crops. Most of the nitrogen (N) in these materials is not directly crop-available and needs to be mineralized first by soil microorganisms. How much is mineralized and when N is mineralized depends strongly on the properties of the material, especially its carbon (C) to N ratio, but also on environmental conditions such as soil temperature and moisture.

Many fertilizers, composts, and amendments are available for organic agriculture. The availability of the N applied with these materials can range from zero to up to 90%. Some plant-based composts may even immobilize N, which means that crop-available N in soil solution is tied up temporarily. Accurate data to estimate N availability is crucial for achieving high N use efficiency, decreasing losses with potentially harmful environmental effects, and making organic production economically viable. Furthermore, composts and most organic amendments contain many different macro- and micronutrients. Finding amendments or combinations of materials that match the crops' demand for different nutrients is more challenging than using single-nutrient fertilizers.

Since their creation some ten years ago, the online California Fertilization Guidelines (<https://www.cdfa.ca.gov/is/ffldrs/frep/FertilizationGuidelines/>) have become an important source of information for growers and crop consultants in California.

The guidelines are a summary of the research done in California and other regions with comparable conditions. The focus of the guidelines is on nutrient management in conventional agriculture.

In the current project we aim to make relevant information about nutrient management in organic systems available online. The website will complement the California Fertilization Guidelines and will include webpages that

summarize the available literature on nutrient availability from different sources in organic systems and an interactive N, phosphorus (P) and potassium (K) budget calculator for major annual crops grown organically in California. The website shall contribute to the efficient use of nutrients in organic crop production by helping growers and consultants find relevant information and supporting their decisions when planning nutrient management for their crops.

Objectives

The objective of the proposed project is to develop webpages and an online interactive nutrient calculator for organic growers and consultants where they can access science-based information on organic nutrient management and develop nutrient budgets for organically grown annual crops. Specific objectives are:

- 1 Summarize the available literature with a focus on studies from California and create webpages for organic nutrient management.
- 2 Develop an interactive tool to calculate field-specific N, P and K budgets.
- 3 Fill knowledge gaps and validate the estimates of the calculator in field trials.
- 4 Conduct outreach to growers, consultants, and other stakeholders.

Description

The project started in January 2025. During the second year we continued reviewing and summarizing the available literature and developing the online calculator (Objectives 1 and 2).

This report focuses on a field trial that was conducted to address Objective 3.

In fall 2025, we initiated a replicated trial at UC Davis investigating the interactions between cover crop residues and organic amendments with respect to N availability. The field site was not certified organic, but crop management followed organic practices. The trial included four cover crop treatments, namely (i) oats, (ii) legume mix (bell beans, winter peas and vetch), (iii) oats and legume mix, and (iv) control. Cover crops were planted on November 3, 2025, and terminated on March 24, 2026 (Figure 1). On April 8, 2026, a pelleted organic 6-6-2 fertilizer (numbers referring to the percents of N, P_2O_5 and K_2O) was applied at 3 rates to subplots within each main plot. The application rates were 0, 75 and 150 lb/ac of plant available N. Sweet corn was planted ten days later and harvested on July 23, 2026 (Figure 1). Soil samples from the top 2 ft were collected at harvest and analyzed for mineral N (ammonium-N and nitrate-N). Aboveground corn biomass was collected in burlap bags for oven-drying. Once dry, it will be analyzed for total dry matter and N in the biomass.



Figure 1: Left: The oats-legume mix cover crop in March 2026 before it was terminated. Center and right: Sweet corn before the harvest on June 23, 2026.

Results and Discussion

Cover crop dry matter yields ranged from 2.4 t/ac for the oats and legume mix to 3.3 t/ac for the oat treatment (Table 1). The weeds growing in the control plots produced a biomass of 1.4 t/ac. Cover crops and the weeds in the control plots had N contents in the dry matter ranging from 2.9 to 3.6% and C:N ratios between 11.1 and 13.4. These C:N ratios are favorable to net N mineralization, so that N immobilization after incorporation was not expected.

Table 1: Cover crop biomass and N content when terminated.

Treatment	Biomass (t/ac dry matter)	N content (% DM)	C:N	N content (lb/ac)
Control	1.4	3.5	11.1	101
Oat	3.3	2.9	13.4	190
Legume mix	2.4	3.6	11.4	172
Oat & legume mix	3.1	3.1	11.6	192

The fresh market sweet corn yield averaged 188 cwt/ac (Figure 2). Yield was increased in the cover crop treatments compared to the control; however, the difference was not statistically significant ($p = 0.058$). While the application of 75 lb/ac of plant available N did not increase yield, 150 lb/ac of plant-available N increased yield. However, the increase was not statistically significant ($p = 0.053$). There was no interaction between cover crop and N rate treatments.

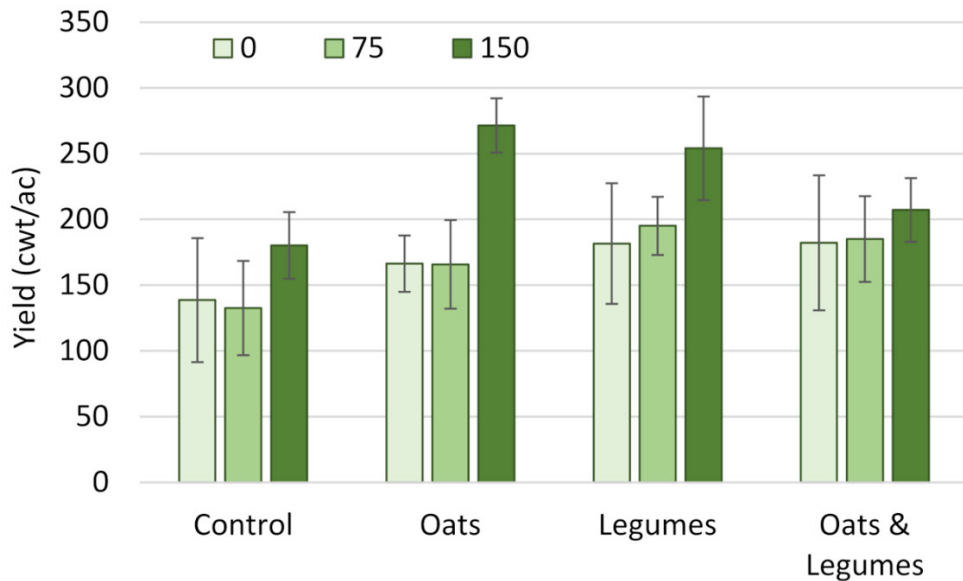


Figure 2: Sweet corn ear yield. Error bars are standard errors. 0, 75 and 150 refer to lb/ac of plant available N applied pre-plant with an organic fertilizer.

The mineral N left in the top 2 ft of the soil profile was lowest in the control plots compared to the plots with a cover crop, but the differences across treatments were not significant. However, residual mineral N increased significantly with increasing N application rates (Figure 3). As was the case with yield, there was no interaction between cover crop treatments and N rates.

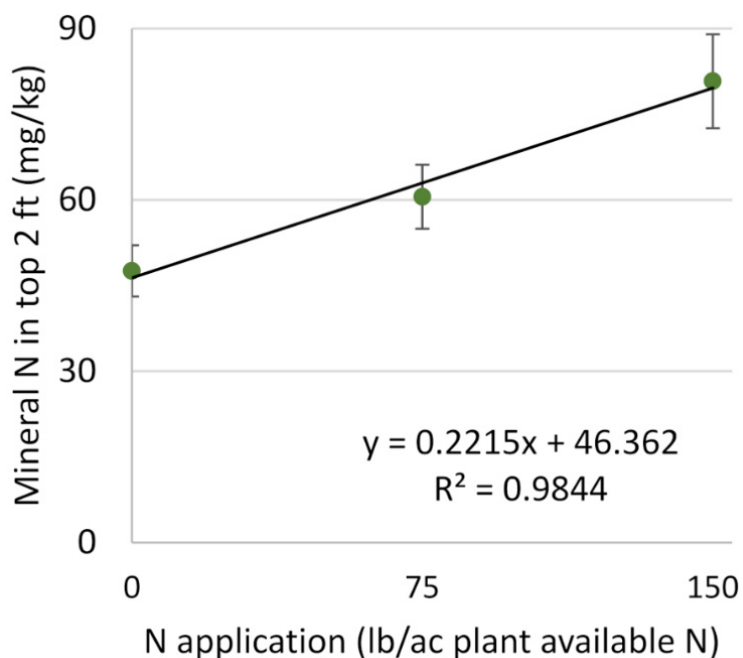


Figure 3: Mineral N (ammonium and nitrate) in the soil profile at corn harvest. Error bars are standard errors.

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Determination of Crop N-Removal Coefficient Values for the Imperial and Coachella Valleys Cropping Systems

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Introduction

Nitrogen (N) balances are an important component of nutrient management and reporting under California's Irrigated Lands Regulatory Program. Crop N-removal coefficients are needed to estimate the amount of N removed from a field in harvested products based on crop yield. Although reliable coefficients have been developed or updated for several commodities in other agricultural regions of California, locally derived information remains limited for the Imperial, Coachella, and Palo Verde Valleys. The distinctive climate, soils, irrigation practices, and cropping systems of the low desert may influence crop N concentration and removal. This project is developing locally representative N-removal coefficients for major regional commodities to support growers, agricultural advisors, and Irrigated Lands Coalitions in evaluating field- and regional-scale N balances.

Objectives

The specific objectives of this study are:

- 1 Develop N-removal coefficients for harvested products of major commodities grown in the Imperial, Coachella, and Palo Verde Valleys.
- 2 Evaluate variability in N-removal coefficients among fields and harvested products using locally collected samples.

- 3 Disseminate project findings and locally derived N-removal information to growers, agricultural advisors, and the Irrigated Lands Coalitions serving the Imperial, Coachella, and Palo Verde Valleys.

