20th Anniversary Program Edition

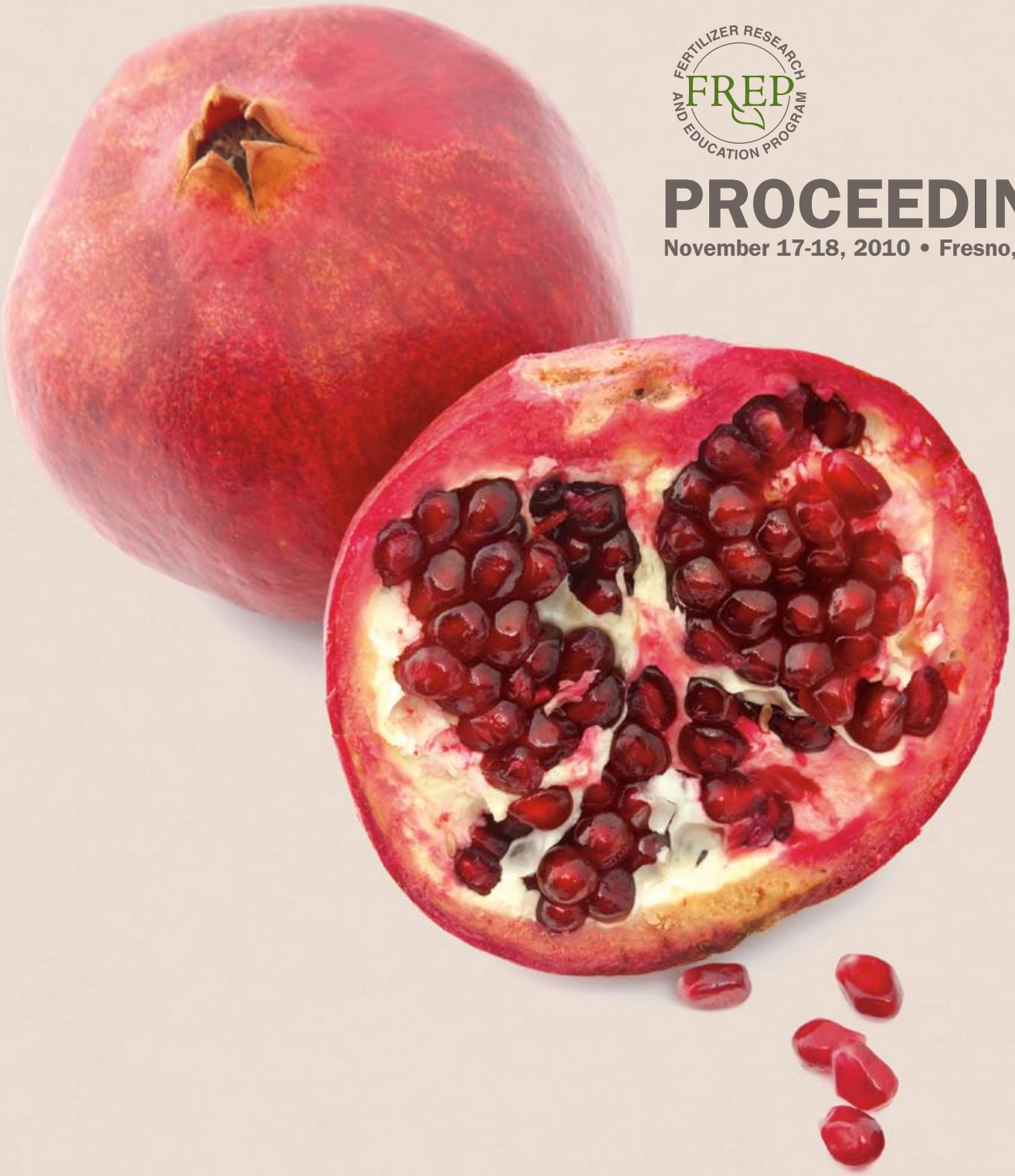
CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

Fertilizer Research & Education Program Conference

FERTILIZER RESEARCH AND EDUCATION PROGRAM
FREP

PROCEEDINGS

November 17-18, 2010 • Fresno, California



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Fertilizer Research & Education Program

cdfa

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November 17-18, 2010
Fresno, California

These 2010 proceedings and conference are dedicated to our dear colleague and friend, Patricia "Kelsey" Olson. She will be greatly missed.

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Introduction

INTRODUCTION

Fertilizer Research and Education Program

FOR 17 YEARS, the California Department of Food and Agriculture's (CDFA) Fertilizer Research and Education Program (FREP) has presented its pioneering fertilizer research at annual conferences. Since 2007, FREP has also collaborated with the Western Plant Health Association (WPHA) to create an alternative conference concept that balances FREP's precise, technical research with discussion on practical application. The combination has allowed FREP the means to convey its research findings in the context of topic overview and practical application and thus extend its outreach to a broader audience of agriculturalists at multiple levels.

The two organizations join resources for a third time this year to offer another integrated agenda. Aptly titled, "Fresh Approaches to Fertilizing Techniques," this 2010 event combines the 18th Annual FREP Conference with WPHA's Central Valley Regional Nutrient Seminar. Over two full days, a panel of speakers provides general and technical information, current research data and practical applications for four key agricultural topics: nitrogen management, water management, tools in plant nutrient management and agricultural laboratories.

Agricultural consultants, advisors, governmental agency and university personnel benefit from the research findings, and in turn pass them on to growers. FREP's commitment to outreach and education continues; constantly seeking new ways to render research results and recommendations more useful and accessible to a broad audience of agricultural professionals.

The summaries from FREP projects presented during the conference—as well as other current, ongoing FREP research—are summarized in these proceedings.

FREP OVERVIEW

FREP funds and coordinates research to advance the environmentally safe and agronomically sound use and handling of fertilizer materials. FREP serves a wide variety of agriculturalists: growers, agricultural supply and service professionals, university extension and public agency personnel, consultants, including certified crop advisers (CCAs) and pest control advisers (PCAs), and other interested parties.

FREP was established in 1990 through legislation with support from the fertilizer industry. The California Food and Agricultural Code Section 14611(b) authorized a mill assessment on the sale of fertilizing materials to provide funding for research and education projects that facilitate improved farming practices and reduce environmental effects from the use of fertilizer. The current mill tax is $0.0005 per dollar sales of commercial fertilizer. The assessment generates approximately $1 million per year for fertilizer research.

Technical Advisory Subcommittee (TASC) of the Fertilizer Inspection Advisory Board (FIAB) guides FREP activities. This subcommittee includes growers, fertilizer industry professionals, and state government and university scientists.

FREP COMPETITIVE GRANTS PROGRAM

Each year, FREP solicits suggestions for research, demonstration, and education projects related to the use and handling of fertilizer materials. FREP strives for excellence by supporting high quality research and education endeavors that have gone through a rigorous statewide competitive process, including independent peer review. The TASC reviews, selects and recommends to the FIAB funding for FREP research and education projects. Since 2009, one or two assigned TASC members steward each research project through completion, following the progress of the project and reviewing the required reports.

Funding is generally limited to $50,000 per year for up to three years; however, large, multi-disciplinary projects may be considered at higher funding levels.

The growing concern of nitrate contamination in ground and surface water from fertilizer use was FREP's initial research focus. In recent years, FREP's research funding has expanded to include agronomic efficiency in the management of nutrients. FREP-funded projects continue to evaluate environmental water and soil quality.

The FREP TASC has laid out specific research priorities for 2011:

- Comparisons of economically viable and commercially ready, integrated fertility-water-soil management approaches that preserve soil and water quality.
- Nutrient requirements for high-value specialty crops or emerging new crops in highly environmentally sensitive areas.
- Devising innovative techniques to improve fertilize use efficiency.

Additional FREP research area goals include the following:

- Crop nutrient requirements—determining or updating nutrient requirements to improve crop yield or quality in an environmentally sound manner.
- Fertilization practices—developing fertilization practices to improve crop production, fertilizer use efficiency or environmental impact.
- Fertilizer and water interactions—developing and extending information on fertigation methodologies leading to maximum distribution uniformity while minimizing fertilizer losses.
- Site-specific fertilizer technologies—demonstrating and quantifying applications for site-specific crop management technologies and best management practices related to precision agriculture.
- Diagnostic tools for improved fertility/fertilizer recommendations—developing field and laboratory tests for predicting crop nutrient response that can aid in making fertilizer recommendations.
- Nutrient/pest interactions and nutrient/growth regulator interactions—demonstrating or providing practical information to growers and production consultants on nutrient/pest interactions.
- Education and public information—creating and implementing educational activities that will result in adoption of fertilizer management, practices and technologies that improve impaired water bodies. Types of activities include:
- On-farm demonstrations that demonstrate to growers improved profitability, reduced risk or increased ease of management.

- Programs to educate growers, fertilizer dealers, students, teachers, and the general public about the relationships between fertilizers, food, nutrition, and the environment.
- Preparation of publications, slide sets, videotapes, conferences, field days, and other outreach activities.
- Additional areas that support FREP's mission, such as air quality, tillage, crop rotation, economics of fertilizer use, and cropping systems.

FREP collaborates and coordinates with other organizations with similar goals to extend FREP research to agricultural advisors who in turn will convey findings to farmers. Our partners include: Western Plant Health Association, California Chapter of the American Society of Agronomy; California Certified Crop Adviser Program; University of California Cooperative Extension Program; University of California Sustainable Agriculture Research and Education Program; State Water Resources Control Board Interagency Coordinating Committee; California Air Resources Board; California Energy Commission; and Monterey County Water Resources Agency.

Growers care and have a vested interest in maintaining the viability of the resources that make farming possible and so successful here in California. We at CDFA/FREP are keenly interested in funding new projects that offer farmers alternative methods to address environmental issues and fertilizer use efficiency.

PROCEEDING BEYOND CONFERENCE PROCEEDINGS

One of FREP's key goals is to ensure that research results generated from the program are distributed to, and used by, growers and the fertilizer industry. Proceedings from past annual conferences, videos, DVDs, and pamphlets on various topics relating to fertilizing techniques are available to interested members of the

Figures 1-3
FREP Project Funding
These figures illustrate the variety of geographical regions, commodities, and disciplines covered by FREP projects during the past 20 years

Figure 1
FREP Projects by location 1990-2010

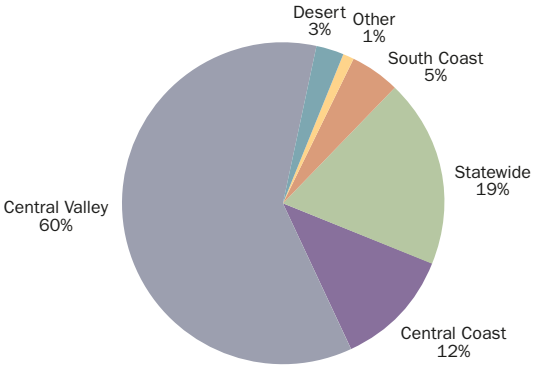


Figure 2
FREP Projects by Discipline 1990-2010

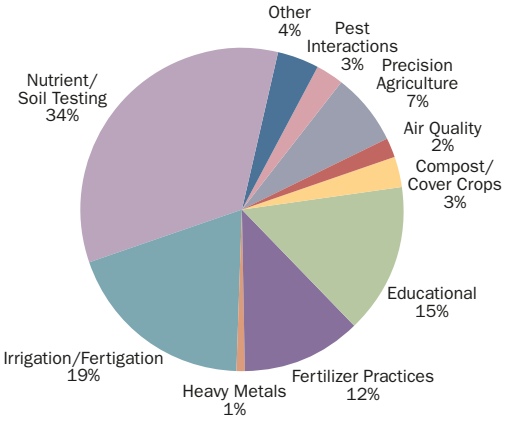
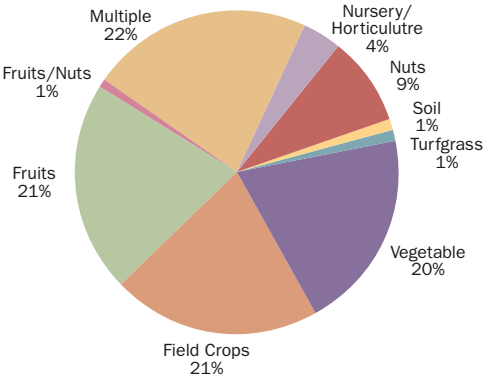


Figure 3
FREP Projects by Commodity 1990-2010



agricultural community at low or no cost by contacting the FREP office.

FREP staff will be conducting an inventory of completed FREP-sponsored research to assess the utility of the research in supporting changes in grower practices. The assessment will examine whether FREP research to date has developed an adequate supply, or variety of alternatives, for growers to reduce their uncertainty of fertilizer management decisions regarding the implementation of fertilizing materials in an environmentally and economically sound way.

The study will also evaluate the applicability of research with respect to relative economic importance of the different crops grown in California. It will also look at crop-specific fertilizer demands with emphasis toward the environmental and agronomic conditions relevant to the crops' respective growing regions. The goal of the effort is to give FREP perspective of where research efforts have paid off with improved fertilizer management practices and areas where more research effort is needed.

We are always interested to hear how we can improve FREP services and activities. We encourage you to complete the conference evaluation form and contact us any time to offer your suggestions.

ACKNOWLEDGMENTS

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

We would like to recognize the leadership provided by the Fertilizer Inspection Advisory Board (FIAB) and its members: S. Jay Yost (Chairman), Brad Baltzer, Thomas Beardsley, David McEuen, Tim McGahey, John Peterson, John Salmonson, Sanford Simon, and Steve Spangler. We would also like to thank the FIAB Technical Advisory Subcommittee who review and recommend projects for funding. The professionalism, expertise and experience of Jack Wackerman (chairman), Michael Cahn, Eric Ellison, Bob Fry, Tom Gerecke, Edward J. Hard, David McEuen, Rob Mikkelsen, Jerome Pier, and Chris Simas have provided FREP with direction to ensure the program achieves its goals.