Description

Field sampling has been conducted across commercial agricultural operations in the Imperial, Coachella, and Palo Verde Valleys. The current dataset represents 281 field samples or harvest observations across 21 harvest-ed-product categories, including forage crops, vegetables, field crops, and perennial fruit crops. Multiple fields, harvests, production areas, and growing conditions were sampled to capture the variability encountered in commercial production. Samples were collected from representative locations within each field at the time of commercial harvest following grower practices.

Composite samples were used to determine the N concentration of harvested plant material. For commodities marketed on a fresh-weight basis, samples were oven-dried to a constant weight to determine percent solids, and the dried samples were ground and analyzed for total N. Percent solids and N concentration were then used to calculate N concentration on a fresh-weight basis. For hay, seed, lint, and similar harvested products, coefficients were calculated using the N concentration of the harvested material on the applicable commercial yield basis. The resulting N-removal coefficient represents the amount of N removed per unit weight of harvested product. Field-level N removal can therefore be estimated by multiplying the crop-specific coefficient by actual harvested yield expressed in pounds. This provides a practical approach for incorporating harvested N removal into field N-balance calculations.

Results and Discussion

Crop N-removal coefficients and their ranges are summarized in Table 1. The expanded dataset demonstrates substantial differences among commodities. Mean coefficients ranged from 0.001120 for table grapes to 0.044708 for alfalfa seed, representing approximately a 40-fold difference among the harvested products evaluated. These differences largely reflect variation in the N concentration and, for fresh commodities, the proportion of solids in the harvested product.

Forage and seed products generally had relatively high N-removal coefficients. Mean coefficients were 0.033295 for alfalfa hay, 0.044708 for alfalfa seed, 0.017581 for bermudagrass hay, 0.013967 for bermudagrass seed, and 0.019630 for kleingrass hay. Durum wheat seed also had a relatively high mean coefficient of 0.028374. These harvested products generally have greater dry matter and/or N concentration per unit of marketed weight than fresh vegetables and fruits and therefore remove more N per pound of harvested product.

Fresh vegetable crops had substantially lower coefficients because water constitutes a large proportion of their harvested weight. Mean coefficients ranged from 0.001233 for fresh onion to 0.004872 for broccoli. Lettuce coefficients differed among market types, averaging 0.001398 for head lettuce, 0.001862 for romaine lettuce, and 0.002213 for green leaf lettuce. Broccoli had the highest mean coefficient among the vegetables evaluated and had a relatively high mean tissue N concentration of 5.52%.

The expanded dataset also provides N-removal information for several harvested products not included in the previous year's summary. Mean coefficients were 0.038140 for Pima cotton seed and 0.012020 for Pima cotton lint. For perennial fruit crops, mean coefficients were 0.002229 for lemon and 0.001120 for table grapes. The addition of these commodities broadens the applicability of the project beyond annual vegetables and forage crops and provides initial locally derived values for other important cropping systems in the low desert region.

Considerable variability was also observed within individual commodities. For example, the alfalfa hay coefficient ranged from 0.017800 to 0.045200 across 28 field observations, while kleingrass hay ranged from 0.011200 to 0.033600 across 19 observations. Among fresh commodities, variation in both percent solids and tissue N concentration contributed to differences in the calculated coefficients. This variability likely reflects differences in crop variety, maturity at harvest, growing conditions, soil characteristics, irrigation and nutrient management, and other commercial production factors.

The increasing number of observations has strengthened the estimates for several major crops. The current dataset includes 28 observations for alfalfa hay, 22 for head lettuce, 21 for romaine lettuce, 15 for broccoli and cauliflower, and 14 for green leaf lettuce. Continued sampling across fields and production conditions improves representation of the variability encountered in commercial agriculture and provides a stronger basis for establishing locally relevant N-removal coefficients.

The practical application of these coefficients is straightforward. The N-removal coefficient can be multiplied by actual harvested yield in pounds per acre to estimate the amount of N removed in the harvested product in pounds N per acre. For example, the mean coefficient of 0.033295 for alfalfa hay represents approximately 0.0333 lb N removed per pound of harvested hay. Applying locally derived coefficients in this manner can improve estimates of harvested N removal and strengthen field-level N-balance assessments.

Conclusions

This project has substantially expanded the locally derived database of crop N-removal coefficients for the Imperial, Coachella, and Palo Verde Valleys.

The current dataset includes 281 field samples or harvest observations representing 21 harvested-product categories and demonstrates that N-removal coefficients vary widely among commodities, from 0.001120 for table grapes to 0.044708 for alfalfa seed. The results demonstrate the importance of using commodity-specific coefficients. Hay and seed products generally remove substantially more N per pound of harvested products than fresh vegetables and fruits, while meaningful variability can also occur among fields producing the same commodity. The larger number of samples collected during this project provides an increasingly robust representation of this variability under commercial production conditions.

The primary practical outcome of this work is a set of locally derived coefficients that can be multiplied by actual harvested yield to estimate N removed from individual fields. These values can support growers, agricultural advisors, and Irrigated Lands Coalitions in developing more representative N balances and improving nutrient-management assessment across the Imperial, Coachella, and Palo Verde Valleys.

Table 1. Mean and range of crop N-removal coefficients, and associated factors used in their development: percent solids and percent nitrogen.

Commodity	# Fields sampled	mean N-Coeff.	min N-Coeff.	max N-Coeff.	mean % solids	min % solids	max % solids	mean %N	min %N	max %N
Alfalfa hay	28	0.033295	0.017800	0.045200	-	-	-	3.33	1.78	4.52
Alfalfa seed	15	0.044708	0.034000	0.053700	-	-	-	4.47	3.40	5.37
Bermuda grass hay	12	0.017581	0.012200	0.024000	-	-	-	1.76	1.22	2.40
Bermuda grass seed	7	0.013967	0.011900	0.015800	-	-	-	1.40	1.19	1.58
Bell pepper (Red)	10	0.001846	0.001598	0.002075	8.05	4.91	9.54	2.33	2.03	3.48
Bell pepper (Green)	10	0.002293	0.001604	0.004863	7.18	5.35	12.76	3.13	2.53	3.81
Broccoli	15	0.004872	0.002601	0.007342	8.91	4.98	11.42	5.52	3.72	6.83
Cauliflower	15	0.002200	0.001591	0.002627	6.21	4.51	8.54	3.63	2.44	4.97
Cabbage	5	0.002074	0.001583	0.002434	6.33	5.19	7.42	3.28	3.05	3.51
Pima cotton seed	9	0.038140	0.034700	0.042100	-	-	-	3.81	3.47	4.21
Pima cotton lint	9	0.012020	0.005900	0.027700	-	-	-	1.20	0.60	2.77
Dehydrator onion	12	0.002445	0.002152	0.002884	22.53	20.61	26.71	1.11	0.98	1.29
Klein grass hay	19	0.019630	0.011200	0.033600	-	-	-	1.96	1.12	3.36
Fresh onion	15	0.001233	0.000374	0.003222	8.20	4.13	12.49	1.52	0.50	2.96
Romaine lettuce	21	0.001862	0.001062	0.002774	5.54	3.32	8.41	3.42	2.16	4.00
Head lettuce	22	0.001398	0.001043	0.002093	4.35	2.66	5.62	3.18	2.88	3.71
Green leaf lettuce	14	0.002213	0.001494	0.003382	6.30	4.18	9.10	3.61	2.71	4.16
Lemon	12	0.002229	0.001910	0.003350	14.75	12.65	21.89	1.51	1.34	1.77
Table grapes	11	0.001120	0.000685	0.001720	16.76	10.80	21.30	0.68	0.34	1.01
Durum wheat seed	10	0.028374	0.024500	0.031400	-	-	-	2.83	2.45	3.14
Durum wheat straw	10	0.010345	0.005600	0.017800	-	-	-	1.03	0.56	1.78

Acknowledgements

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Monitoring and Assessing Variability of Nutrient Status in Almond Orchards with Remote Sensing Imagery Empowered by Artificial Intelligence

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Introduction

Optimizing nutrient management in almond orchards is crucial for maximizing yield, reducing costs, and protecting groundwater sources and the environment. Current monitoring methods rely on limited leaf sampling, which cannot capture fine-scale variability or rapid changes in nutrient status, limiting timely, site-specific decisions. Hyperspectral imagery, combined with artificial intelligence, offers an opportunity to monitor nutrient status remotely, accurately, and at scale (Berger et al., 2020; Liu et al., 2021), including recent almond-specific work on leaf- and canopy-scale nitrogen sensing (Chakraborty et al., 2025; Oswald et al., 2025); however, its operational use for almond nutrient management remains undeveloped. This project is developing an integrated remote sensing and AI approach using proximal, airborne, and spaceborne hyperspectral sensing to assess spatial and temporal nutrient variability, link it to soil and yield patterns, and guide efficient sampling strategies, improving productivity, fertilizer efficiency, and environmental outcomes across California.

This year's work builds on the initial single-orchard pilot phase, using a multi-year, multi-orchard leaf dataset to advance three efforts reported here: a statistical framework describing how sixteen leaf traits vary with canopy position, season, orchard, and cultivar; continued development of a hyperspectral deep learning model, shaped by patterns identified in the statistical analysis; and ongoing work exploring how to scale these leaf-level models using multi-year drone imagery collected alongside ground sampling.

Objectives

The specific objectives for this phase are:

- 1 Collect comprehensive ground-truth data by sampling almond leaves for chemical analysis across multiple canopy heights, varieties, and orchard locations, and over different time periods to capture maximum variability in nutrient status.
- 2 Obtain hyperspectral measurements from leaves to establish direct relationships between leaf-level spectral signatures, drone and satellite-based imagery, and laboratory-derived nutrient concentrations.
- 3 Acquire and process aerial imagery from drone-based multispectral and thermal sensors to generate high-resolution spatial information.
- 4 Integrate multi-source datasets (leaf chemical analysis, drone imagery, hyperspectral leaf data, and satellite imagery) to develop and validate an AI-driven framework for large-scale monitoring of nutrient status in almond orchards.

Description

The combined leaf dataset now includes 565 samples from four almond orchards across the 2021–2026 growing seasons in California’s Sacramento and San Joaquin Valleys, including a new Davis orchard added in 2026 (20 trees, middle canopy, sampled three times between May and late July). The most complete multi-trait dataset spans 2023–2025, sampled from the top, middle, and bottom canopy. Leaves were scanned with a hyperspectral spectroradiometer, weighed, measured for leaf area, dried, and sent for laboratory nutrient analysis. The resulting dataset includes ten macro- and micronutrients (nitrogen, phosphorus, potassium, calcium, magnesium, zinc, manganese, iron, copper, boron), two physical traits (leaf mass per area, equivalent water thickness), and four pigment and structural traits (chlorophyll, carotenoids, anthocyanins, and a leaf structural parameter) derived from the spectral data using PROSPECT-PRO (Féret et al., 2021).

Drone imagery was also collected during field sampling in 2026 to begin scaling leaf-level measurements to whole trees and orchards, including RGB and multispectral imagery (red, green, blue, red-edge, and near-infrared bands). The leaf level tissue analysis will be used as an indication of nutrient levels in target trees (Figure 1) when we scale up the modeling approach from leaf level to canopy level.



Figure 1. Drone imagery of the Davis orchard. Red arrows show the 20 Nonpareil trees sampled across the growing season.

The 2023 to 2026 dataset is being analyzed using mixed-effects models to determine how leaf traits vary within canopy, phenology, location, and cultivar. In parallel, we trained a preliminary hyperspectral deep learning model, based on a convolutional neural network long short-term memory (CNN-LSTM) architecture adapted from a grapevine trait-prediction model (Farajpoor et al., 2025). The statistical results are being used to guide model development, particularly how phenological stage and canopy position can be incorporated alongside spectral information. Fine-tuning of the CNN-LSTM and development of three additional AI model variants are ongoing.

Results and Discussion

The statistical analysis showed a clear temporal shift: early-season leaves were higher in nitrogen, phosphorous, chlorophyll, and carotenoids, while later-season leaves had more calcium, magnesium, leaf mass per area, and structural development. Seasonal progression was the strongest influence, affecting nearly every trait with very high confidence. Orchard location also produced strong differences for most traits, and within canopy position produced a smaller, but still significant effect for many traits.

A multivariate ordination of all 16 traits together (Figure 2), illustrates correlated shifts across multiple leaf traits: a group of traits (calcium, magnesium, leaf mass, leaf structure) that rise together as leaves mature, a mobile-nutrient group (nitrogen, phosphorus) that declines together early in the season, and a pigment group following a similar decline, with orchard forming a second axis.

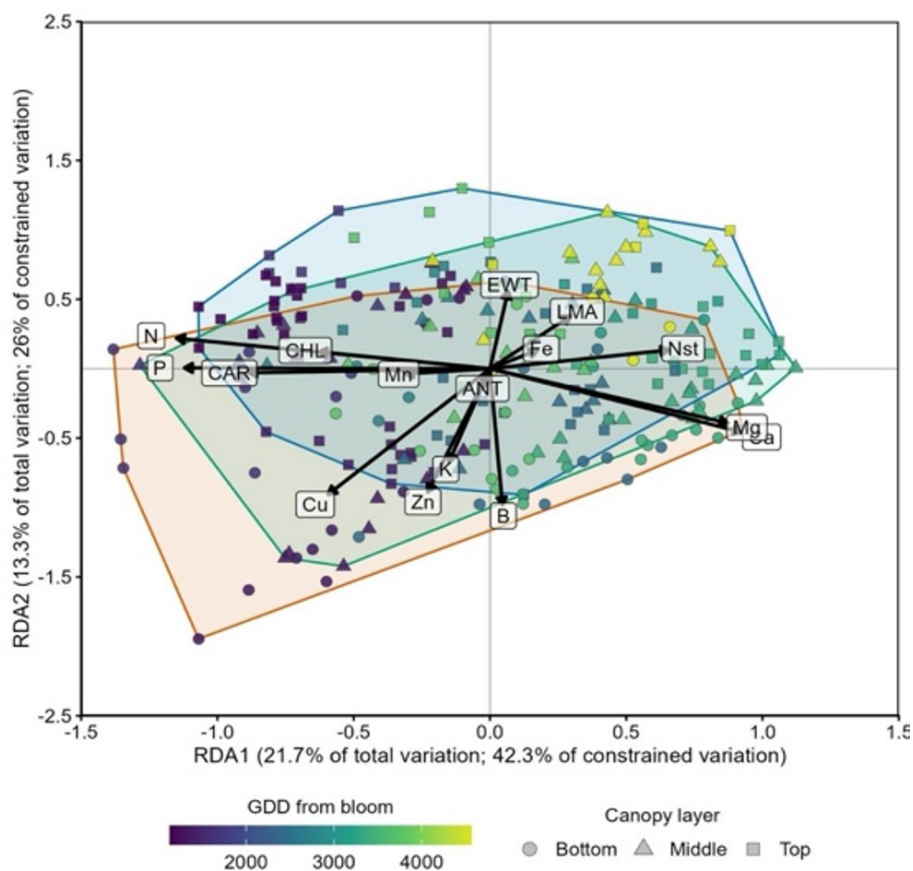


Figure 2. Redundancy analysis (RDA) ordination of the 16 leaf traits, Point shape indicates canopy layer (bottom, middle, and top), color indicates growing degree days (GDD) from bloom, and shaded regions indicate orchard location. Samples separate primarily along the season axis (RDA1).

The canopy effect varied by trait. Magnesium, boron, and chlorophyll showed strong canopy effects consistent across all three orchards. Potassium, copper, nitrogen, calcium, and zinc values also varied significantly with canopy position, but the strength of these effects differed meaningfully by orchard location. Manganese did not have a significant canopy effect, but its seasonal trajectory varied by orchard, possibly due to differences in soil or management between sites.

Nitrogen, phosphorus, and copper decline predictably from bloom onward. Because nitrogen and phosphorus are phloem-mobile, this may reflect the tree redistributing them away from leaves toward reproductive tissues and new growth as leaves mature. Calcium, on the other hand, moves only through the xylem in one direction, so it accumulates over time. Micronutrient patterns (zinc, manganese, iron, and copper) are consistent with reduced availability in alkaline or poorly drained soils, both documented conditions in California almond orchards (Connel, 2017).

Boron has a more complex seasonal pattern, which varied by orchard, and is consistent with soil boron availability or irrigation water quality, a known driver of boron toxicity and deficiency locally. We did not test soil or water directly, so these remain plausible explanations rather than confirmed causes. Potassium showed one of the most consistent canopy patterns, with generally higher concentrations in the lower canopy.

Once the laboratory results are complete from the final 2026 data acquisition, we will test whether treating orchard as a random effect improves our ability to separate general nutrient patterns from orchard-specific differences. These statistical patterns are being used directly to inform which variables and relationships the deep learning model should incorporate to improve its reliability across orchards and seasons.

This year, a CNN-LSTM, along with three architecture variants, is being developed to predict these traits directly from leaf reflectance. Current work is focused on making the most of the data we have — filling gaps across years and orchards, data processing, and methods to use our complete hyperspectral dataset to further improve accuracy and robustness of the model — alongside direct testing of how well the model generalizes to orchards it has not seen before. Incorporating GDD and canopy height directly into the model has shown promising results in our experiments and we are continuing to test the best way to build the statistical findings into the final architecture.

Conclusions

This year's analytic results quantify how almond leaf nutrient status varies with season, canopy position, and orchard location, with growing degree days as the most consistent driver and canopy height effects that differ by site. These patterns matter for interpreting conventional leaf sampling for improving hyperspectral trait prediction across orchards. The project is also moving from leaf-scale prediction toward tree- (drone) and orchard-scale (satellite) monitoring, combining multi-year RGB, multispectral, and thermal drone imagery, and hyperspectral satellite data with field measurements. This will support the practical, remote-sensing-based mapping of within-field nutrient variability for more precise management. The data collected this year will also allow us to test more general models that account for orchard-to-orchard variability, with the goal of improving transfer to new sites.

Acknowledgements

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Development of Three Citrus Modules in the Decision Support Tool CropManage for Orange, Mandarin, and Lemon

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Introduction

As citrus growers in California's Central Valley grapple with significant water quality and quantity issues and associated regulations, the need for precise fertilization and irrigation practices is more critical than ever. Currently, citrus growers farm over 200,000 acres in the valley but lack access to a specialized, free decision-support tool that could guide them in making informed in-season decisions about irrigation and fertilizer applications. The crops' physiological characteristics are unique amongst commodities grown in the valley, adding a layer of complexity to developing such a tool.

The goal of this project is to build a decision-support tool to address this need. This project builds off years of research, experimentation, and software development efforts and will culminate in the development of three new citrus-specific modules for the University of California's (UC) CropManage (CM) online platform, namely oranges, mandarins, and lemons. CM is a free publicly available irrigation and nitrogen (N) application decision support tool developed by UC researchers with funding from FREP, CDFA, USDA, UC Agriculture and Natural Resources, and the Department of Water Resources.

The tool integrates crop, water, and N use data and models with local weather information from the California Irrigation Management Information System (CIMIS), soil information from the NRCS and other sources, grower management, and soil/plant sample data to make in-season recommendations for a variety of horticultural crops. The tool was originally developed for Central Coast vegetable and berry cropping systems and later expanded to include predominant crops in other regions like the Central Valley. This project supports this expansion.