We thank the Western Plant Health Association as a valued partner in the "Fresh Approaches to Fertilizing Techniques" conference. Renee Pinel and Pam Emery's perspective, input and support have led to greater outreach and dissemination of FREP research findings.

Vital contributors to the FREP program are the projects leaders and cooperators, as well as numerous professionals who peer-review our project proposals – their contributions significantly enhance the quality of the FREP program.

Special recognition also goes to the leadership at the California Department of Food and Agriculture. This includes Asif Maan, Acting Inspection Services Division Director; Amadou Ba, Fertilizing Materials Inspection Program Branch Chief; Edward J. Hard, FREP Program Lead; Erica Jue, Agricultural Technician III for soliciting, organizing and performing 1st cut edits of the proceedings; Kevin Richardson, Agricultural Technician III for soliciting, organizing the conference binder and updating the Introduction for the Proceedings. Additional help from Devan Arredondo and all of the FFLDERS Branch support staff is also greatly appreciated.

Conference Program

Conference Program

WEDNESDAY, NOVEMBER 17, 2010

9:00-9:15 **Welcome**
Asif Maan, Acting Director of Inspection Services, Feed, Fertilizer, Livestock Drugs & Egg Regulatory Services, Division of Inspection Services, CDFA

Renee Pinel, President/CEO, WPHA

Facilitator
Rob Mikkelsen, International Plant Nutrition Institute

Salinity

9:15-9:45 What is Salinity?
Jerome Pier, Crop Production Services

9:45–10:30 Practical Aspects of Salinity Management
Steve Grattan, UC Davis

10:30–10:45 **Break**

10:45-11:15 Almond Rootstocks for Salinity Management
David Doll, UC Cooperative Extension, Merced County

11:15-11:45 Growing Crops in High Salinity Soil – A Farmer's Perspective
Ron Macedo, RAM Farms

11:45-12:45 **Lunch (provided)**

Precision Nutrient Management

12:45-1:15 What is Precision Agriculture? When Is It Useful?
Tim Stone, Britz-Simplot, Inc.

1:15-1:45 GPS and Satellites- Their Use in Precision Ag
Jason Ellsworth, Wilbur-Ellis Company

1:45-2:15 Nutrient Uptake Curves on Specific Crops, Turf and Ornamentals
Anne Collins, Dellavalle Laboratory, Inc.

2:15-2:30 **Break**

2:30-3:00 Can a Better Tool for Assessing 'Haas' Avocado Tree Nutritional Status be Developed?
Carol Lovatt, UC Riverside

3:00-3:30 Nitrogen Application Timing and Practices in Sweet Cherry Orchards
Gregory Lang, Michigan State University

3:30-4:00 Utilizing Technology for Precision Nutrient Management
Michael Larkin, Crop Production Services

4:00 p.m. **Concluding Remarks**

THURSDAY, NOVEMBER 18, 2010

9:00-9:15 **Welcome**
Charles Krauter, Professor Emeritus, Plant Pathology, CSU Fresno
Renee Pinel, President/CEO, WPHA

Facilitator
Keith Backman, Dellavalle Laboratory, Inc.

Fertigation and Fertilizer Practices

9:15-9:30 Fertigation- Its Importance in Agriculture
Keith Backman, Dellavalle Laboratory, Inc.

9:30-10:00 Water-Run Nitrogen Fertilizer Practices on Field Crops
Stuart Pettygrove, UC Davis

10:00-10:30 Improving Pomegranate Fertigation and Nitrogen Use Efficiency with Drip Irrigation Systems
James Ayars, USDA-ARS

10:30-10:45 **Break**

10:45-11:15 Fertigation of Quality Wine Grapes
Sebastian Braum, Yara North America, Inc.

11:15-11:45 Updating Nutritional Strategies for Today's California Pear Industry
Kitren Glozer, UC Davis

11:45-12:45 **Lunch (provided)**

Statewide and Regional Nutrient Management

12:45-1:15 Formulating an Efficient Nutrient Management Plan for Row Crops
Tim Hartz, UC Davis

1:15-1:45 Development of Certified Crop Adviser Specialty Certification and Continuing Education in Manure Nutrient Management
Stuart Pettygrove, UC Davis

1:45-2:15 Development of a Nutrient Budget Approach to Fertilizer Management in Almond
Patrick Brown, UC Davis

2:15-2:30 **Break**

2:30-3:00 Foliar Fertilization and Nutrient Monitoring of Tomatoes
Scott Stoddard, UCCE Farm Advisor, Merced and Madera Counties

3:00-3:30 Developing Testing Protocols to Assure the Quality of Fertilizer Materials for Organic Agriculture
William Horwath, UC Davis

3:30 p.m. **Concluding Remarks**

Summaries of Presented FREP Research Projects

Optimizing Nitrogen Availability in Cherry Growth to Obtain High Yield and Fruit Quality, Interpretive Summary

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INTRODUCTION

Average sweet cherry yields in California (approximately 3.4 tons/acre) are typically less than those in the Pacific Northwest (approximately 5.5 tons/acre), partly due to insufficient chilling in some years and excessive vigor that promotes vegetative growth at the expense of reproduction. It is unlikely that the most commonly used fertilization practice, soil-applied nitrogen (N) just after harvest, supplies N in an optimal, demand-driven timing (i.e., to meet reproductive needs without excessively promoting vegetative growth). Furthermore, because cherry have higher chilling requirements than peach or almond, the dormancy-breaking treatments in winter that are often applied further impact nutrient (particularly N) storage in, and demand by, tissues and organs. Cherry culture in California continues to evolve as a very site-specific industry, in which rootstock, scion, biome and climate constitute a variable set that is quite complex, unique and challenging. Far from a 'set' protocol in any of these aspects, the management of sweet cherry in California and an appropriate fertilizer regime for it will continue to evolve.

OBJECTIVES

This project directly addresses the research-based development of cost effective N fertilization practices to improve N fertilizer use efficiency and minimize environmental impacts in sweet cherry production. The FREP program goals aligned with this project include 1) nutrient uptake by tree crops, including determination of tissue nutrient thresholds, and 2) guidelines for orchard fertilization patterns, including

foliar nutrient management and effective fertilizer timing. Specifically, for sweet cherry, the objectives include:

1. Quantify the seasonal pattern of N partitioning to sweet cherry tissues as influenced by soil and foliar applications, formulations, timing, and rootstock.
2. Determine the relationship of fruiting spur N reserves to subsequent spring spur leaf development, fruit set, and fruit growth potential.
3. Determine the impact of fall dormancy-inducing and late winter dormancy-breaking treatments on fruiting spur N reserves and early spring growth demand for N.
4. Develop recommendations to balance soil and foliar N application methods (timing and rates) to optimize annual fruit yields and quality while minimizing excessive vegetative growth.
5. Quantify the seasonal pattern of P, K, Zn, Fe, B, Ca, S, Mg, Mn, and Cu partitioning to sweet cherry tissues as influenced by optimized N fertilization recommendations and rootstock.

DESCRIPTION

Three experimental orchards were selected by rootstock and location. All were planted in 1998 with 'Bing' as the scion cultivar. Orchard 1 is on *P. mahaleb* seedling rootstock near Lodi, while Orchards 2 and 3, located near Linden and contiguous within a single site, are, respectively, on dwarfing clonal rootstock Gisela 6 (*P. cerasus x P. canescens*) and Mazzard (*P. avium*) seedling rootstock. Ten nitrogen treatments (Table 1) were assigned to each orchard. Inherent differences of training system (tree architecture) and precocity (earliness to bear) are also differences, based on rootstock. Due to warm weather in January, rates of dormancy release chemicals (CAN and KNO3), as included in the N treatments, were reduced in 2009 from levels used in 2008. They were subsequently eliminated from the treatment list (in 2010) as it became apparent they were not contributing to the project goals and were increasing potential for late frost damage.

The program has been adapted annually, as needed. Tissue N sampling protocol has changed to reflect our increased understanding of N cycling in tissues over the growing season and dormant season. We originally expected to compare results of the various objectives across the sites; however, the effects of rootstock proved to be so great that this was impractical. We have made a number of observations as to the overall rootstock effects on these trials.

Effects of CAN17 and KNO_3 for rest-breaking were evaluated in bloom development; the effects of a significant freeze event in the Linden orchards (Gisela and Mazzard) in 2009 were evaluated as potential for crop load reduction. Over the life of the project, the Gisela6 orchard has developed serious decline conditions that are probably partially site-specific, and may also include a response to the high levels of N that had been applied prior to the project start. These trees, and the pollenizer cultivar (also on Gisela6), have had poor vigor in the last several years. These were treated with high N levels equivalent to those of the standard trees in the adjacent blocks in order to increase vigor, but the opposite effect may have actually occurred, although we have no definitive method of testing this theory at this time. The trees have developed extensive 'blindwood' (non-productive scaffolds and limbs with few spurs and poor foliation). Symptoms of crinkleleaf, a viral disease, became increasingly apparent and widespread, although this may have been more an opportunistic condition than the primary causal agent of decline. Nonetheless, after spring tissue sampling and during fruit development, we found that fruit were extremely small and relatively

unmarketable, the trees were approaching collapse, and we abandoned any further work in that orchard.

Nutrient analyses have been completed for the project; however, not all analyses have been obtained. Measurements of vegetative growth and harvest data are continuing to be analyzed and will be summarized for the FREP Conference and final report.

RESULTS AND DISCUSSION

N Cycling

As the final analyses for 2010 have not yet been completed, the data shown in this summary is that from 2008 to 2009 (Figure 1) and the last complete year (2009; Tables 2-6). The patterns of rising and falling tissue levels is very similar among trials, so that they could be averaged out to fit a 'demand-supply' curve (Figure 1) that illustrates movement of tissue N out of storage tissues and into rapidly growing buds with peak N levels prior to harvest.

When treatments were grouped by those 'in common' applied from bloom (after March sampling) to postharvest (prior to September sampling), and tissue analyses for nitrogen were compared during that time, the following treatment effects were seen:

- In February, there were no differences among shoot and spur buds with respect to tissue N, which was not yet mobilized from storage tissues to meristems
- March shoot buds showed no difference among treatments (no treatments had been applied); tissue N ranged from 2.18 to 2.32
- March spur buds showed no difference among treatments; tissue N ranged from 2.89 to3.11
- Thus, in March during bud swell, more N had mobilized into spur buds than shoot buds to support bloom and fruit set.
- In September, after terminal bud set, tissue levels in both spur and shoot buds had decreased to those of dormant buds. Although there were treatment differences within bud type, the differences were the same across bud types, in that the highest N was found in buds that had received both bloom and postbloom N, and only 45 lb actual N per acre postharvest; whereas the other treatments were either all lower (for shoot buds) or only the 90 lb postharvest treatment was lower and the other treatments were intermediate to the highest and lowest (spur buds).
- Approximately half of the tissue N present prior to bloom, fruiting and harvest was present postharvest (September), suggesting that about half the nitrogen available in the fruiting spurs was removed by the crop.
- Shoot leaf nitrogen levels in April had dropped approximately 25% after harvest; additional decline in N was found in September shoot leaves, to levels similar to, or slightly higher than, those of dormant buds. The exception was, again, the treatment that received both bloom and postbloom N, and only 45 lb actual N per acre postharvest. These leaves had not declined from July levels.
- The same pattern was found in spur leaves, which had slightly higher levels of N than shoot leaves, during rapid fruit growth (April), but declined to similar N levels as shoot leaves in July and September, with only the exception treatment (bloom + postbloom + 45 lb N postharvest) higher and at levels that had not declined from July to September.
- Clearly, there is a treatment effect in 2008 from this combination, which was not found with either bloom, postbloom, or 45 lb N postharvest alone, nor with 90 lb N postharvest (which tended to be the lowest tissue N treatment).

- April shoot and spur leaf levels would be considered 'high' and barely adequate in July, possibly due to the orchard routinely being heavily cropped.

In all orchards and treatments, percent N in both shoot and spur tissues (buds and leaves) increased sharply from dormant season to early growth season with remobilization of stored nutrients at bud break. Nitrogen values for fruit from all orchards tended to be similar to that found in fully-expanded leaves, ranging from 2.9 to 4.4% N. No significant differences in N status were found within a particular organ (shoot bud, spur bud, leaf, or fruit) within a given orchard.

The Mahaleb/Lodi site has proved to be the most suited to the objectives of this project as it has not had freeze problems, extensive decline, or lack of productivity that is not due to N nutrition. Vegetative vigor, measured by number of shoot breaks and new shoot growth (length) in Mahaleb, was greatest in trees treated with urea pre-leaf fall (season prior to growth season) and strongly reduced in trees treated at bloom/petal fall.

Reproductive Vigor, Yield, Yield Efficiency, Fruit Quality and Fruit Maturity

2009 constitutes the last full set of data on yields and fruiting for all three orchards and is included in this summary (Tables 7 and 8, Figure 2). Spring 2010 was the coldest average March-May in California since 1898 (data records researched online for Sacramento area), which negatively affected fruit development and even maturity. A very late series of cold rains and hail that began May 25, also negatively affected yields and fruit quality in the Northern San Joaquin County cherry production region. The following are conclusions based on the first two years of the project, as current season data is still being analyzed.

At the Mahaleb/Lodi orchard, yield and yield efficiency were increased in treatments that included bloom and petal fall applications of Pacific Hort Grow Plus N and lowest in the treatment with 'reduced' $CaNO_3$, dormancy-inducing and -breaking (CAN) treatment (Table 8, Figure 3). Furthermore, the lowest yielding treatment was not the lowest total N per year, thus, the quantity of N throughout the year does not appear to have affected yield negatively. While it is not clear why this treatment was the lowest-yielding for Mahaleb, it was also the lowest yielding (but not significantly so) for Mazzard. It was clear from field observations of bloom in these treatments and temperature data collected in the orchard that the CAN treatments greatly advanced bloom ahead of pollenizers and induced bloom during a period of late freeze.