The potential impacts of this initiative are significant. By providing citrus growers and advisors with access to a refined decision-support tool, this project can lead to increased adoption rates of CM and the management practices embedded within it, resulting in more efficient fertilizer and water use. This, in turn, enhances the likelihood of regulatory success while maintaining and enhancing a productive and diverse agricultural landscape.

Objectives

The overall objective of this project is to develop CM modules for orange, mandarin, and lemon varieties. Specific objectives include the following:

- 1 Improve the understanding of N and water use dynamics in micro-irrigated citrus orchards grown under the atmospheric conditions of the San Joaquin Valley and Tulare Lake Basin, through field measurements, monitoring, and data-driven modeling.
- 2 Refine the experimental version of three citrus modules within CM with knowledge gained from field studies and modeling.
- 3 Ground-truth CM recommendations for N and water applications at heavily monitored citrus study orchards.
- 4 Conduct outreach and training on the developed modules to citrus growers and advisors.

Description

This project consists of 1) identifying cooperating growers to establish monitoring sites and receive critical input on module development/refinement, 2) collecting necessary water and N data (soil N, tissue N, applied water, N in water) across space and time from multiple study sites to refine experimental modules and verify CM recommendations, 3) finetuning CM citrus modules based on collected data and grower feedback, and 4) conveying findings and offering outreach and training opportunities to the citrus grower and advisor community. Through these steps, this project will deliver a needed free, accurate, and reliable tool for citrus growers to farm efficiently and with confidence.

Results and Discussion

During the second year of the project, efforts have been focused on continued monitoring and data collection at 9 commercial orchards across Fresno, Tulare, and Kern counties, including three sites each with navel orange, mandarin, and lemon. Additionally, a literature review of California-based citrus N studies has been completed to support refinement of N uptake models in CM and the plant N data collection strategy. Below describes preliminary findings of work completed to date.

First, unmanned aerial vehicle (UAV) flights are being conducted to monitor changes in canopy cover and compare them to satellite based-estimates from SIMS (Satellite Irrigation Management Support). This is needed because canopy cover is a key input into CM to generate irrigation recommendations and the software will default to using satellite-based estimates if none are provided by the user. Across the 2025 growing season, UAV data showed relatively stable values through spring, summer, and fall across sites and varieties (Figure 1). However, satellite-based estimates showed a decrease from spring to summer and a recovery in the fall (Figure 1). This trend was confirmed by randomly selecting 225 citrus fields across the Central Valley and extracting estimates from satellite imagery, and similar findings were reported by Dhungel et al., 2024 confirming our study sites are not anomalous in this regard. While canopy management practices (e.g., hedging, thinning) have an effect on canopy cover, they do not explain the difference between UAV data (direct high-resolution measurements) and satellite-based estimates. The differences suggest that the satellite estimates may have an artefact (e.g., due to changes in citrus leaf color or leaf angle during the summer), but additional investigation is needed. This discrepancy will be addressed to ensure reliable irrigation recommendations for citrus are generated by CM.

Second, flow meters installed to track grower irrigation applications through CM show that cumulative applied irrigation generally parallels CM recommendation patterns, but that current CM recommendations consistently exceed grower applications across all sites and years (2025 and 2026 to date), even when the satellite-based estimates of canopy cover were used that resulted in lower estimates of crop ET in summer months. Intentional deficit irrigation has been confirmed in some cases, which can be customized in CM and will be done in collaboration with participating growers. Soil moisture sensor data show a draw down of soil moisture in some sites, confirming deficit irrigation, while other sites are relatively stable (which does not necessarily rule out that full crop ET is not achieved). Eddy-covariance towers are installed at three of the study sites to measure actual ET and the data will be used to better quantify the water balance, verify site specific crop coefficients, and refine CM.

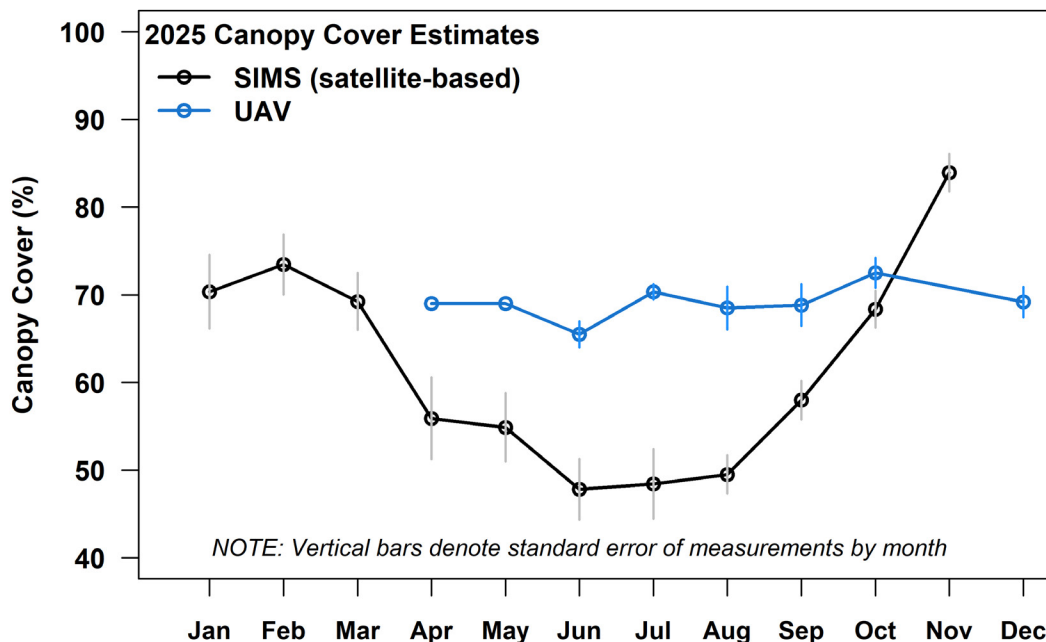


Figure 1. Mean and standard error of canopy cover estimates for 2025 across nine study sites derived from UAV flights and SIMS satellite-based estimates.

Third, a literature review of California specific N cycling studies in citrus orchards suggests that the majority of N uptake in both navel orange and mandarin occurs over a span of approximately 120 days from post-bloom through late summer/early fall in a relatively linear fashion (Brown et al., 2020), followed by a period of N translocation within trees, as the fruit matures and the trees undergo seasonal physiological processes (Krueger 2005). Moreover, fruit are the major N sink for mature trees. Crop N demand can be determined with yield estimates and recently published N removal coefficients from Geisseler (data for all studied crops presented in http://geisseler.ucdavis.edu/Geisseler_Report_U4_2026_04_03.pdf) along with N required for tree growth/maintenance estimated at 0.1-0.15 lbs N/tree/year (Brown et al, 2020 and personal communication with D. Amaral). With this information, preliminary N uptake models have been developed for CM to generate timely N fertilization recommendations. Additional sampling work is planned to help verify these assumptions through the remainder of the project.

Conclusion

Strategies and tools are needed to support growers in coping with mounting pressures to protect and conserve water resources. CM is a free and practical option for making informed in-season decisions about when and how much N and water to apply to efficiently produce a full crop. When managed together, the utilization of these inputs can be optimized. Through research projects such as this, CM recommendations are able to be refined to increase their reliability and grower confidence in them.

Acknowledgements

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Nutrient Management Education on the Central Coast of CA

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Introduction

The Agriculture and Land-Based Training Association (ALBA), a 501(c)(3) nonprofit based in the Salinas Valley, is in the second year of a three-year project focused on improving access to practical nutrient and irrigation management education on California's Central Coast. The project responds to the region's ongoing challenge of nitrate contamination in groundwater and to the need for beginning and small-scale farmers to have practical, bilingual information and technical support they can apply in commercial production. By combining classroom instruction, hands-on field learning, and individualized technical assistance, the project aims to improve nutrient and water management while strengthening the capacity of local organizations to support growers.

Objectives

- 1 Educate 175+ farmers, 30 college students, and 25 agricultural professionals and service providers on soil fertility and plant nutrition management techniques.
- 2 Provide direct technical assistance to 60+ farmers on innovative and proven conservation practices that protect groundwater resources.
- 3 Conduct outreach to 500+ farmers, college students, and agricultural professionals on project results and CDFA, UCCE, and other agency tools and resources for nutrient management best practices.

Description

ALBA integrated the project into its existing bilingual farmer education and incubation programs. Its annual Farmer Education Course provides more than 250 hours of experiential learning for aspiring organic farmers, including instruction in plant nutrition, irrigation principles, nutrient budgeting, cover crops, compost, crop rotation, and other soil and crop management topics. Field days reinforce classroom concepts through activities such as soil nitrate quick testing and irrigation system evaluations.

The Organic Farm Incubator provides beginning farmers with subsidized access to land, equipment, and irrigation infrastructure, along with ongoing technical assistance from ALBA staff and project partners. ALBA's office and classroom are located at the center of its 100-acre training site, where approximately 35 to 40 start-up farmers operate each year. This setting allows nutrient and irrigation management education to be connected directly to commercial production decisions throughout the growing season.

The Resource Conservation District of Monterey County (RCDMC) provides regular on-site assistance with soil fertility and irrigation management and works closely with ALBA staff to coordinate and deliver technical support. The Resource Conservation District of San Benito County (RCDSBC) has begun to extend similar assistance in San Benito and Santa Clara counties. The project also uses ALBA's one-acre demonstration field for field-based learning and outreach to farmers, students, agricultural professionals, and other visitors.

Results and Discussion

During the second year, the project delivered more than 20 workshops and 20 field days and reached approximately 50 beginning farmers, 22+ ag professionals, and 35+ college students through classroom instruction, hands-on demonstrations, and individualized technical assistance. Training emphasized practical nutrient and irrigation management strategies, including nutrient budgeting, cover cropping, compost use, crop rotation, irrigation principles, soil fertility management, and efficient water use.