We have not found clear effects of the nutritional programs included in these trials on fruit quality. Site specificity, rootstock, training system and pruning habits appear to be the primary contributors to fruit quality, in addition to climate.

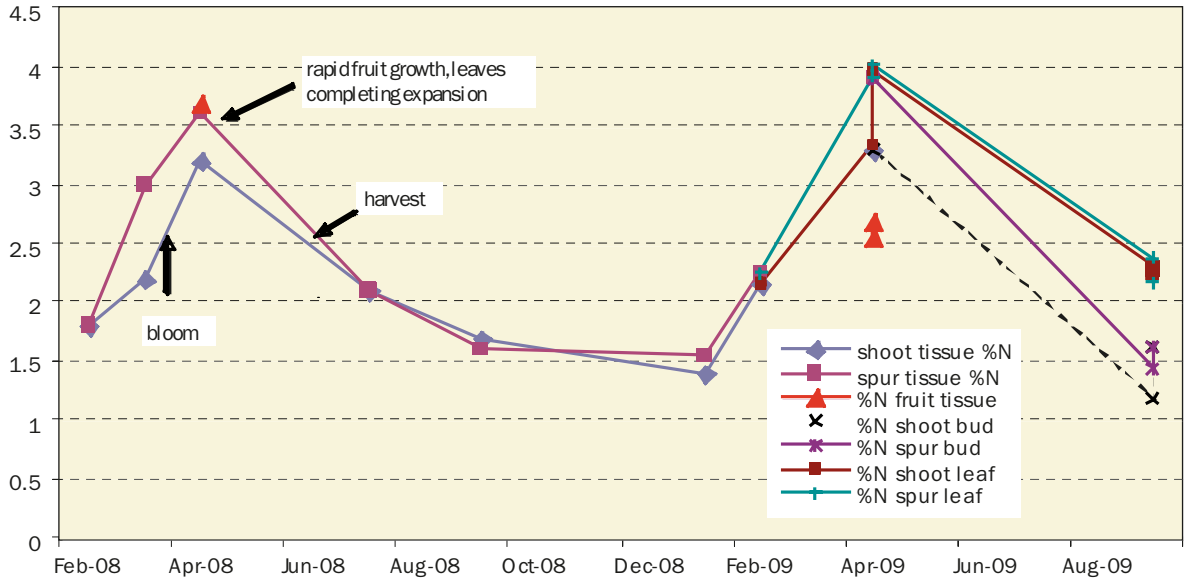
Table 1
Nitrogen (N) treatments applied to 'Bing' (*Prunus avium*) sweet cherry at three orchards[x] in 2008-9, comparing 'standard' postharvest (*PH*) soil application ($CaNO_3$ 15.5% N) with reduced soil-applied $CaNO_3$ supplemented with foliar N applications 'timed' to phenological events. Foliar N treatments include: **CAN17** (16.7% v/v, 17% N) or **KNO_3** (13.7% N) for dormancy release (DR), **PacificHort Grow Plus N** (*PHG+N*; 15% ammoniacal N) applied twice (prior to full bloom, 5-7 days post-petal fall), **low-biuret urea** (46% N) applied post-bloom (*PBLM*), pre leaf-fall (PLF; two applications late Sept-Oct 7 days apart), or pre leaf-fall with 20 lb/acre $ZnSO_4$ for dormancy induction (*DI*).

Treatments and N actual lb/acre	DR Jan 20	PHG+N Mar 323, 330	PBLM	PLF	DI	Total actual N (lb/acre/yr)
90 $CaNO_3$						90
90 $CaNO_3$	KNO_3 0.7				9.2	99.9
90 $CaNO_3$	CAN 26.8 or 53.5 [y]				9.2	126 or 152.7
45 $CaNO_3$	CAN 26.8 or 53.5				9.2	81 or 98.5
45 $CaNO_3$				25 + 20		90
45 $CaNO_3$		1.12				46.12
45 $CaNO_3$		1.12		25 + 20		91.12
45 $CaNO_3$			2.3			47.3
45 $CaNO_3$			2.3	25 + 20		92.3
45 $CaNO_3$		1.12	2.3	25 + 20		93.42

[x]Orchards vary by rootstock and location [*P. mahaleb* in Lodi, CA; 'Gisela 6' or 'Mazzard' (both *P. avium*) in Linden, CA].

[y]DR treatment applied either 150 gal/acre or 75 gal/acre for 'Gisela 6' trees (dwarfing rootstock); for CAN17 actual N was either 53.5 or 26.8 lb/acre . Moderate rates of RBAs were used to reduce the risk of phytotoxicity in an unseasonably warm pre-bloom period.

Figure 1.
2008-2009 Change in tissue N over time in vegetative and reproductive tissues of 'Bing' sweet cherry averaged from data collected at three orchards. Recommended tissue content (%N) shown below (developed in cherry-growing areas other than California).



Recommended Cherry Leaf %N (summer, vegetative shoot leaf)	Deficient	Low	Optimum	High	Excessive
	< 1.7	1.7 - 2.1	2.2 - 2.6	2.7 - 3.4	> 3.4

Table 2
Nitrogen (N) tissue levels in 'Bing' (*Prunus avium*) sweet cherry at three orchards[x] in **January 2009** prior to dormancy release treatments, comparing 'standard' postharvest (*PH*) soil application ($CaNO_3$ 15.5% N) with reduced soil-applied CaNO3 supplemented with foliar N applications 'timed' to phenological events. Foliar N treatments include: **CAN17** (16.7% v/v, 17% N) or **KNO_3** (13.7% N) for dormancy release (*DR*), **PacificHort Grow Plus N** (*PHG+N*; 15% ammoniacal N) applied twice (prior to full bloom, 5-7 days post-petal fall), **low-biuret urea** (46% N) applied post-bloom (*PBLM*), pre leaf-fall (PLF; two applications late Sept-Oct 7 days apart), or pre leaf-fall with 20 lb/acre $ZnSO_4$ for dormancy induction (DI).

Rootstock and orchard location	Mahaleb		Gisela 6		Mazzard	
Treatment and total actual N (lb/acre/yr)	shoot	spur	shoot	spur	shoot	spur
90 $CaNO_3$ (90)	1.39ab[z]	1.46ab	1.52bcd	1.87ab	1.26	1.45ab
90 $CaNO_3$, *DR* (KNO_3), *DI* (99.9)	1.36ab	1.46ab	1.52bcd	1.85abc	1.31	1.48a
90 $CaNO_3$, *DR* (CAN), *DI* (126 or 152.7)	1.30b	1.41b	1.52bcd	1.87ab	1.34	1.46a
45 $CaNO_3$, *DR* (CAN), *DI* (81 or 98.5)	1.28b	1.36b	1.47d	1.93ab	1.23	1.34cd
45 $CaNO_3$, *PLF* (90)	1.40ab	1.54a	1.62b	1.96ab	1.27	1.44ab
45 $CaNO_3$, *PHG+N* (46.12)	1.33ab	1.39b	1.52bcd	1.82bc	1.23	1.28d
45 $CaNO_3$, *PHG+N*, *PLF* (91.12)	1.45a	1.56a	1.73a	1.98a	1.29	1.46ab
45 $CaNO_3$, *PBLM* (47.3)	1.33ab	1.40b	1.49cd	1.72c	1.22	1.36bcd
45 $CaNO_3$, *PBLM, PLF* (92.3)	1.45a	1.59a	1.62b	1.96ab	1.28	1.41abc
45 $CaNO_3$, *PHG+N*, *PBLM, PLF* (93.42)	1.44a	1.58a	1.61bc	1.99a	1.34	1.50a
Significance	**	***	***	**	NS	**

[x]Orchards vary by rootstock and location [*P. mahaleb* in Lodi, CA; 'Gisela 6' or 'Mazzard' (both *P. avium*) in Linden, CA].

[y]DR treatment applied either 150 gal/acre or 75 gal/acre for 'Gisela 6' trees (dwarfing rootstock); for CAN17 actual N was either 53.5 or 26.8 lb/acre.

[z] Means in the same column and orchard with different letters differ by Duncan's multiple range test at $P < 0.05$; ***, **, * or NS = significance at 0.1, 1, 5% level, or non-significant, respectively.

Table 3
Nitrogen tissue levels[y] in 'Bing' (*Prunus avium*) sweet cherry at **'Mahaleb/Lodi'** orchard in April 2009 prior to postbloom treatment, comparing 'standard' postharvest (*PH*) soil application ($CaNO_3$ 15.5% N) with reduced soil-applied $CaNO_3$ supplemented with foliar N applications 'timed' to phenological events. Foliar N treatments include: CAN17 (16.7% v/v, 17% N) or **KNO_3** (13.7% N) for dormancy release (*DR*), PacificHort Grow Plus N (*PHG+N*; 15% ammoniacal N) applied twice (prior to full bloom, 5-7 days post-petal fall), low-biuret urea (46% N) applied post-bloom (*PBLM*), pre leaf-fall (*PLF*; two applications late Sept-Oct 7 days apart), or pre leaf-fall with 20 lb/acre $ZnSO_4$ for dormancy induction (DI). Bearing spur leaf area (**in^2**) and dry weight (g) per 8 leaves per replicate tree compared by N treatment.

Treatment and total actual N (lb/acre/yr)	Shoot leaf	Spur leaf (bearing)			Fruit
		%N	Area	Weight	
90 $CaNO_3$ (90)	3.36 [x]	3.93 abc	9.47 bc	1.78 bc	3.01
90 $CaNO_3$, *DR* (KNO3), *DI* (99.9)	3.38	3.95 abc	9.08 cd	1.65 cd	2.84
90 $CaNO_3$,*DR* (CAN), *DI* (152.7)	3.22	3.76 ac	9.22 cd	1.72 bc	2.63
45 $CaNO_3$, *DR* (CAN), *DI* (98.5)	3.28	3.74 c	10.85 a	2.34 a	2.61
45 $CaNO_3$, *PLF* (90)	3.43	4.09 ab	10.23 ab	1.98 ab	2.92
45 $CaNO_3$, *PHG+N* (46.12)	3.15	3.75 c	8.37 d	1.64 cd	2.92
45 $CaNO_3$, *PHG+N*, *PLF* (91.12)	3.28	3.92 abc	9.62 bc	1.81 bc	2.82
45 $CaNO_3$, *PBLM* (47.3)	3.36	3.93 abc	8.93 cd	1.58 d	2.79
45 $CaNO_3$, *PBLM, PLF* (92.3)	3.46	4.16 a	10.03 b	1.81 bc	2.82
45 $CaNO_3$, *PHG+N, PBLM, PLF* (93.42)	3.49	4.11 a	9.58 bc	1.71 cd	2.95
Significance	NS	**	***	***	NS

[x]Means in the same column and orchard with different letters differ by Duncan's multiple range test at $P < 0.05$; ***, **, * or NS = significance at 0.1, 1, 5% level, or non-significant, respectively.

[y] %N by dry weight of combined leaf or fruit sample per replicate tree.

Table 4
Nitrogen (N) tissue levels in 'Bing' (*Prunus avium*) sweet cherry at **'Gisela /Linden'** orchard in **April 2009** prior to postbloom treatment, comparing 'standard' postharvest (*PH*) soil application ($CaNO_3$ 15.5% N) with reduced soil-applied $CaNO_3$ supplemented with foliar N applications 'timed' to phenological events. Foliar N treatments include: **CAN17** (16.7% v/v, 17% N) or **KNO_3** (13.7% N) for dormancy release (*DR*), **PacificHort Grow Plus N** (*PHG+N*; 15% ammoniacal N) applied twice (prior to full bloom, 5-7 days post-petal fall), **low-biuret urea** (46% N) applied post-bloom (*PBLM*), pre leaf-fall (*PLF*; two applications late Sept-Oct 7 days apart), or pre leaf-fall with 20 lb/acre $ZnSO_4$ for dormancy induction (*DI*). Bearing spur leaf area (cm^2) and dry weight (g) per 8 leaves per replicate tree compared by N treatment.

Treatment and total actual N (lb/acre/yr)	Shoot leaf	Spur leaf (bearing)			Fruit
		%N	Area	Weight	
90 $CaNO_3$ (90)	3.97 ab [x]	4.20	7.52	1.74	2.60
90 $CaNO_3$, *DR* (KNO_3), *DI* (99.9)	4.11 ab	4.02	7.32	1.65	2.62
90 $CaNO_3$, *DR* (CAN), *DI* (126)	4.17 a	3.80	6.97	1.66	2.41
45 $CaNO_3$, *DR* (CAN), *DI* (81)	4.11 ab	4.02	7.40	1.77	2.66
45 $CaNO_3$, *PLF* (90)	4.16 a	3.87	7.50	1.57	2.59
45 $CaNO_3$, *PHG+N* (46.12)	4.05 ab	4.22	7.30	1.73	2.43
45 $CaNO_3$, *PHG+N, PLF* (91.12)	3.77 b	3.93	7.37	1.42	2.56
45 $CaNO_3$, *PBLM* (47.3)	3.73 b	3.91	7.12	1.70	2.66
45 $CaNO_3$, *PBLM, PLF* (92.3)	3.85 ab	4.01	7.32	1.59	2.50
45 $CaNO_3$, *PHG+N, PBLM, PLF* (93.42)	3.79 b	3.92	7.39	1.52	2.51
Significance	***	NS	NS	NS	NS

[x] Means in the same column and orchard with different letters differ by Duncan's multiple range test at $P < 0.05$; ***, **, * or NS = significance at 0.1, 1, 5% level, or non-significant, respectively.

[y] %N by dry weight of combined leaf or fruit sample per replicate tree.