Hands-on learning was a central component. All first- and second-year farmers in ALBA's Organic Farm Incubator participated in soil nitrate quick testing and irrigation system distribution uniformity evaluations. Weekly nutrient and irrigation management meetings gave farmers recurring opportunities to review field conditions, discuss production challenges, interpret test results, and receive individualized recommendations during the growing season. Some farmers also used tools such as telemetric flow meters, CropManage, and tensiometers to better understand irrigation timing and water use.

These activities helped connect nutrient management concepts to day-to-day farm decisions. Nutrient budgeting gave participants a framework for matching fertilizer applications more closely to crop needs, while soil nitrate testing and irrigation evaluations provided field-level information that could be discussed with advisors. The combination of recurring meetings and on-farm demonstrations also allowed technical assistance to respond to changing crop and field conditions rather than being limited to one-time workshops.

The project also increased regional technical assistance capacity. RCDSBC staff participated in substantial cross-training with RCDMC to build knowledge and experience in nutrient and irrigation management, and RCDSBC hired a three-quarter-time employee to expand grower support.

This investment in partner capacity increases the number of growers who can receive practical assistance beyond ALBA's training site and strengthens coordination among organizations serving farmers across the Central Coast.

As an education and technical assistance project rather than experimental research, its second-year results are primarily implementation and outreach outcomes. Experience to date indicates that practical, bilingual instruction is most useful when farmers can pair classroom concepts with field measurements, repeated advisor contact, and opportunities to apply the information in their own operations. The final project year will continue these activities while documenting participation, technical assistance, and adoption of nutrient and irrigation management practices.

Conclusions

The second year demonstrated the value of combining bilingual classroom education, on-farm demonstrations, and recurring technical assistance for beginning farmers. Soil nitrate quick testing, irrigation system evaluations, nutrient budgeting, and weekly management meetings gave participants multiple ways to connect nutrient management concepts with commercial farm decisions. For agricultural advisors and practitioners, a key takeaway is that repeated, field-based engagement can make nutrient and irrigation management information more accessible and actionable for beginning and small-scale growers.

The project also strengthened the regional technical assistance network through cross-training and added staffing at RCDSBC. Continued collaboration among ALBA, RCDMC, RCDSBC, and other partners will help expand access to practical nutrient management support and conservation resources across the Central Coast.

Acknowledgements

ALBA acknowledges support from the California Department of Food and Agriculture Fertilizer Research and Education Program (CDFA FREP), the Resource Conservation District of Monterey County, and the Resource Conservation District of San Benito County.

Soil Nitrogen and Nitrate Leaching Potential During Young Orchard Replanting: First-Year Observations from a Modesto Almond Orchard

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Introduction

Young orchard blocks are disproportionate sources of nitrate leaching to groundwater. When an old almond orchard is removed, the soil deep-ripped, and organic amendments and fertilizer incorporated ahead of replanting, a large nitrogen pool is placed in a profile with no crop to use it: newly planted almonds take up less than 50 lbs N per acre in their first year, so winter rain on the bare, freshly ripped soil can move nitrate below the root zone before young trees can reach it. Our study site, a 140-acre commercial almond orchard west of Modesto managed with high-frequency low-concentration (HFLC) fertigation since 2018, has recorded this pattern once already: after the SW1 block (Block 5) was replanted in 2019, nitrate in that block's shallow monitoring wells rose sharply within one to five years. When the ranch's oldest block (SW2, Block 3, planted in 2000) was removed in fall 2025 and replanted on February 27, 2026, we measured the soil nitrogen pool created by standard orchard-recycling and replanting practices and tracked its movement through the profile across the first winter.

Objectives

- 1 Quantify the soil inorganic nitrogen pool created in the Block 3 root zone and deep profile by orchard removal, soil ripping, and pre-plant amendments (almond bark chips, compost, and fertilizer pellets).

- 2 Compare post-amendment soil nitrogen with the block's own 2018-2025 history and with the four planted blocks sampled on the same dates.
- 3 Track nitrate redistribution through the 0-6 ft profile across the 2025-2026 winter rains, from the pre-rain sampling (November 21, 2025) to the post-rain sampling at planting (February 28, 2026).
- 4 Evaluate nitrate leaching potential during orchard establishment, using the monitoring-well record from the 2019 replanting of Block 5 as a field-scale analog.

Description

Soil inorganic nitrogen has been monitored in all five orchard blocks since 2018 at 0-30 cm (0-1 ft) and 30-60 cm (1-2 ft), with periodic deeper sampling. Samples are extracted with 2M KCl, analyzed for nitrate-N ($\text{NO}_3\text{-N}$) and ammonium-N ($\text{NH}_4\text{-N}$), and converted to lbs N per acre using NRCS SSURGO bulk densities. For the replant study, Block 3 sampling was intensified: five deep cores to 10 ft in November 2024 (old orchard standing), then twelve locations sampled in 1-ft increments to 6 ft on November 21, 2025 (after removal, ripping, and amendments, before the winter rains) and again on February 28, 2026, one day after replanting, following 6.9 inches of rain recorded at the Modesto City-County Airport in three storm periods (late December, New Year's week, and mid-February). Twenty shallow monitoring wells sampled since 2015 provide the groundwater record.

Results and Discussion

Replanting practices created a large nitrogen pool. Under the old orchard, Block 3 root-zone (0-60 cm) inorganic N was stable near 20-50 lbs N per acre for five years (Figure 1), and the whole 0-6 ft profile held only about 46 lbs $\text{NO}_3\text{-N}$ per acre in November 2024 (Table 1). After removal, ripping, and amendment incorporation, the November 21, 2025 sampling found 182 lbs inorganic N per acre in the top 2 ft alone (over 90 percent as nitrate) and 290 lbs $\text{NO}_3\text{-N}$ per acre in the 0-6 ft profile, about six times the pre-removal total and four to ten times the root-zone N in the orchard's four planted blocks that same day (17-48 lbs per acre). Nitrate was concentrated at 1-2 ft, the depth of ripping and amendment incorporation (Figure 2).

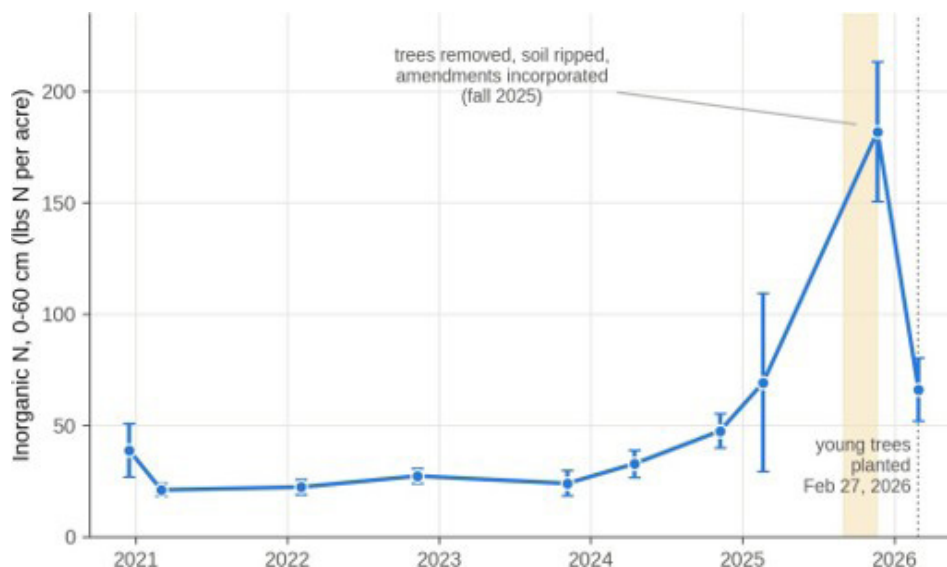


Figure 1. Block 3 (SW2) root-zone (0-60 cm) inorganic nitrogen, December 2020 through February 2026. Points are means of 3 sampling locations (12 for the last two dates); bars are standard errors.

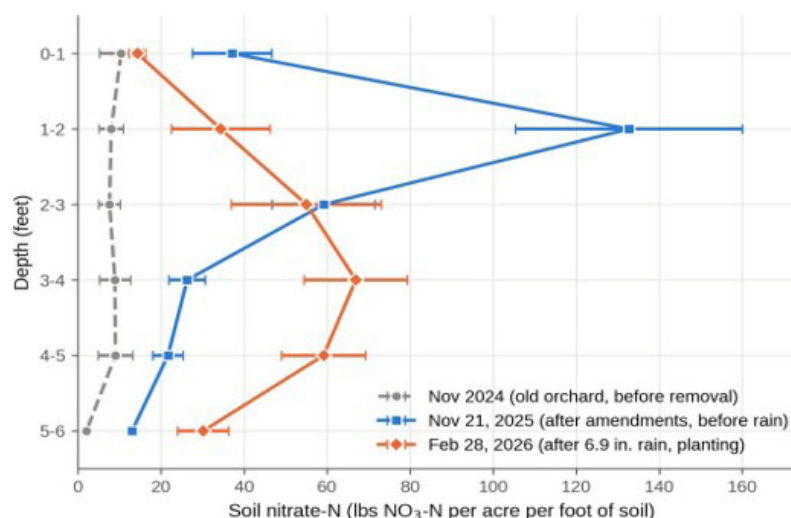


Figure 2. Block 3 soil nitrate-N by depth (lbs NO₃-N per acre per foot): November 2024 under the old orchard (5 cores), November 21, 2025 after amendments and before the rains, and February 28, 2026 after 6.9 inches of rain, one day after replanting (12 locations; bars are standard errors).