Table 5
Nitrogen (N) tissue levels in 'Bing' (*Prunus avium*) sweet cherry at **'Mazzard/Linden'** orchard in **April 2009** prior to postbloom treatment, comparing 'standard' postharvest (*PH*) soil application (CaNO3 15.5% N) with reduced soil-applied $CaNO_3$ supplemented with foliar N applications 'timed' to phenological events. Foliar N treatments include: **CAN17** (16.7% v/v, 17% N) or **KNO_3** (13.7% N) for dormancy release (*DR*), **PacificHort Grow Plus N** (*PHG+N*; 15% ammoniacal N) applied twice (prior to full bloom, 5-7 days post-petal fall), **low-biuret urea** (46% N) applied post-bloom (*PBLM*), pre leaf-fall (*PLF*; two applications late Sept-Oct 7 days apart), or pre leaf-fall with 20 lb/acre $ZnSO_4$ for dormancy induction (*DI*). Bearing spur leaf area (cm^2) and dry weight (g) per 8 leaves per replicate tree compared by N treatment.

Treatment and total actual N (lb/acre/yr)	Shoot leaf	Spur leaf (bearing)			Fruit
		%N	Area	Weight	
90 $CaNO_3$ (90)	4.01[x]	2.83	7.5	1.46 b	3.41
90 $CaNO_3$, *DR* (KNO_3), *DI* (99.9)	3.85	2.81	7.3	1.58 b	3.22
90 $CaNO_3$, *DR* (CAN), *DI* (152.7)	3.98	2.83	7.0	1.66 b	3.08
45 $CaNO_3$, *DR* (CAN), *DI* (98.5)	3.98	2.77	7.4	2.03 a	3.12
45 $CaNO_3$, *PLF* (90)	4.00	2.81	7.5	1.52 b	3.37
45 $CaNO_3$, *PHG+N* (46.12)	4.04	2.87	7.3	1.54 b	3.50
45 $CaNO_3$, *PHG+N, PLF* (91.12)	4.10	2.71	7.4	1.51 b	3.24
45 $CaNO_3$, *PBLM* (47.3)	3.84	3.00	7.1	1.51 b	3.11
45 $CaNO_3$, *PBLM, PLF* (92.3)	3.96	2.81	7.3	1.46 b	3.08
45 $CaNO_3$, *PHG+N, PBLM, PLF* (93.42)	3.98	2.77	7.3	1.54 b	3.33
Significance	NS	NS	NS	***	NS

[x] Means in the same column and orchard with different letters differ by Duncan's multiple range test at $P < 0.05$; ***, **, * or NS = significance at 0.1, 1, 5% level, or non-significant, respectively.

[y] %N by dry weight of combined leaf or fruit sample per replicate tree.

Table 6
Current season shoot growth in 'Bing' (*Prunus avium*) sweet cherry at **'Mahaleb/Lodi'** orchard in 2009 in response to nitrogen (N) fertilization, comparing 'standard' postharvest (*PH)* soil application ($CaNO_3$ 15.5% N) with reduced soil-applied CaNO3 supplemented with foliar N applications 'timed' to phenological events. Foliar N treatments include: CAN17 (16.7% v/v, 17% N) or **KNO_3** (13.7% N) for dormancy release (*DR*), **PacificHort Grow Plus N** (*PHG+N*; 15% ammoniacal N) applied twice (prior to full bloom, 5-7 days post-petal fall), **low-biuret urea** (46% N) applied post-bloom (*PBLM*), pre leaf-fall (*PLF*; two applications late Sept-Oct 7 days apart), or pre leaf-fall with 20 lb/acre ZnSO4 for dormancy induction (*DI*). Measurements represent an average of two limbs per replicate tree (number of new shoot 'breaks' per limb, length of each new shoot and all new shoots, combined, per limb).

Treatment and total actual N (lb/acre/yr)	#Shoot breaks	Shoot length (in)	
		Individual	Combined
90 $CaNO_3$ (90)	8.1 a[x]	13.3 cde	121.3 ab
90 $CaNO_3$, *DR* (KNO_3), *DI* (99.9)	8.3 a	15.3 bc	127.0 ab
90 $CaNO_3$, *DR* (CAN), *DI* (152.7)	7.6 a	17.0 ab	127.0 ab
45 $CaNO_3$, *DR* (CAN), *DI* (98.5)	7.8 a	14.5 bcd	109.9 ab
45 $CaNO_3$, *PLF* (90)	9.1 a	18.3 a	165.7 a
45 $CaNO_3$, *PHG+N* (46.12)	4.2 b	10.4 e	41.2 c
45 $CaNO_3$, *PHG+N, PLF* (91.12)	8.2 a	14.3 bcd	115.0 ab
45 $CaNO_3$, *PBLM* (47.3)	8.8 a	11.5 de	115.2 ab
45 $CaNO_3$, *PBLM, PLF* (92.3)	10.0 a	12.1 de	139.2 ab
45 $CaNO_3$, *PHG+N, PBLM, PLF* (93.42)	7.2 ab	12.4 cde	93.4 bc
Significance	*	***	**

xMeans in the same column and orchard with different letters differ by Duncan's multiple range test at $P < 0.05$; ***, **, * or NS = significance at 0.1, 1, 5% level, or non-significant, respectively.

Table 7
Yield (lb) and yield efficiencyx in 'Bing' (*Prunus avium*) sweet cherry at 3 different orchards in 2009 in response to nitrogen (N) fertilization, comparing 'standard' postharvest (*PH*) soil application ($CaNO_3$ 15.5% N) with reduced soil-applied $CaNO_3$ supplemented with foliar N applications 'timed' to phenological events. Foliar N treatments include: **CAN17** (16.7% v/v, 17% N) or **KNO_3** (13.7% N) for dormancy release (*DR*), **PacificHort Grow Plus N** (*PHG+N*; 15% ammoniacal N) applied twice (prior to full bloom, 5-7 days post-petal fall), **low-biuret urea** (46% N) applied post-bloom (*PBLM*), pre leaf-fall (*PLF*; two applications late Sept-Oct 7 days apart), or pre leaf-fall with 20 lb/acre $ZnSO^4$ for dormancy induction (*DI*).

Rootstock and orchard location	Mahaleb Lodi		Gisela 6 Linden		Mazzard Linden	
Treatment and total actual N (lb/acre/yr)	Yield	Efficiency	Yield	Efficiency	Yield	Efficiency
90 $CaNO_3$ (90)	153a[x]	0.14abc	50.9	0.12	59.5	0.06
90 $CaNO_3$, *DR* (KNO_3), *DI* (99.9)	153a	0.11b-e	53.6	0.10	55.1	0.06
90 $CaNO_3$, *DR* (CAN), *DI* (126)	149a	0.10cde	50.0	0.09	41.9	0.04
45 $CaNO_3$, *DR* (CAN), *DI* (81)	96b	0.06e	64.6	0.13	31.1	0.03
45 $CaNO_3$, *PLF* (90)	152a	0.11b-e	62.2	0.11	67.9	0.08
45 $CaNO_3$, *PHG+N* (46.12)	176a	0.17a	42.1	0.09	64.6	0.06
45 $CaNO_3$, *PHG+N, PLF* (91.12)	186a	0.14ab	45.0	0.10	59.5	0.06
45 $CaNO_3$, *PBLM* (47.3)	134ab	0.10b-e	65.8	0.12	62.8	0.07
45 $CaNO_3$, PBLM, *PLF* (92.3)	136ab	0.09de	62.2	0.12	53.1	0.06
45 $CaNO_3$, *PHG+N, PBLM, PLF*(93.42)	152a	0.11bcd	54.2	0.10	61.3	0.06
Significance	*	***	NS	NS	NS	NS

xMeans in the same column and orchard with different letters differ by Duncan's multiple range test at $P < 0.05$; ***, **, * or NS = significance at 0.1, 1, 5% level, or non-significant, respectively.

Table 8
Cumulative yield (lb) for 'Bing' (*Prunus avium*) sweet cherry at three orchards in response to nitrogen (N) fertilization, comparing first season treatments only ('standard' postharvest (*PH*) soil application [$CaNO_3$ 15.5% N] had not yet been applied for first treatment by harvest 2008) with full year of treatments for 2009 (soil-applied $CaNO_3$ supplemented with foliar N applications 'timed' to phenological events). Foliar N treatments include: **CAN17** (16.7% v/v, 17% N) or **KNO_3** (13.7% N) for dormancy release (*DR*), **PacificHort Grow Plus N** (*PHG+N*; 15% ammoniacal N) applied twice (prior to full bloom, 5-7 days post-petal fall), **low-biuret urea** (46% N) applied post-bloom (*PBLM*), pre leaf-fall (*PLF*; two applications late Sept-Oct 7 days apart), or pre leaf-fall with 20 lb/acre $ZnSO^4$ for dormancy induction (*DI*).

Rootstock and orchard location Treatment and total actual N (lb/acre/yr) applied by harvest		Mahaleb /Lodi	Gisela /Linden	Mazzard /Linden
2008	2009			
90 $CaNO_3$ (0; applied after harvest)	90 $CaNO_3$ (90)	248.2 ax	81.1 a	118.6 a
45 $CaNO_3$, *PHG+N* (1.12)	45 $CaNO_3$, *PHG+N* (46.12)	302.3 a	64.6 a	130.4 a
45 $CaNO_3$, *PBLM* (2.3)	45 $CaNO_3$, *PHG+N*, *PLF* (91.12)	244.1 a	115.3 a	128.4 a
45 $CaNO_3$, *PHG+N*, *PBLM, PLF* (3.42)	45 $CaNO_3$, *PHG+N*, P*BLM, PLF* (93.42)	283.4 a	92.4 a	145.8 a
Significance for treatment means differences	NS	NS	NS	

[x]Means in the same column and orchard with different letters differ by Least Squares Means (Tukey) at P = 0.05; ***, **, * or NS = significance at 0.1, 1, 5% level, or non-significant, respectively.

OUTREACH ACTIVITIES

January 27, 2009

California Cherry Advisory Board Annual Research Review

San Joaquin UCCE County Building
Robert J. Cabral Agricultural Center
2101 E. Earhart Avenue, Stockton, California 95206-3949

Optimizing nitrogen availability in cherry growth for high yield and fruit quality

Presented by Dr. G. Lang

Approximately 300 growers and PCAs in attendance

The presentation was well-received and the annual report (2008 FREP annual report) was included in the annual Proceedings

November 18, 2009

Annual FREP Conference

Visalia Convention Center, Visalia

Optimizing nitrogen availability in cherry growth for high yield and fruit quality

Presented by Dr. K. Glozer

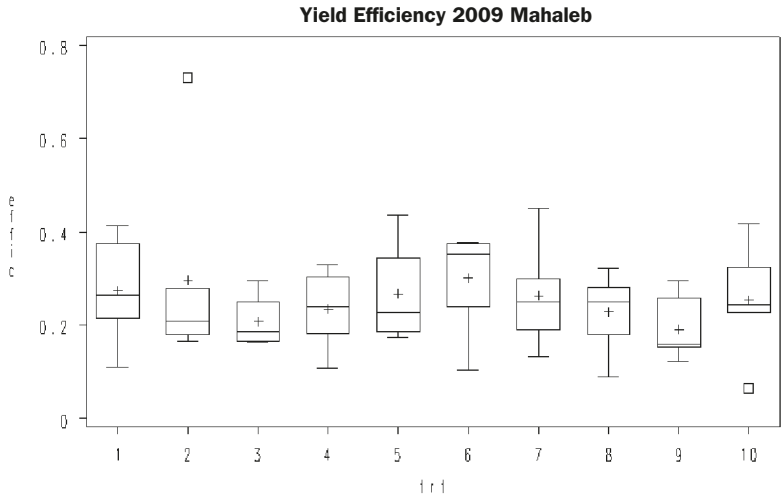
Approximately 200 PCAs, researchers and other agribusiness personnel in attendance

The presentation was well-received and the interpretive summary was included in the annual Proceedings; a handout of the PowerPoint presentation was passed out at the meeting

ACKNOWLEDGEMENTS

The researchers appreciate the support by the California Department of Food and Agriculture, Fertilizer Research and Education Program, the California Cherry Advisory Board, PacificHort and SQM Specialty Plant Nutrition.

We appreciate the participation of Dr. Maria Paz Garcia-Suarez, Visiting Scholar, in the 2009 growing season.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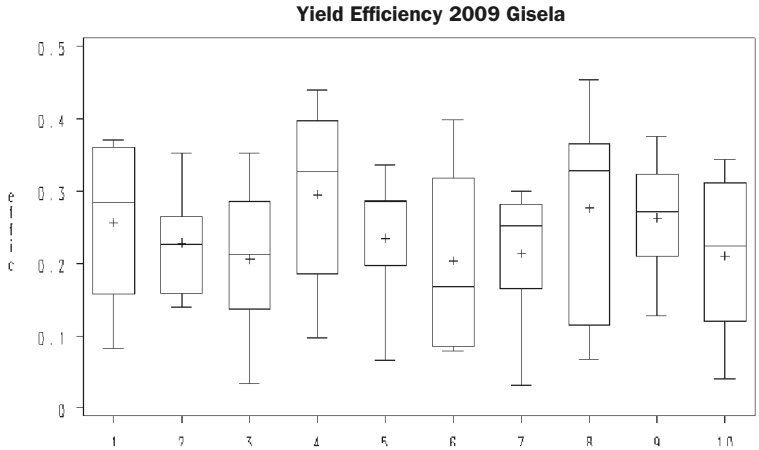
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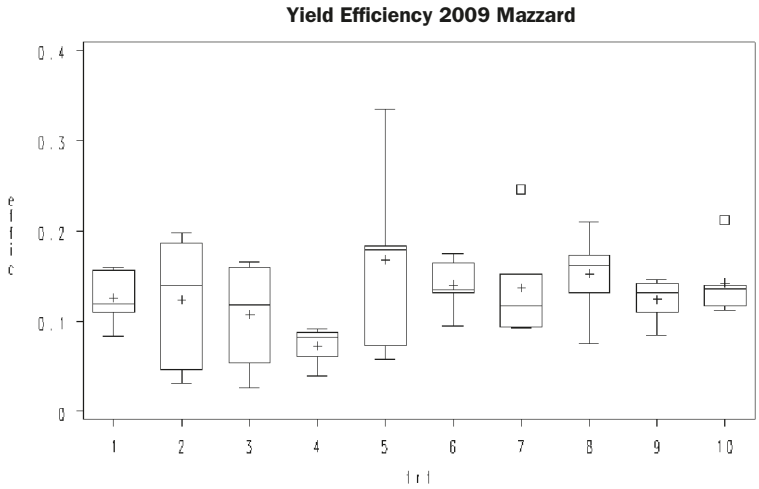
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Improving Water Run Nitrogen Fertilizer Practices in Furrow- and Border Check Irrigated Field Crops

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INTRODUCTION

Injection of N fertilizer during furrow and border check irrigation events is a common practice in California and elsewhere in the Western U.S. It often is the only practical method for applying N to surface gravity irrigated crops from mid to late season. A rough estimate is that this method of applying N is practiced on 500,000 acres of crops in California, mainly grains, forages, vegetables and cotton.

A disadvantage of this practice is the potential for non uniform nutrient applications stemming from non uniform irrigation. This can lead to over and underfertilization within a field and increased leaching of nitrate to groundwater. Growers may compensate for the anticipated spatial variability by increasing N fertilizer rates to ensure that all parts of the field receive adequate N.

Techniques for improving irrigation water distribution uniformity and thereby the uniformity of the water run fertilizer is well known. These include reducing furrow lengths by cutting fields in half, use of surge irrigation and compacting furrow bottoms with "torpedoes" pulled through the field behind a tractor. These techniques may be expensive, complicated, or effective only under a limited set of conditions, and therefore, they have not been widely adopted by farmers.

A method for improving uniformity of the water run fertilizer that does not depend so much on increasing irrigation distribution uniformity, is to delay the injection of fertilizer during an irrigation event, until the water has advanced some distance down the length of the field. Fertilizers and other chemicals injected after water has already advanced will catch up to the advancing water relatively quickly. This can improve fertilizer distribution uniformity by avoiding the presence of the applied material on the upper end of the field during the early stages of the irrigation, when infiltration is the greatest.

We report here, the results of on farm experiments conducted during 2005-2007 (Phase 1) and measurements made during regular grower water run N fertilizer applications in corn fields during 2008 (Phase 2). Data were

collected to determine the uniformity of N applied in one-dimensional transects, i.e., in single furrows or border checks. At several of the locations in the Phase 1 experiments, results were compared for continuously injected N fertilizer and delayed injection. The 2008 data were collected in a follow-up study designed to further document apparent N losses that we observed during the 2005-2007 studies. Phase 1 results have been reported in previous FREP conference proceedings and are presented here without much detail. Descriptions of the Phase 2 studies and conclusions and recommendations have not been presented previously.

OBJECTIVES

1. Investigate the relationship of timing of water run fertilizer injection during furrow and border check irrigation events on N application uniformity and to determine the role of ammonia volatilization.
2. Develop recommendations for N fertilizer injection timing for soils with different textures or water intake rates.
3. Extend the information developed in the project through presentations at professional meetings, cooperative extension newsletter articles, and a U.C. peer reviewed technical bulletin.

DESCRIPTION

The primary investigator evaluated the performance of water run fertilizer N applications during furrow and border check irrigation events in 26 annual crop fields in Yolo, San Joaquin, and Tulare Counties during four summers, between the years 2005 through 2008. At fields used in Phase 1 (2005-07), the normal continuous injection fertigation practice was compared to an alternative delayed injection strategy, in which irrigation water is allowed to flow down the furrow before N fertilizer injection is started. Most of the data were collected from fields receiving anhydrous ammonia (AA, 82-0-0). At a few sites, we used urea ammonium nitrate solution (UAN, 32-0-0). Measurements were carried out at in fields that were at an early stage of crop development or in bush bean fields to allow researchers to easily see the advancing water during irrigation events.

The Phase 2 (2008) measurements were made in 15 fields in Tulare County during the farmers' regular fertigation activity, rather than in researcher initiated furrow comparisons. In 13 of the 15 Phase 2 sites, the corn crop was at an advanced stage of growth (i.e., tall), which is more typical of conditions during fertigation events in commercial fields.

Field conditions for Phase 1 and 2 are shown in Tables 1 and 2, respectively.

Phase 1 N Fertilizer Injection Timing – Experimental Treatments

At the Phase 1 sites with anhydrous ammonia, we attempted to carry out one treatment each day with measurements taken on one or two furrows. Treatments carried out, one on each of three days in sequence, were (1) continuous fertilizer injection, i.e., inject N fertilizer for the entire set, (2) delay injection until water reaches approximately halfway down the length of the field, and (3) delay until water reaches 75-80% of the length of the field. At most sites, the target N application rate was 40 to 60 lb N/acre. However, target rates, often, were not achieved because of irrigation set time uncertainty and in some cases, due to inaccuracy in fertilizer injection controllers.

During fertigation events, the following measurements were made:

(1) Water flow rate into individual furrows using standard RBC flumes and converting flume readings into flow rates in gallons/minute using the flume manufacturer's chart.

Table 1
Summary of farm field sites used in 2005-2007 for water run fertilizer N treatment comparisons. AA=Anhydrous ammonia, UAN=urea ammonium nitrate 32% N solution.

Date	Site Code	County	Crop	Soil texture (0-8 inch depth)	Length of irrigation run (ft)	Soil pH	Fertilizer
2005							
6/6-7	PA05A	Tulare	Corn	Sandy loam/loam	1100	7.5	AA
6/13-14	SA	San Joaquin	Corn	Silty clay	900	7.0	AA
6/21-23	ST05	Tulare	Corn	Sandy loam/ loamy sand	1800	7.1	AA
6/29-7/1	PA05B	Tulare	Corn	Sandy loam	1200	7.5	AA
7/25-27	VE	San Joaquin	Corn	Loam/sandy loam	1300	7.5	AA
2006							
6/6-8	ST06	Tulare	Corn	Sandy loam	1300	7.6	AA
6/27-29	SO	Tulare	Corn	Loam**	2400	7.6	UAN
7/18-20	RE	Tulare	Corn	Loam	1250	7.5	AA
2007							
7/18-19	CO	San Joaquin	Beans	Clay loam	1500	7.6	UAN
7/25-26	TR	Yolo	Beans	Loam/clay loam	1300	7.5	UAN
7/31-8/2	BA	Tulare	Corn	Clay loam	1200	7.5	AA
**Border check irrigation system, no till							

Table 2
Summary of farm field site characteristics used for monitoring of performance of farmer water run anhydrous ammonia applications in 2008.

Site #	Crop	Approx canopy height (ft)	Canopy cover %	Field length (ft)	Irrigation Type (B=border, F=furrow)	Air temp (deg F)
2008-1	Sudangrass	1	25-30	878	B	82
2008-2	Milo sorghum	2.25	60	1295	F	89
2008-3	Corn	6.5	100	2175	F	91
2008-4	Corn	9	100	1295	F reduced till	62
2008-5	Corn	4.5	95-100	1270	F, siphons	67
2008-6	Corn	6.5	100	2574	F, flat	88
2008-7	Corn	7.5	95-100	352	F	82
2008-9	Corn	7.5	95-100	1283	B, no till, flat	96
2008-8	Corn	7	100	1123	F	94
2008-10	Corn	7	95-100	1300	F	70
2008-11	Corn	7	95-100	1300	F	92
2008-12	Corn	7.5	100	2525	F+B	66
2008-13	Corn	5	75	1270	F+B	65
2008-14	Corn	8	95-100	502	F+B	92
2008-15	Corn	8	95-100	2000	F+B	98

(2) Irrigation water advance times at markers placed at 100 ft intervals down the furrow to the end of the field;

(3) NH_4-N concentration in the irrigation water at the head of the furrow and at intervals along the length of the furrow approximately every 20 to 60 minutes during the irrigation set.

(4) At sites using anhydrous ammonia, water pH measurements were made.

(5) At some sites, furrow water temperature, air temperature, and wind speed at the furrow water surface were measured.

For each data set (at most sites, there were three sets of individual furrow data), we attempted to use advance times and furrow inflow rates to estimate an infiltration function. The infiltration function was then used to estimate the depth of water applied at several points along the length of the furrow. We then multiplied those water depths by the time weighted sample N concentrations and the appropriate conversion factor to obtain total N application quantities (expressed as lb N/acre) over an entire fertigation event.

In some of the data sets, the advance data were not well behaved, and we could not estimate an infiltration function. This occurred in some irrigation sets as a result of (1) large fluctuation in furrow inflow rates due to changing water levels in head ditches or stand pipes or pump malfunction, (2) variable slope in fields caused the advance to stall or speed up as it flowed down furrows, (3) fluctuation in advance due to variability in soil infiltration capacity across the field.

RESULTS AND DISCUSSION

In both the Phase 1 and Phase 2 studies, we observed apparent significant ammonia volatilization losses at many of the sites using anhydrous ammonia (AA), with an average loss of N across all sites of 13% and as high as 30% at individual sites. We did not directly measure NH_3 loss, but the pattern of decrease in ammonium concentration as water flowed down the furrow, together with the high pH of the ammonia containing water (usually 9.5-10) provided circumstantial evidence for NH_3 volatilization loss. The volatilization losses contributed significantly to non uniformity of N rate applied during fertigation. There was no apparent volatilization loss of N when urea ammonium nitrate (UAN) solution fertilizer was used.

At a few of the sites, furrow water temperatures were monitored. Temperature increases from the head to the end of the furrow, often 10 degrees Fahrenheit or more, likely contributed to ammonia volatilization loss during AA fertigation.

With delays in injection, until irrigation water had advanced 50% or more of the distance down the furrow (i.e., the field length), fertilizer N quickly caught up to the advancing irrigation water front and in a few cases, we were able to document improvements in the spatial distribution of the N application rate.

A conclusion of this research is that in some situations, particularly where there are long fields and irrigation sets of 6 hours or more, growers should consider converting from AA to a somewhat lower rate of the more expensive UAN; and if that is done, consideration should be given to the delayed fertilizer injection strategy. Other improvements in management of fertigation during surface gravity irrigation events are listed below in the conclusions section.

Impact of anhydrous ammonia (AA) on irrigation water pH

As expected, the injection of anhydrous ammonia (AA) into irrigation water greatly increased the water pH. At all sites, irrigation water (from wells and surface supplies) had a pH before fertilizer injection of 6.9-7.8. AA injection by bubbling it into irrigation water in ditches or standpipes resulted in pH values of 9.0 to 10.5 (Table 3). Ammonia volatilization is highly sensitive to

pH (Jayaweera and Mikkelsen, 1990), because at high pH values, more of the ammonia is present as dissolved NH_3 gas, rather than as the non volatile NH_4+ ion. At each site, the observed pH varied with NH_4 concentration (data not shown), but combining data from different sites did not indicate a consistent relationship of the pH or pH increase with NH_4 concentration.

Table 3
Anhydrous ammonia increases pH of irrigation water.

Site	pH of irrig water before AA injection	pH of water after AA injection	NH^4 concentration, mg N/L after AA injection
2008-1	7.3	9.9	27
2008-4	7.8	10.0	105
2008-5	7.4	10.0	133
2008-6	7.1	9.0	5
2008-9	7.3	10.1	31
2008-12	7.3	9.2	24
2008-13	7.8	10.2	125

Increase in temperature of irrigation water down furrow

Water temperature is another factor that controls the rate of ammonia volatilization (Jayaweera and Mikkelsen, 1990). On warm days, cool irrigation water was significantly heated as it flowed down the furrow as shown in Table 4 and Figs. 1. Water in furrows at the tail end of fields was >10 degrees Fahrenheit warmer than at the head of the field in seven of the 2008 sites, including five sites with 95-100% canopy cover. This temperature gradient likely contributed to loss of volatile ammonia after irrigation water entered fields during fertigation with anhydrous ammonia.

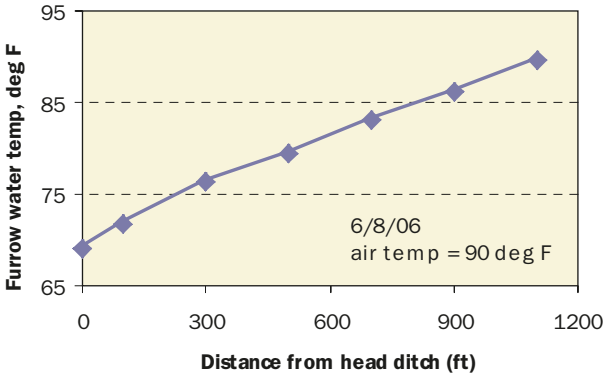
Ammonia volatilization loss during anhydrous ammonia fertigations

The primary investigator did not directly measure ammonia volatilization loss from water during our research activities. However, the observed

Table 4
Summary results from 2008 (Phase 2) fertigation measurements. In sites # 3 and 6, apparently NH_3 had either not reached the end of the field or had already been turned off, as indicated by low N concentrations and pH values.