One winter of rain moved the nitrate pool 1 to 2 feet deeper. By planting day, root-zone (0-60 cm) inorganic N had fallen 64 percent, from 182 to 66 lbs per acre. That nitrogen was not gone: it had moved downward. Nitrate at 3-4, 4-5, and 5-6 ft roughly doubled to tripled (Table 1, Figure 2), the nitrate center of mass moved from about 2.2 to 3.3 ft deep, and the 0-6 ft inventory was statistically unchanged (290 versus 260 lbs NO₃-N per acre; paired comparison across the twelve locations, not significant). The 6.9 inches of winter rain displaced the nitrate front 1 to 2 feet, below the reach of first-year roots but still above 6 ft.

Continued displacement at that rate under irrigation and future winters would carry it toward the water table (20-30 ft) within several seasons.

Table 1. Block 3 mean soil nitrate-N by depth (lbs NO₃-N per acre per foot of soil)

Depth (feet)	Nov 2024, old orchard	Nov 21, 2025, after amendments	Feb 28, 2026, after winter rain	Change, Nov 2025 to Feb 2026
0-1	10	37	14	-23
1-2	8	133	34	-98
2-3	8	59	55	-4
3-4	9	26	67	+41
4-5	9	22	59	+37
5-6	2	13	30	+17
Total, 0-6 ft	46	290	260	-30 (not significant)

The 2019 replanting of Block 5 shows where this nitrogen can end up. After the adjacent SW1 block (Block 5) was replanted in 2019, nitrate-N in its four monitoring wells rose sharply: MW13 climbed from about 55-60 mg/L to a 2020 peak above 100 mg/L, and MW18 rose from about 16 mg/L in 2017 to about 90 mg/L by 2024-2026, nine times the 10 mg/L drinking water standard, while the mean of the sixteen wells elsewhere in the orchard moved only from about 22 to 31 mg/L (Figure 3). The question for Block 3 is therefore not whether leachate will reach groundwater but how much nitrogen the replant year adds. The roughly 260 lbs NO₃-N per acre still in the profile at planting, minus modest first-year tree uptake, is the pool available to repeat the Block 5 pattern.

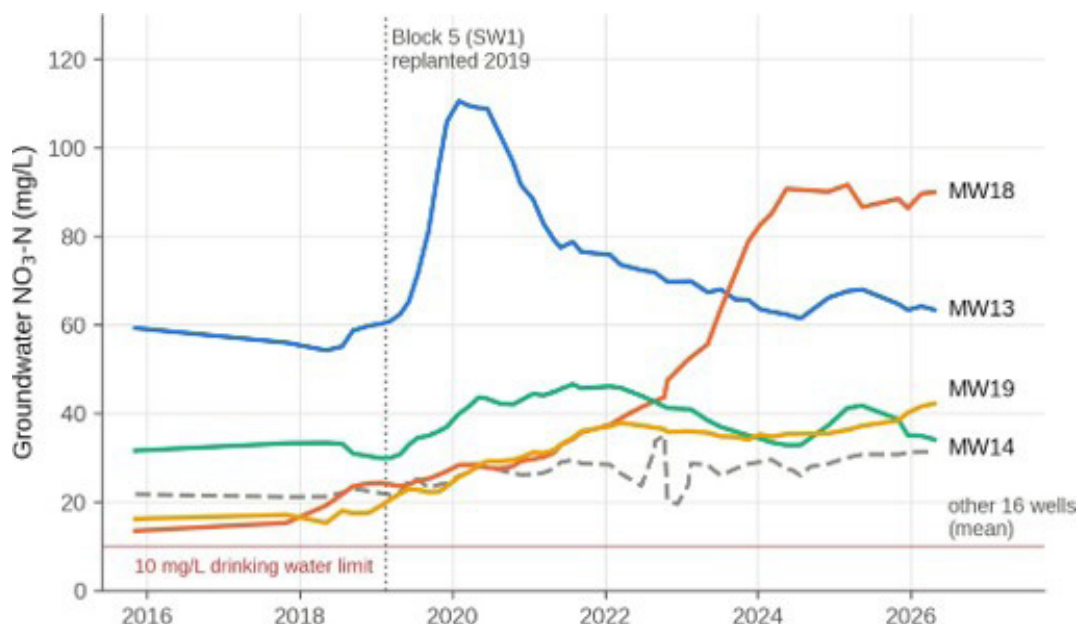


Figure 3. Nitrate-N in the four shallow monitoring wells in Block 5 (SW1), replanted in 2019, compared with the mean of the sixteen wells in the rest of the orchard (three-sample running means).

Conclusions

Standard replanting practice loaded this soil profile with about 300 lbs inorganic N per acre before a single tree was planted, and one moderate winter (6.9 inches of rain) pushed that nitrate 1 to 2 feet deeper before planting day. Because first-year almonds take up less than about 50 lbs N per acre, most of this pool is at risk of leaching, and the well record from the 2019 replant next door shows the outcome: multi-year nitrate increases of 50 mg/L or more in shallow groundwater. For growers replanting on recycled orchard ground: (1) credit the nitrogen already supplied by compost, amendments, and mineralizing residue before adding pre-plant or first-year fertilizer, since the profile may already hold several years of young-tree demand; (2) where possible, favor low-N, slow-release amendments (such as bark chips alone) over N-rich pre-plant blends; and (3) budget first-year fertigation conservatively and confirm need with soil tests rather than applying by calendar. We will continue quarterly soil, vadose-zone, and groundwater monitoring in Block 3 through the establishment years to quantify how much of this pool reaches groundwater and how quickly.

Acknowledgements

We thank the California Department of Food and Agriculture Fertilizer Research and Education Program (FREP) for supporting this project, the Almond Board of California for co-funding the long-term site, and the cooperating grower for field access and operations records. Teena Armstrong and Dillon McMenomy (UC Davis) performed the soil sampling and laboratory analyses summarized here.

Nitrogen Runoff and Leaching Loss from Container Nursery Production

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Introduction

Nitrogen (N) application rates in container nursery production can be very high, ranging from roughly 1,000 to 7,000 lbs. N per acre annually, because growers rely heavily on controlled-release fertilizer (CRF) and water-soluble fertilizer (WSF) to meet plant demand. Fertilizer is also one of the largest input costs for nursery operations, so nitrogen that is lost from the production system represents both an economic loss and an environmental concern, particularly for groundwater quality.

Under the state Irrigated Lands Regulatory Program's Irrigation and Nitrogen Management Plan (INMP) reporting requirements, growers must estimate the nitrogen removed by the crop to help calculate how much nitrogen could potentially leach to groundwater. For traditional row and orchard crops, this removal coefficient is straightforward because it is tied directly to harvested yield. For container nursery production, it is far more complicated: the soilless substrate and any unused fertilizer leave the nursery along with the plant, and California nurseries grow thousands of different plant taxa in a wide range of container sizes, substrates, and irrigation and fertilization strategies.

Two irrigation methods, drip and overhead, and two fertilizer strategies, CRF and WSF, are both common across California nurseries, often used in combination. Substrates also vary widely in their carbon-to-nitrogen (C:N) ratio, from about 58:1 for peat moss to 1,000:1 for sawdust, which affects how much nitrogen is immobilized by microbes rather than lost in runoff or leachate. Most prior research on WSF and CRF leaching has relied on drip irrigation and individual container studies even though overhead irrigation is more common, and often the only economically feasible method for smaller containers. As a result, existing data do not fully capture the aqueous nitrogen losses most representative of commercial nursery operations.

This project was developed to fill that gap by directly comparing nitrogen losses across the substrate, irrigation, and fertilizer combinations most common on California nurseries, generating information that can help growers reduce nitrogen loss and support a more workable, science-based alternative to the current INMP reporting requirement for the nursery industry.

Objectives

- 1 Compare nitrogen losses from soilless substrates with different carbon-to-nitrogen ratios, using a single fertilizer and irrigation method.
- 2 Measure the percentage of applied nitrogen lost through leaching and runoff for controlled-release and water-soluble fertilizer applications.
- 3 Compare nitrogen losses between overhead and drip irrigation methods, applied in combination with controlled-release and water-soluble fertilizer.

Description

To capture nitrogen losses under realistic nursery conditions, the project team is constructing an experimental container nursery at the University of California South Coast Research and Extension Center (SCREC) in Irvine, California, a location representative of the climate found across much of California's nursery industry. The system consists of sixteen experimental beds designed to mimic the graveled surfaces and irrigation infrastructure common at commercial wholesale nurseries. Each bed is approximately two feet deep, lined with pond liner, backfilled with a gravel layer, and topped with compacted native soil. Leachate that moves through the soil profile is captured in a below-ground tank, while surface runoff is collected separately, allowing the team to measure both volume and nitrogen concentration for each pathway.

The first experiment will use eight of the sixteen beds to compare nitrogen leaching and runoff from two soilless substrates that differ in carbon-to-nitrogen ratio, with four beds allocated to each substrate. A single container size, plant species, irrigation method, and fertilizer type will be held constant so that substrate is the only variable being tested. The second experiment, conducted on all sixteen beds, will use a two-by-two factorial design comparing CRF and WSF fertilizers across overhead and drip irrigation, with four beds per treatment combination. For both experiments, irrigation, rainfall, and runoff or leachate samples will be analyzed for nitrogen concentration, and plant biomass and tissue nitrogen content will be measured at the end of each production cycle to calculate an overall nitrogen mass balance and nitrogen use efficiency for each treatment. Results will be shared with growers and regulators through UC Cooperative Extension outreach, including field days, workshops, trade publications, and bilingual (English/Spanish) programming.

Results and Discussion

This is the first interpretive summary for the project, reporting on progress during year one. Construction is currently underway on the first eight experimental nursery beds, including installation of the pond liner, gravel base, compacted native soil, and irrigation infrastructure needed to support the first experiment comparing nitrogen losses between soilless substrates of different C:N ratios. Site preparation and bed construction are proceeding according to the timeline established in the project work plan, and the project remains on schedule.

Because data collection has not yet begun, no nitrogen loss results are available for this reporting period. Once construction of the first eight beds is complete, the project team will finalize substrate selection and begin the first experiment, with irrigation, rainfall, and runoff water sampling to follow.

Conclusions

While it is too early to report nitrogen loss results, the project has established the experimental infrastructure needed to directly compare nitrogen losses across the substrate, irrigation, and fertilizer combinations most commonly used in California container nursery production. Growers and regulators can expect the first substantive results, comparing nitrogen losses between low and high C:N ratio substrates, once the first experiment concludes. In the meantime, this project's long-term goal is to translate direct measurements of nitrogen loss into practical, science-based recommendations and a more workable alternative to the current Irrigation and Nitrogen Management Plan requirement for nursery producers.

Acknowledgements

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Advancing Irrigation and Nitrogen Management of Cantaloupe in Southern California Using Field Experiments and Remote Sensing

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Introduction

Melon production is significant in Southern California, with 4,800 and 3,045 acres of cultivation in Imperial and Riverside counties, respectively. Excess irrigation and nitrogen application threaten the sustainability of agricultural production in the region. Agricultural drainage can transport fertilizers, salts, and other contaminants to the Salton Sea, an impaired water body in California. Growers need management practices that reduce nitrogen exports and improve air quality while maintaining competitive yields and excellent produce quality. With the adoption of pressurized irrigation systems in melon production, there is a need to compute nutrient requirements accurately for the region's conditions.

Since 2023, growers in Imperial County have been required to report nitrogen fertilizer applications. Overirrigation negatively impacts nitrogen use efficiency because it causes nitrogen leaching into deeper soil layers and increases the risk of groundwater contamination. Consequently, science-based irrigation and nitrogen recommendations should be developed for the major soil types in the region to support farm productivity and environmental stewardship. The overall goal of this project is to enhance the sustainability of cantaloupe production in Southern California.

Objectives

- 1 Evaluate the response of cantaloupe to different irrigation and nitrogen amounts in heavy- and coarse-textured soils in Southern California.
- 2 Develop recommendations for irrigation and nitrogen management of cantaloupe in the region.
- 3 Develop and evaluate remote sensing-based statistical models for yield prediction using drone and satellite data.

Description

Field trials were established at two locations with different soil types: the UC Riverside Agricultural Experiment Station (UCR AES) in Riverside and the UC ANR Desert Research and Extension Center (UC DREC) in Holtville, CA. Table 1 shows the first irrigation and harvest dates for both sites.

Table 1. First irrigation and harvest dates for UCR AES (UCR Agricultural Experiment Station) and UC DREC (UC ANR Desert Research and Extension Center) sites.

	UCR AES site	UC DREC site
First irrigation	14 May, 2026	5 March, 2026
First harvest	13 August, 2026	-
Final harvest	24 August, 2026	5 June, 2026

UCR AES site

The soil at this site ranges from loam to sandy loam. The experiment was established as a split-plot design, with irrigation treatments as the main-plot factor and nitrogen treatments as the subplot factor. Treatments were randomly assigned to plots, with four replicates. Three irrigation treatments were based on crop evapotranspiration (ET_c): (i) 100% ET_c (I1), (ii) 150% ET_c (I2), and (iii) 50% ET_c (I3). Each plot consisted of five 5-ft-wide beds, 30 ft long. One drip tape per bed was buried about 5 cm below the soil surface. Irrigation treatments began 32-34 days after planting and crop establishment. The nitrogen treatments represented three N budgets: (i) a grower-recommended rate; (ii) a rate based on the California Fertilization Guidelines (CFG) without accounting for residual soil nitrate or nitrate in irrigation water; and (iii) a CFG-based rate adjusted for preplant residual soil nitrate in the top foot and nitrate in irrigation water. The resulting N budgets were 175 lb/acre (N1), 130 lb/acre (N2), and 30 lb/acre (N3). All plots received 55 lb N/acre preplant. For treatments with N budgets greater than 55 lb/acre, the difference was fertigated through the drip system at three crop stages. For N3, whose calculated budget was below the common preplant application, no additional N was applied during the growing season; thus, N3 received only the 55-lb/acre preplant application.

Soil and biomass sampling and remote sensing data collection were conducted at different growth stages. Preplant and final-harvest soil samples were collected at three depths (0-30 cm, 30-60 cm, and 60-90 cm), whereas in-season soil samples were collected only from the top 30 cm. Drone-mounted cameras collected thermal and multispectral imagery. Hand-held sensors were used to measure surface temperature, NDVI (normalized difference vegetation index), LAI (leaf area index), chlorophyll index, stomatal conductance, and leaf petiole nitrate content. Biomass samples were analyzed for total leaf nitrogen and leaf petiole nitrate. Fruit samples at final harvest were analyzed for Brix (a measure of fruit sweetness) and total nitrogen.

Melons were harvested in two phases based on fruit appearance. All melons picked from the inner three rows of each plot were weighed for yield estimation. Fruits were classified as marketable or unmarketable and weighed separately.

UC DREC site

The site was affected by Cucurbit yellow stunting disorder (CYSD), transmitted by the silverleaf whitefly, which has affected crop performance and yield. Soil, biomass, and yield data are still being processed and analyzed. Therefore, results from this site are not included in this preliminary interpretive summary.

Results and Discussion

Preliminary first-year results from UCR AES are presented here; soil, biomass, and remote-sensing analyses are ongoing, and UC DREC results are not yet included. Marketable yield differed significantly among irrigation treatments ($p < 0.05$), with 100% and 150% ET_c producing statistically similar yields and both exceeding 50% ET_c. Neither N budget nor the irrigation-by-N interaction significantly affected marketable yield (Table 2); treatment-combination means are shown in Table 3. These preliminary data show no statistically significant difference in marketable yield between 100% and 150% ET_c and no significant marketable-yield response to N budget. Further interpretation of N availability, uptake, and movement will depend on ongoing soil and plant analyses.

Table 2. Analysis of variance showing the main and interaction effects of irrigation and N budget on crop yield. Values are mean $\pm$ standard error (N=4).

	Marketable yield, ton/acre	Unmarketable yield, ton/acre
Irrigation		
100% ET _c	24.54 $\pm$ 0.75 a	10.61 $\pm$ 0.43 b
150% ET _c	25.17 $\pm$ 0.87 a	13.10 $\pm$ 0.66 a
50% ET _c	15.44 $\pm$ 1.15 b	7.97 $\pm$ 0.45 c
N budget		
175 lb/acre	22.80 $\pm$ 1.55 a	11.01 $\pm$ 0.91 a
130 lb/acre	21.44 $\pm$ 1.79 a	11.13 $\pm$ 0.61 a
30 lb/acre	20.91 $\pm$ 1.51 a	9.54 $\pm$ 0.81 a
Analysis of variance P > F [a]		
Irrigation	0.0004*	0.0002*
N budget	0.2700	0.0529
Irrigation x N budget	0.5353	0.3533

[a] The ANOVA table presents significance levels for the main effects of irrigation and N budget and their interaction. * indicates significance at $p < 0.05$.

Table 3. Marketable and unmarketable yield by irrigation and N-budget treatment combination. Values are mean $\pm$ standard error (N=4).

Irrigation	N budget	Marketable yield, ton/acre	Unmarketable yield, ton/acre
100% ET _c	175 lb/acre	25.91 $\pm$ 1.09 a	10.92 $\pm$ 0.78 abc
100% ET _c	130 lb/acre	23.86 $\pm$ 0.81 ab	10.92 $\pm$ 0.88 abc
100% ET _c	30 lb/acre	23.85 $\pm$ 1.85 ab	9.98 $\pm$ 0.64 bcd
150% ET _c	175 lb/acre	26.38 $\pm$ 0.90 a	14.44 $\pm$ 0.93 a
150% ET _c	130 lb/acre	26.18 $\pm$ 1.53 a	12.93 $\pm$ 0.93 ab
150% ET _c	30 lb/acre	22.93 $\pm$ 1.66 ab	11.92 $\pm$ 1.39 ab
50% ET _c	175 lb/acre	16.12 $\pm$ 1.40 bc	7.67 $\pm$ 0.24 cd
50% ET _c	130 lb/acre	14.28 $\pm$ 2.37 c	9.52 $\pm$ 0.72 bcd
50% ET _c	30 lb/acre	15.93 $\pm$ 2.50 bc	6.73 $\pm$ 0.53 d

*Within each column, means followed by the same letter are not significantly different at $\alpha = 0.05$.

Melons with mold, cracking, or softness were classified as unmarketable. Unmarketable yield differed significantly among irrigation treatments ($p < 0.05$), with 150% ET_c producing the highest unmarketable yield. This pattern suggests that overirrigation may have contributed to conditions favoring fruit rot or cracking; however, these preliminary data do not establish a causal mechanism. Additional data and analyses are needed before drawing conclusions about effects on fruit quality or economic returns.

Future Analysis

Soil and biomass samples are being analyzed for nutrients to assess the fate of applied nitrogen at different growth stages. Thermal and multispectral drone imagery collected at different growth stages will be used to evaluate crop responses to the treatments. Soil moisture sensors installed at 5, 15, 25, 40, and 60 cm depths will be used to track soil water movement following irrigation events. Soil moisture and reference evapotranspiration (ET_o) data will be used to derive site-specific crop coefficients (K_c) using a soil water balance. Yield-prediction models will be developed using drone imagery.

Conclusions

These first-year UCR AES results are preliminary and represent only part of the project dataset. Marketable yield was statistically similar between 100% and 150% ET_c, whereas 50% ET_c produced lower yield. N budget did not significantly affect marketable yield in this trial. Unmarketable yield was higher at 150% ET_c, but the underlying cause and practical implications require further analysis. Soil, plant, remote-sensing, and UC DREC data remain under analysis; therefore, no final management recommendations or conclusions regarding optimal irrigation or N rates are given at this stage.