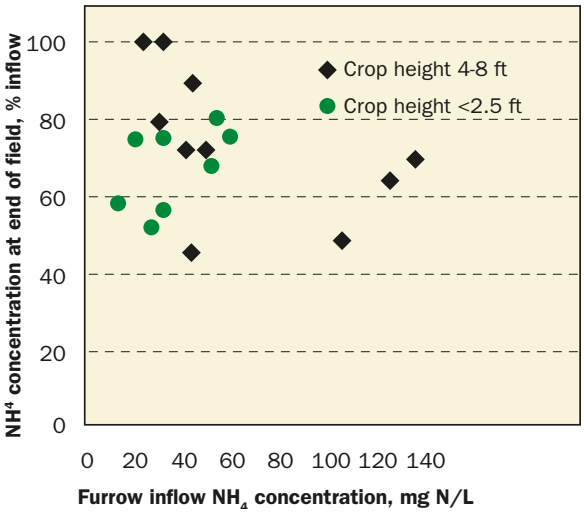
Site #	Head end water temperature, deg F	Tail end water temp deg F	Change in water temp deg F (head minus tail)	Head end avg pH	Tail end avg pH	pH change (head minus tail)	NH_4 concentration at head, mg N/L	NH_4 at tail, as % of head end
2008-1	80	96	17	9.9	9.6	0.38	21	75
2008-2	79	93	14	10.2	9.3	0.90	27	52
2008-3	75	89	15	10.2	7.2	3.00	102	1
2008-4	72	65	-6	10.0	9.1	0.90	105	49
2008-5	68	67	0	10.0	9.8	0.20	133	70
2008-6	74	79	5	9.0	7.6	1.35	5	23
2008-7	70	74	4	9.9	9.5	0.40	30	104
2008-8	84	85	1	9.9	9.4	0.45	25	129
2008-9	69	82	12	10.2	9.3	0.90	31	79
2008-10	63	67	4	9.7	9.2	0.55	43	73
2008-11	64	88	24	9.4	9.1	0.30	48	72
2008-12	68	65	-3	9.2	9.1	0.05	24	105
2008-13	72	67	-6	10.2	9.7	0.50	125	64
2008-14	64	76	12	10.0	9.6	0.35	43	90
2008-15	64	80	17	9.7	9.1	0.60	43	45
Mean NH4 tail value – sites 3 and 4 excluded; sites 7, 8, and 12 set to 100% **Avg 0.50 74**								

Fig. 1
Increase in furrow water temperature at increasing distance from head of field.



decrease in NH_4 concentration down the furrow and the pH data provides good evidence that ammonia was lost by volatilization. We observed this during the majority of anhydrous ammonia fertigation events monitored in this project. Fig. 2 summarizes data from 19 sites combined from Phase 1 and Phase 2 of the project. Three of the 19 sites showed no apparent volatilization loss. The lowest losses (using tail end/head end NH^4 concentrations as the indicator) occurred at

Fig. 2
Ammonium N concentration in irrigation water at upper and lower end of field during water run anhydrous ammonia application at 19 on farm locations during 2005-2008. Y axis values are water NH_4 concentrations at the bottom end of fields expressed as a percentage of the top end (inflow) concentration.



inflow NH_4 concentrations of <40 ppm N; but there was not a consistent relationship, and high losses occurred at both high and low inflow NH_4 concentrations (Fig. 2).

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are drawn from our experimental results, from consideration of the technical literature on this topic, and from our observations of grower and irrigator practice at our on farm research sites in the Central Valley.

1. Delaying injection of water run N fertilizers until irrigation water is advanced 30- 50% of the distance across the field may provide more uniform spatial distribution of the fertilizer nitrogen compared to continuously injected fertilizer, especially under the following conditions:

   a. Long fields (one-quarter mile or longer)

   b. Soil with rapid infiltration capacity, e.g., due to sandy texture

   c. Slow advance of water across field due to shallow field slope, low irrigation water inflow rate, and high soil infiltration capacity

2. In nearly every fertigation event where anhydrous ammonia was used, we observed declining concentrations of NH_4 in irrigation water with increasing distance from the field inlet point. At the tail end (bottom) of fields, we observed NH4 concentrations from 10 to 50% lower than at the irrigation water inlet point. In a follow up study in 2008 with more mature crop canopies, we observed a similar range of concentration decreases. The average decrease for all project data (19 fertigation events) was 26%, which is approximately equivalent to a loss of 13% of the total quantity of fertilizer N applied during the single fertigation event. The magnitude of

apparent loss was not related to the target application rate or N concentration at the field inlet point.

3. Loss of volatile NH_3 during fertigation with anhydrous ammonia can exacerbate poor N distribution uniformity and thus increases the justification for using more expensive non-volatile N sources such as urea ammonium nitrate solutions. In addition to the contributing factors listed in recommendation #1, three additional factors can increase NH_3 volatilization and therefore increase the justification for use of non volatile N fertilizer sources:

   a. High temperatures (>90° F) during fertigation events

   b. Soil pH values above 8.0

   c. High wind speed (>10-15 mph) or combinations of wind, small crop canopy and bed/furrow geometry that results in exposure of the surface of irrigation water to the high winds

4. In highly permeable soils, the mobility of urea and nitrate (which constitutes 75% of the total N in the most commonly used urea ammonium nitrate fertilizer solutions) can result in high N leaching losses at the upper (head) end of fields during fertigation events, particularly where irrigation water distribution uniformity is poor. In contrast, significant leaching of anhydrous ammonia N during fertigation is not expected to be significant. For this reason, a delayed injection strategy should be considered when urea ammonium nitrate is used in fertigation of highly permeable soils.

5. Where soil water intake rate varies greatly among furrows, e.g., wheel vs. non wheel rows, irrigators sometimes adjust siphon pipes or gate openings for the purpose of equalizing water advance rates. While such adjustments may improve the uniformity of the advance rate among furrows, they do not improve uniformity of the depth of water applied; and they can make the fertigation N application rate even more non uniform. A delayed injection strategy alone will not address this particular cause of non uniform N application.

6. Regardless of fertigation injection timing (continuous or delayed), attention to fertilizer tank output settings is needed. In some situations, fertilizer tank settings should be adjusted from one set to the next based on the observed irrigation system performance, which can deviate from the anticipated behavior depending on soil conditions, land slope, temperature, etc. Using a constant fertilizer tank output setting based on an assumed typical irrigation rate, such as "1 acre per hour", may lead to substantial deviation from the target N application rate.

7. Where anhydrous ammonia is used for fertigation, the delayed injection approach and adjustment of tank settings during an irrigation set or between irrigation sets in a field may be impractical. It will not always be possible for fertilizer supply company employees to provide this more frequent on site service. Farm personnel should not carry out such adjustments unless they have obtained the necessary training and certification in the handling of this hazardous material.

8. When fertigating with anhydrous ammonia, an inexpensive pocket pH combination electrode is very useful for checking for presence of NH_4 in irrigation water. The primary investigator observed that water pH always increased from 7-8 to 9-10 when anhydrous ammonia had been injected, making it easy to determine if the ammonia had arrived at a given location in the head ditch, valve, or field. Also, during fertigation with anhydrous ammonia, the observed

differences in pH between the inlet point at the top end of the field and the bottom of the field (e.g., 10.0 at the top vs. 9.5 at the bottom) corresponded to differences in the NH_4 concentration as measured later in the laboratory.

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Improving Pomegranate Fertigation and Nitrogen Use Efficiency with Drip Irrigation Systems

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INTRODUCTION

The California Department of Water Resources (DWR) Bulletin 160-05 states: "In the future, water management challenges will be more complex as population increases, demand patterns shift, and environmental needs are better understood…" The competition for water will increase as the population of California increases to nearly 50 million people by 2050 and environmental flows increase to meet the demands in the Sacramento-San Joaquin Delta. California agriculture is facing severe, recurring water availability shortages, groundwater quality deterioration and accumulation of salts in the shallow, perched water table. To compensate for the lack of sufficient surface water, growers on the west side of the San Joaquin Valley are pumping from deep saline aquifers, bringing salts to the surface that are causing drainage issues and irrigated acreage to be drastically reduced.

Research and demonstration have shown that well managed surface drip (DI) and subsurface drip irrigation (SDI) systems can eliminate runoff, deep drainage, minimize surface soil and plant evaporation and reduce transpiration of drought tolerant crops. Reduction of runoff and deep drainage can also significantly reduce soluble fertilizer losses and improve groundwater quality. The success of DI and SDI methods depends on the knowledge and management of fertigation, especially for deep SDI. Reductions in wetted root volume, particularly if combined with deficit irrigation practices, restrict available nutrients and impose nutrient based limits on growth or yield. This is particularly important with an immobile nutrient such as phosphorus. Avoiding nutrient deficiency or excess is critical to maintaining high water and fertilizer use efficiencies (WUE and FUE). This interaction has been demonstrated for field and vegetable crops but no similar research has been conducted for permanent crops.

During droughts, water deliveries are reduced or even stopped and if water stress is severe enough to limit plant growth, fertilizer application should be proportionally reduced. This can only be accomplished if fertilizers are applied frequently and only as needed by the crop as part of the irrigation supply.

Pomegranate acreage in California is now about 29,000 acres and University of California, Davis, farm advisor, Kevin Day noted that "from 2006 to 2009 the number of acres planted with pomegranate trees…increased from approximately 12,000 to 15,000 acres in 2006 to 29,000 acres in 2009" (Personal communication K. Day 2009). The rising demand for juices, e.g. pomegranate, blueberry, with healthy bioactive compounds, mineral nutrients and high antioxidant contents are partially contributing to this growth in acreage. Pomegranate is both a drought and salt tolerant crop that can be grown on saline soils and is thus ideally suited for the west side of the San Joaquin Valley as a replacement for lower value crops.

There have been no studies that evaluated the fertilization requirements of developing pomegranate orchard using either surface drip or subsurface drip irrigation. This project will initially determine the fertilizer requirements for a developing pomegranate orchard.

OBJECTIVES

The overall objective of this project is to optimize water nitrogen interactions to improve FUE of young and maturing pomegranate and to minimize leaching losses of nitrogen. Specific objectives are:

1. Determine the real time seasonal nitrogen requirements (N) of DI- and SDI-irrigated maturing pomegranate that improve FUE without yield reduction.
2. Determine the effectiveness of three nitrogen injection rates with DI and SDI on maintaining adequate N levels in maturing pomegranates.
3. Determine the effect of real time seasonal nitrogen injections (N) with DI- and SDI-irrigated maturing pomegranate on N leaching losses.
4. Develop fertigation management tools that will allow the growers to achieve objective 1 and present these results to interested parties at yearly held field days and seminars.
5. Determine if concentrations of macronutrients (P, K, Ca, Mg) and micronutrients (Zn, Cu, Mn, Fe, B, Se) and eventually healthy bioactive compounds in soil, peel and fruit are influenced by precise irrigation/fertigation management with DI and SDI.

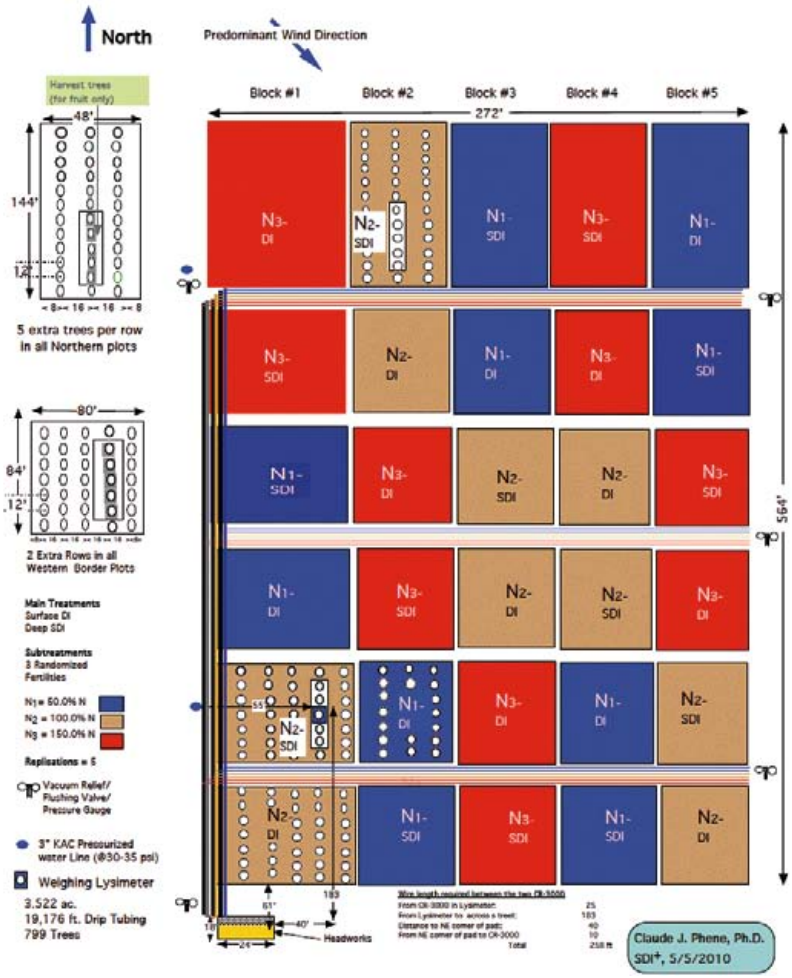
DESCRIPTION

This project will be conducted concurrently with an evapotranspiration (ETc) pomegranate research project at the United States Department of Agriculture, Agricultural Research Service (USDA-ARS) San Joaquin Valley Agricultural Sciences Center (SJVASC) that is funded through Agricultural Research Initiative at California State University, Fresno. The ETc project will determine accurate water requirements of young, maturing pomegranate using two large weighing lysimeters containing saline soils.