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Nutrient Management: A Collaborative Approach between Agriculture and Regulatory Programs in the San Diego Region

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Introduction

Agriculture is a high value component of the overall economy in San Diego County and is primarily composed of specialty crop production. The agricultural community is comprised of mostly small farms, with 69% of farms between 1-9 acres. San Diego agriculture is unique and includes considerable variability in crops and topography, grower experience and knowledge, languages spoken, race, heritage and age.

Agriculture in the San Diego area has long grappled with water quality regulations, particularly those focusing on nitrate contamination of surface water. Groundwater is relatively sparse in San Diego County. Growers in the area are regulated under both the MS4 program and the General Agricultural Order, with many overlapping requirements. The San Diego Region Irrigated Lands Group (SDRILG) (1) was developed to assist with grower monitoring requirements and required grower education; approximately 1100 irrigated agricultural producers pay fees for group membership.

Recently, the San Diego Regional Water Quality Control Board (Regional Board) worked to establish a new Ag Order, including the required statewide implementation of the "Eastern San Joaquin Order" (ESJ Order) (2) as a condition for San Diego agriculture. The ESJ Order was adopted by the State Water Board in 2018 with a primary focus on nitrate management in groundwater. The State Water Board determined that portions of the ESJ Order were precedential and directed all Regional Boards to revise their irrigated lands regulatory programs to be consistent with the ESJ Order during the following five years.

Most of the precedential requirements of the ESJ Order proved to be very problematic for agriculture in San Diego as the Order was developed for a more homogenous, larger-scale crop production system that has well-established fertilizer and irrigation needs, harvests one crop once per year, and occurs on relatively flat land. None of this is found in San Diego agriculture, which has more farms than any other county in the nation. Agriculture is intensive, small-scale, extremely diverse, and most of the minor, specialized crops grown here do not have standardized data to guide growers as to how much fertilizer to use, how much irrigation is optimum, or how to manage pests on their crops. Also, San Diego has more nurseries than any other county in the United States; many grow over 250 different species, each with differing growth and input requirements and with multiple crops per year. Reporting requirements in the ESJ Order would have required several thousand pages of data for many nurseries in the area.

The topography and location of agricultural production operations is also quite variable. Many of the farms are located in areas with multiple land uses. Farmed areas in San Diego are generally hilly, and growers who farm downhill of other land uses often accommodate runoff from those uphill uses, many of which apply the same nutrients and other materials to their property as the farming operations do. It is normal to find farming operations and nurseries surrounded by horse facilities, golf courses, parks, schools and residential areas. This complexity makes it difficult to accurately assign the source of the nutrient and other runoff issues. In addition, groundwater is extremely scarce with many growers using district water to irrigate crops.

After much collaboration between the SDRILG and the Regional Board, staff ultimately found the application of the Eastern San Joaquin Ag Order to be unworkable for the San Diego Region. As a result, the unusual decision was made by the Regional Board staff to shift the effort from adoption of the Eastern San Joaquin Order to a focus on Best Management Practices (BMPs) for water quality management at this time. This project will: 1) analyze the specific BMP needs collaboratively with regulatory program staff and 2) support the SDRILG in providing data-driven outreach and education to its members. This will allow for implementation of the most effective BMPs for the unique agricultural operations in our area and for education of the growers as to their effective use.

Objectives

Table 1: Objectives and Methods of Information Delivery to Clientele Groups

Objective 1: Determine where and how BMP adoption will have the greatest impact by reviewing the most common nitrogen management-related violations found during farm inspections by Regional Board and MS4 program staff during the past five years. Organize by watershed, and crop type and prioritize violations that can best be addressed through appropriate BMPs.	Timeline
Task 1.1: Collect and Review and organize agricultural data collected by the Regional Board, the County of San Diego Ag, Weights and Measures Ag Water Quality Program (AWQP) and water quality programs of other jurisdictions regarding violations when inspecting farming operations under the MS4 and other programs.	1/26-6/26
Task 1.2 Prioritize outreach and education efforts to most needed areas and topics, based on the results of Task 1.1	6/26-8/27
Objective 2: Establish and extend BMPs that will assist growers in meeting regulatory requirements for surface and groundwater contamination.	Timeline
Task 2.1 Develop and deliver educational meetings and demonstrations focused on Tree and Vine Crops.	6/26-8/27
Task 2.2 Develop and deliver educational meetings and demonstrations focused on Horticulture and Nursery Production and Row Crop Production.	8/27-12/28
Objective 3: Define methods to assist those who are not able to access training and other information due to "Low Tech" capacity within the SDRILG.	Timeline
Task 3.1: Continuously outreach to the self-identified "low tech" members of the SDRILG through alternative methods to determine their needs.	6/26-12/28
Task 3.2: Provide specific materials and meetings to fulfill the educational requirements of the "low tech" members.	6/26-12/28
Objective 4: Create a Resource Collection available to members of the SDRILG and others that will assist them in learning about and implementing BMPs for nitrogen management on their farms.	Timeline
Task 4.1: Develop a Resources Collection of program materials, both digital and in hard copy, for the members of the SDRILG and others interested in the information. These materials will assist in guiding them through the process of understanding and utilizing BMPs.	6/26-12/28

Description

The above table describes the general timeline and tasks and activities for each objective. It should be noted that any workshops or materials are available to both members and non-members of the San Diego Region irrigated Lands Group. Educational meetings and workshops are the core of the programmatic outreach.

The program will be divided by crop type, with educational efforts focused on tree and vine crops the first year and horticulture, nursery and row crops the second year. All meeting and other educational materials will be available as they are developed and after program completion through the SDRILG.

Results and Discussion

Tasks 1.1 and 1.2

Collect, review and organize agricultural data collected by the Regional Board, the County of San Diego Ag, Weights, and Measures Ag Water Quality Program, and water quality programs of other jurisdictions regarding violations when inspecting farming operations under the MS4 and other programs.

This initial task has been completed. We were able to receive data from the AWQP, which manages the MS4 program for programs located under the County's jurisdiction, from the Regional Board Ag Order Program, and from several cities with agricultural production within the city limits. The AWQP conducts over 400 inspections each year, by far the highest number of any jurisdiction. The most common infraction that kept growers out of compliance with any program was the failure to complete their paperwork, other documentation and educational hours. Other infractions that occurred with frequency included "non-stormwater entering the stormwater channels", "erosion and sediment being discharged off the property", "spills and leaks" and "improper storage of hazardous materials, including fertilizer materials" as the top five. We have already provided an online presentation on properly filling out documentation and other paperwork for members of the SDRILG and will orient the rest of the educational materials around these items.



Figure 1. Presentation to the RVVA

Task 2.1

Develop and deliver educational meetings and demonstrations focused on Tree and Vine Crops. We began our educational meetings by providing a program for the Ramona Valley Vineyard Association (RVVA) on April 28th. The meeting was well-attended by growers from the area. We are scheduling additional field-based Tree and Vine crop meetings for this fall.

Task 3.1

Outreach to the self-identified “low tech” members of the SDRILG through alternative methods. We reviewed the membership of the SDRILG (1100 members) and determined that approximately 20% of the members did not have sufficient computer skills to participate in online presentations and document management. We are providing specific workshops, mailed information, and hard copies of other educational documents for their use. In addition, we have elected to produce a guidebook to staying in compliance and taking care of reporting and other paperwork as a hard copy for these members.

Task 4.1

Development of a resource collection will continue throughout the project.

Conclusions

We have developed some interesting and useful information regarding grower needs and compliance with the water quality regulatory programs, and we will incorporate these things into our program going forward. We also understand the needs of the clientele and how we can work with that to make the educational components a success. We are just getting started on the delivery of the education and outreach programs and look forward to reaching more of the groups needing this information, as well as continuing to work with the regulatory agencies to address their programs structures and updates.

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**COMPLETED
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Completed FREP Projects

The following is a chronological list of final reports for FREP-funded research. Following the title is the name of the principal 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.

Development of Precision Yield Monitor for Almond • *Patrick H. Brown and Stavros Vougioukas, 22-1455*

Nutrient Management and Irrigation Efficiency Outreach and Education for Latino and Southeast Asian Farmers • *Deborah Nares, 21-0573*

Nitrogen Response of Industrial Hemp Cultivars Grown for CBD, Essential Oils, and Fiber • *Robert B. Hutmacher, 20-0964*

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

Outreach and Revenue Generation for Sustaining CropManage Irrigation and Nutrient Management Decision Support Tool • *Michael Cahn, 20-0962*

Certification and Distance Learning for Fertigation • *Stuart Styles, 20-0961*

Enhancing Nitrogen and Water Use Efficiency in California Carrot Production Through Management Tools and Practices • *Ali Montazar, 20-0960*

Development of Site-Specific Nitrogen Fertilization Recommendations for Annual Crops • *Daniel Geisseler, 20-0880*

Nitrogen Content of the Harvested Portion of Specialty Crops to Estimate Crop Nitrogen Removal and Improve Nitrogen Management in Crops • *Richard Smith, 20-0250*

Techniques to Minimize Nitrate Loss from the Root Zone During Managed Aquifer Recharge • *Toby O'Geen, 20-1019*

Irrigation and Nitrogen Management, Monitoring, and Assessment to Improve Nut Production While Minimizing Nitrate Leaching to Groundwater • *Thomas Harter, 19-0968*

Immobilization of Nitrate in Winter-Fallow Vegetable Production Beds to Reduce Nitrate Leaching • *Richard Smith, 19-0955*

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*

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Pima Cotton Nitrogen Management, Uptake, Removal - Impacts of Varieties, Subsurface Drip & Furrow Irrigation • *Robert Hutmacher, 18-0597*

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*

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

Evaluation of Nitrogen Uptake and Applied Irrigation Water in Asian Vegetables Bok Choy, Water Spinach, Garlic Chives, Moringa, and Lemongrass • *Aparna Gazula, 17-0515*

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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*

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