This project will use a 3.5-acre pomegranate orchard (varietal Wonderful) located on the Kearney Agricultural Center that contains a large weighing lysimeter. This lysimeter will be used to manage the irrigation scheduling on the site and determine the crop water use for the SDI treatment. The trees will be irrigated at 100% of crop water use measured by the lysimeter. The lysimeter tree will be irrigated using subsurface drip irrigation. Trees were planted with rows spaced 16 ft apart and trees in the harvest rows spaced at 12 ft along the row. There are two

border rows with trees spaced at 12 ft apart. These extra trees will be dug up and harvested twice yearly for total nutrient uptake measurements during the last years of the project. Figure 1 is a schematic of the plot layout (complete randomized block with sub-treatments) showing main irrigation treatments and N-fertility sub treatments. The main irrigation treatments are DI and SDI (20-24 in depth) systems with dual drip irrigation laterals, each 3 ft from the trees. The fertility sub-treatments are 3 N treatments (50% of adequate N, adequate N, based on biweekly petiole analysis and 150% of adequate N, all applied by continuous injection of AN-20). Potassium and PO4-P will be supplied by continuous injection of P=15 ppm and K=50

Figure 1
Experimental plot plan for pomegranate grown on Kearney Agricultural Center field.



ppm to maintain adequate levels. The pH of the irrigation water will be automatically maintained at 6.5+/-0.5. Tree and fruit responses will be determined by trunk and canopy measurements, pruned plant biomass, bimonthly plant tissue analyses and fruit yield and quality. When appropriate, flowers, fruit yields and quality will be measured and statistically analyzed. Analysis of variance (ANOVA) for the completely randomized design (CRD) with subsamples will be used to determine the treatment significance.

RESULTS AND DISCUSSION

The field experimental layout was used to guide the installation of the tubing in the subsurface drip plots. This was done by plowing in the tubing using shanks designed for this purpose. The drip tubing donated by Toro Irrigation was installed on April 16-19, 2010. The pad for the filters and control system was cleared and the sand media filters donated by Lakos Corporation were installed May 21, 2010. The filters were connected to the UC Kearney water supply on May 26-29, 2010. The control pad was constructed during the week of August 30, 2010.

The pomegranates (varietal Wonderful) were planted on a 12 ft by 16 ft spacing on April 27-28, 2010. These trees were the same size and age as the trees that were planted on the San Joaquin Valley Agricultural Sciences Center for a study on the water requirements of developing pomegranate. The trees were staked at planting and pruned May 6, 2010 and there is good development on all the trees. The pomegranates have been manually irrigated twice weekly using a water tank throughout the summer. There was an outbreak of False Cinch Bug that required an application of the insecticide Provada, which seemed to have controlled the pest.

Because of the delay in completing the paperwork for the contract, it was not possible to purchase the remainder of the materials needed to complete the installation of the irrigation system prior to planting the crop. The remaining materials for the drip have been purchased and the installation will be completed in September. At this time, the irrigation system will be tested and put into operation. The irrigation will probably be terminated in September to harden off the plants for winter. At that time measurement of the trunk diameter and canopy size will be made.

Soil sampling will be conducted in the fall to establish a baseline for the initial nitrate nitrogen content of the soil.

ACCOMPLISHMENTS

Project installation completed, soil sampling, and basic plant measurements made.

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The following companies have contributed to this project: Paramount Farming – trees; Toro Irrigation – drip tubing; Lakos – filter set; Dorot – Valves; BCP Electronics– Electrical supplies

European Pear Growth and Cropping: Optimizing Fertilizer Practices Based on Seasonal Demand and Supply with Emphasis on Nitrogen Management, Interpretive Summary

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INTRODUCTION

N fertilization recommendations for California European pear trees have been modified from 1991, 75 to 125 lbs actual N per acre per year (lb N_{act}/A/yr) to 2007, 2 lbs actual N per ton of crop per acre per year (lb N_{act}/t/A/yr). Tissue N critical value is 2.2%, adequate N range is 2.3 to 2.6% (UC recommendation). The 2007, recommendation establishes BMP based on two physiological premises for N management: (1) efficiency of N use in cropping, a 30 t/A orchard should receive 60 lbs Nact/A/yr; (2) vegetative vigor control, no N if average shoot growth exceeds 12 inches.

A 2008 survey of growers found N usage in the main production region of the Sacramento River Delta varied from 40 to 60 lbs N_{act}/A/yr (a single organic producer) to a typical rate of 120lbs N_{act}/A/yr. Annual shoot growth is often 3 to 5 feet. Vigor control is difficult with high water tables and leads to higher fire blight (FB) susceptibility; FB management is the highest production cost. BMP should reflect N partitioning spatially in tissues and temporally during the growth and rest cycles to minimize over-usage, increased vigor, and ground water leaching.

There is no 'one size fits all' approach to fertilizer management. Some growers take the approach

that inputs can be reduced or skipped on an annual basis if no adverse effects result (yield, fruit quality or tree deficiency symptoms) and tissue levels don't indicate inadequacy. Other growers tend to perceive reduction in N as a risk for reduced crop load and fruit size and that CV's established when tonnage was lower and most fruit went to processing (thus fruit size was less important), or fresh fruit were not stored (often stored 2+ months at present), should be re-evaluated. California's Delta trees are 30 to 100 plus years old, may retain tissue nitrogen for years without applied N (1997-2000 unpublished study, Ingels), and are intensively farmed in a highly sensitive waterway.

Diagnostic methods for nutrient sampling will be re-examined in this study. Currently, UC recommends testing annually by collecting non bearing spur leaves in mid summer (postharvest). Various publications and recommended critical values for European pear elsewhere generally utilize mid-shoot leaves. Analyses after harvest do not allow adjustment for current season yields and quality, and it is possible that leaves collected from fruit-bearing spurs, where demand is likely to be highest, may prove to be a better indicator of nutrient status for cropping. Fruit quality is dependent on N, Ca, K and P (and their 'balance'); optima should reflect current strategy of maximum yield and 'target fruit'. High nitrogen is considered detrimental to fruit quality, as a balance among nitrogen, calcium and potassium, particularly.

OBJECTIVES

1. Determine the relationship between seasonal tissue N partitioning and concentration and tree productivity and growth (i.e. reassess the currently accepted leaf N critical values, timing of sampling and tissues tested). **Orchards Elliot 1 and McCormack**
2. Compare typical and reduced N to validate recommended N management and the possibility of customizing BMP based on tissue levels, fruit quality and crop load **Orchards Elliot 1 and McCormack**
3. Quantify effects on crop load and fruit quality due to N, K and Ca as influenced by application amount, form and timing **Orchard Elliot 2**
4. Refine current management guidelines for N, K and Ca usage to maintain productivity and fruit quality while reducing potential of over fertilization **Orchards Elliot 1 and 2 , McCormack**
5. Monitor and quantify growers' irrigation practices in each trial site with the goal of optimum irrigation management to reduce nitrate leaching Cooperate with growers to follow recommended irrigation frequency as outlined by UC recommendations (Pear Production and Handling Manual, UCANR Publication 3483, Mitcham and Elkins (eds), 2007) **Orchards Elliot 1 and 2 , McCormack**

DESCRIPTION

A practical approach has been adopted in which we us three 'Bartlett' orchards with existing conditions that allow manipulation. These orchards represent the majority of Delta 'Bartlett' orchards with a range of yields of (20 to 32 t/A/yr), tree age, rootstock, soil and growing conditions. All are sampled annually for tissue nutrient levels, and irrigation water and soil N profiles. Orchards **'Elliot1'** and **'Elliot2'** are on Sutter Island. **Elliot1** has had low N beginning in 2007 at about 60 lbs N_{act}/A/yr, adjusted to 120 lbs N_{act}/A/yr in 2009 through 2010 in the orchard outside our test area. We began monitoring **Elliot1** in a preliminary project, funded by the California Pear Advisory Board, in which **Elliot1** (60 lbs Nact/A/yr) was compared to a 'HighN' orchard (120 lbs N_{act}/A/yr, uninterrupted) nearby.

The 'LowN' treatment will be annually adjusted to reflect crop load, to approximate

UC recommendations. HighN = NH_4SO_4 (60 lbs N_{act}/A) in fall + $Ca(NO_3)_2$ 62 lbs N_{act}/A via fertigation in spring and LowN = spring fertigation only are the treatments. Yields are typically about 20 to 25 tons/acre. In 2008, leaf analyses showed 'normal' nutrient levels with the exception of N (3.04%), excessive by UC. Soil pH was 6.33, nitrates 10.9 ppm, ammonium 1 ppm, and of other nutrients tested; only Mg exchangeable appeared excessive at 588ppm. 'Low' to 'very low' soil nutrients included: soluble K, Ca, Mg, and boron.

The primary investigators will test for N:K:Ca effects on fruit quality and cropping in **Elliot2**. Until 2007, the typical fertilizer program in Elliot 2 was 100 lbs N_{act}/A/yr immediately after harvest and a fall application of potash (application of K is 'budget dependent'). In 2007 and 2008, no fertilizer was applied. Beginning in 2009, the block was fertigated in spring with KMend (potassium thiosulfate $K_2S_20_3$), soluble potash (K_2O) at 25% and S at 17%, by weight, for a total of 150 lb K/acre. No reduction in vigor and no loss of yield (approximately 25 tons/A) or fruit quality from 2007 onward has been reported by the grower. Urea (1 lb/100 gallons/acre) is applied in each fireblight spray for 'fruit finish', for a total of 0.7 to 2.76 lbs N/acre. This is a typical application practice for 'Bartlett' growers in California.

Our project will compare application method and timing of K, critical for fruit quality, as well as any effects of reduced N. The K treatments are either split fertigations of calcium nitrate (total of 60 lbs N each) and KMend or 500 lbs K_2O (muriate of potash) at 150 lbs Kact/A/yr applied to soil in fall. The spring application allows adjustment of fertilizer quantity based on current season crop load, is applied during the time of greatest demand by growing fruit, and is thought to contribute to better 'fruit finish' and storage longevity.

'McCormack' Orchard will also be used to compare 'optimized' and 'reduced' N to test customizing BMP. McCormack Orchard rows have a North/South orientation with a 'drop' towards the south half, with higher water table and better soil, resulting in increased vigor, earlier harvest, heavier crop load and larger fruit than in the N half. Recent management changes (flood changed to solid set sprinkler irrigation, increased N and better pruning) have increased yields from 20 to 23 t/A/yr to 30-32 t/A/yr. Both halves of the orchard have received a total of 152 lbs N_{act}/A/yr. The south half will receive 90 lbs N_{act}/A/yr (fertigated in May-June) and the north half will receive 192 lbs Nact/A/yr (fertigation 6 to 7 time from May to June equals 90 lbs N_{act}/A/yr from CAN17 + 40 lbs Nact/A Ca(NO3)2 soil applied twice May-June) + additional N in fall as urea in a custom blend that includes K muriate potash (300 lbs/A) and micronutrients) to equalize fruit development rate and vegetative vigor between the N and S halves of the orchard.

In **Elliot1** and **McCormack Orchards** the relationship between tissue N partitioning, timing and level of N application with yield, fruit quality and vigor will be addressed. At **Elliot2** tissue partitioning of N will also be tracked, but the emphasis will be on the effects of timing of K application (and method/form of application) on tissue macronutrient levels, fruit quality and yield. We will compare early and late sampling of both vegetative and reproductive leaf tissues with 'standard' sampling (non-bearing spur leaves in late June-July) at all orchards; fruit nutrient levels will be tested at **Elliot2** as well. A collateral study of postharvest and storage fruit quality as affected by treatment will be conducted at UC Davis, funded by the California Pear Advisory Board.

A survey of grower fertilization practices will be conducted in the 'late' pear district (Lake and Mendocino Counties), similar to that previously done in the Delta, funded by the California Pear Advisory Board. Annual reporting to growers

in both districts at the CPAB annual research meetings, as well as annual reporting at the FREP conference, will be done.

RESULTS AND DISCUSSION

Elliot1 Nutrient Analyses, 2009 through 2010

In 2009, no differences of N level were found between Elliot1 and the 'HighN' orchard in March vegetative and floral buds, but only between bud types (Table 1); spur buds were much higher in N content than shoot buds as reserves were mobilized for flowering and fruiting. N was lower and below the critical value for bearing spur leaves (both orchards) after harvest, while N of shoot and vegetative spur leaves was much higher and adequate. October analyses of both buds and leaves found that buds had much lower levels of N than did leaves (either type) and N levels in all tissues were slightly lower in **Elliot1**. Significant differences between 'high' and 'low' N orchards on October 1 were found for N content. Partitioning into different plant organs (vegetative vs reproductive) was clear and independent of N level treatment, with leaf N values below the critical values set for mid-summer levels, illustrating both movement of N into storage tissues and probably removal of N with cropping. Leaf analyses from April, 2010 show no significant difference between high and low N treatments, within leaf types (Figure 1) and mean values averaged from 2.55%N to 2.99%N (range 2.33-3.29, across leaf types), despite reduced N applications.

McCormack Nutrient Analyses

April values for tissue N levels, among leaf types, ranged from 2.34% to 3.25%. Fruiting spur leaves had N values slightly lower than those of either shoot or vegetative spur leaves, which might be accounted for by higher demand by growing fruit (Figure 2).

Table 1
Tissue N (% nitrogen) measured in **'Elliot1'** orchard (60 lbs N_{act}/A/yr) verses a 'HighN' orchard (120 lbs N_{act}/A/yr) in expanding pear buds and leaves, March 9, July 7 and October 1, 2009. Means separation by Student's t-test or LS Means, 5% level. ***, **,* = significance at 0.001, 0.01, and 0.05, respectively. Means with the same letters **within rows (a given orchard)** do not significantly differ. Differences between replicate blocks within a single treatment/orchard combination were found to be significantly different in July and October.

March 9	Shoot terminal bud	Spur bud	Significance bud type
60 lbs N	1.60 b	2.50 a	***
120 lbs N	1.62 b	2.42 a	**

July 7	Shoot leaf	Spur leaf		Significance		
		Nonbearing	Bearing	Orchard		Leaf type
60 lbs N	2.75 a	2.48 b	2.09 c	***		
120 lbs N	2.64 a[z]	2.41 b	2.15 c	***		

October 1	Shoot leaf	Spur leaf	Shoot bud	Spur bud	Significance		
					Orchard	Leaf type	Bud type
60 lbs N	2.02 a	1.89 b	0.855 c	0.788 c	***	*	***
120 lbs N	2.17 a	2.13 b	0.886 c	0.806 c	***	*	***

Figure 1
Distribution of tissue nitrogen in pear leaves, April 2010 at **Elliot1** Orchard. Nitrogen application treatments are: High N (120 lbs Nact/A/yr) and Low N (60 lbs N_{act}/A/yr).

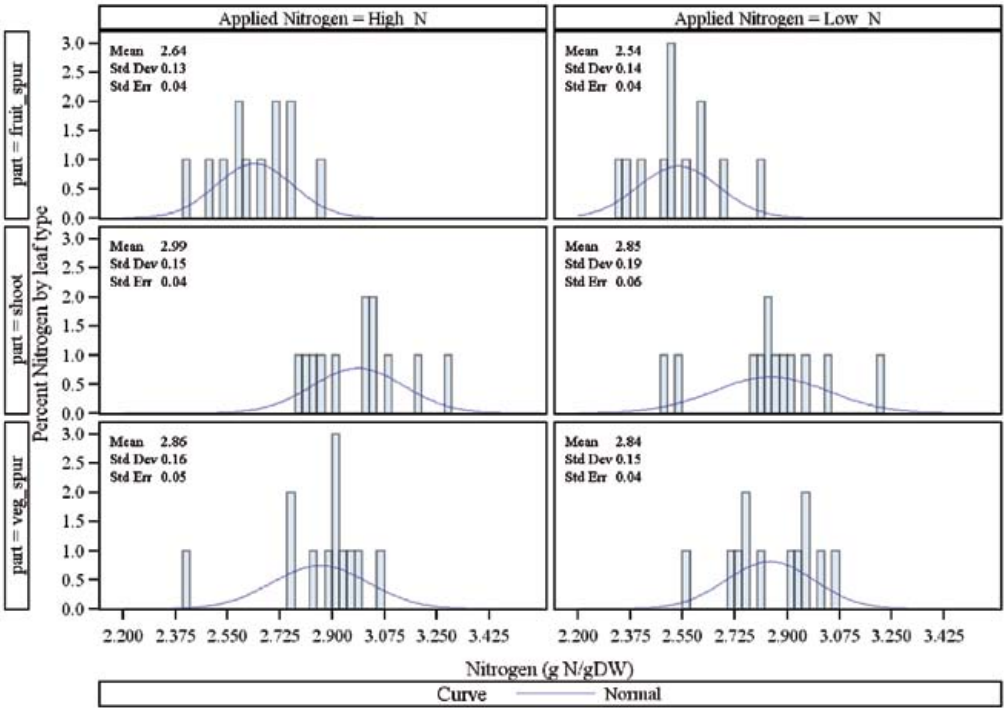
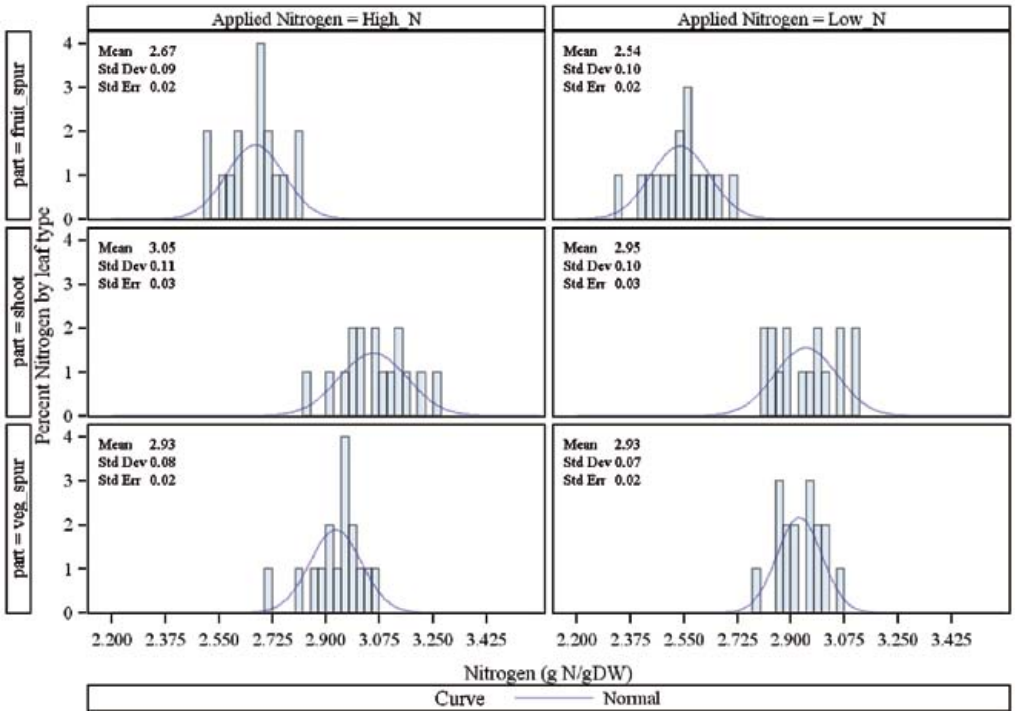


Figure 2
Distribution of tissue nitrogen in pear leaves, April 2010 at **McCormack** Orchard. Nitrogen application treatments are: High N (192 lbs Nact/A/yr) and Low N (90 lbs N_{act}/A/yr).



Elliot2 Nutrient Analyses

April values for tissue N levels, among leaf types, ranged from 2.74% to 3.14% (Figure 3). Fruiting spur leaves had N values slightly lower than those of either shoot or vegetative spur leaves, as did our other two sites. Fruit N was lower still, at ~2.30-2.35%. Conversely, boron was highest in fruit and lowest in fruiting spurs (Figure 4). Additional nutrient distributions are shown in Figures 5 through 9.

Figure 3
Distribution of tissue nitrogen in pear leaves, April 2010 at **Elliot2** Orchard, test orchard for N:K:Ca effects on fruit quality and cropping.

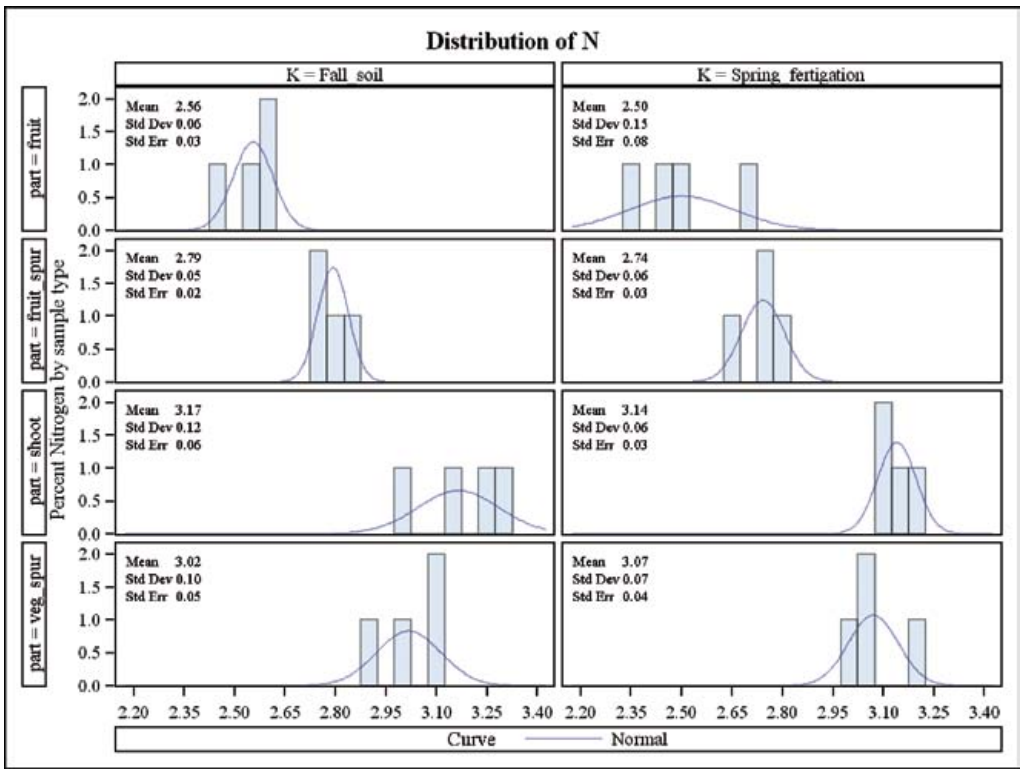


Figure 4
Distribution of boron in fruit and leaf tissues at **Elliot2** orchard, April, 2010.

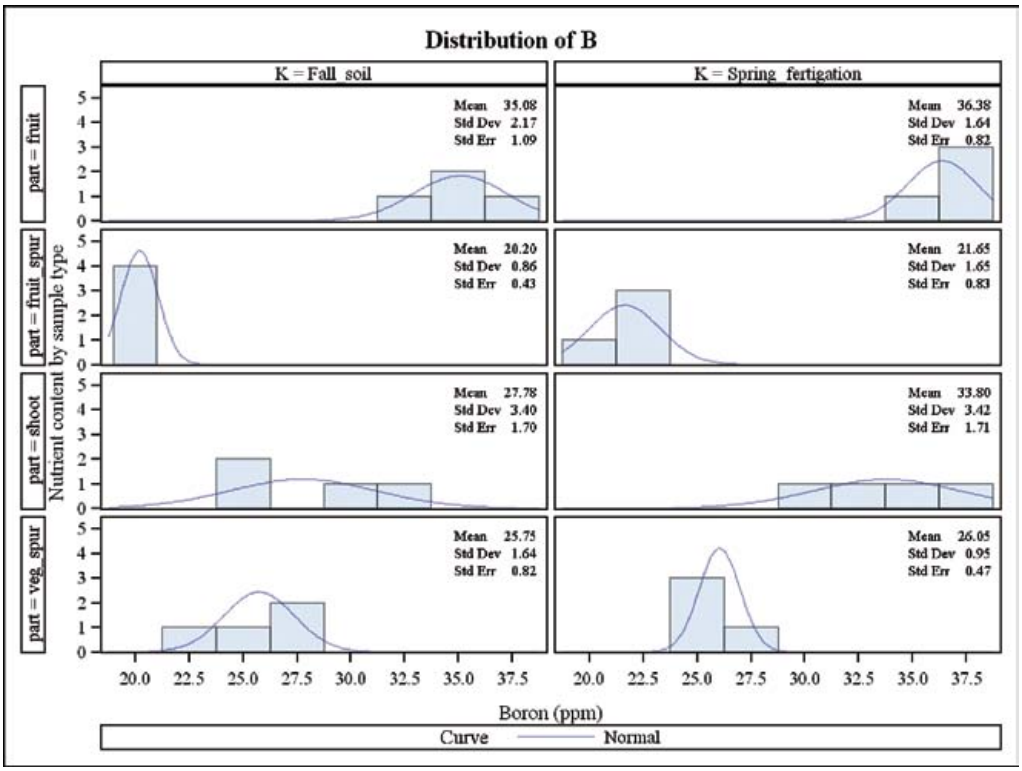


Figure 5
Distribution of phosphorus in fruit and leaf samples from **Elliot2**, April, 2010.

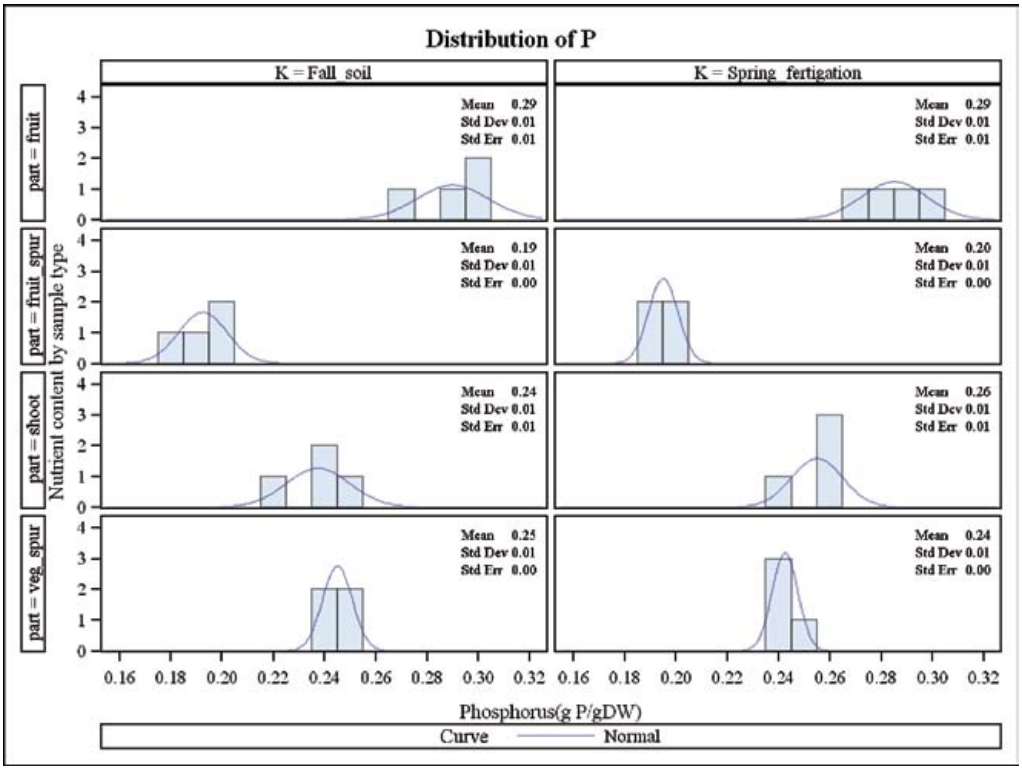


Figure 6
Distribution of zinc in fruit and leaf tissues at **Elliot2**, April, 2010.

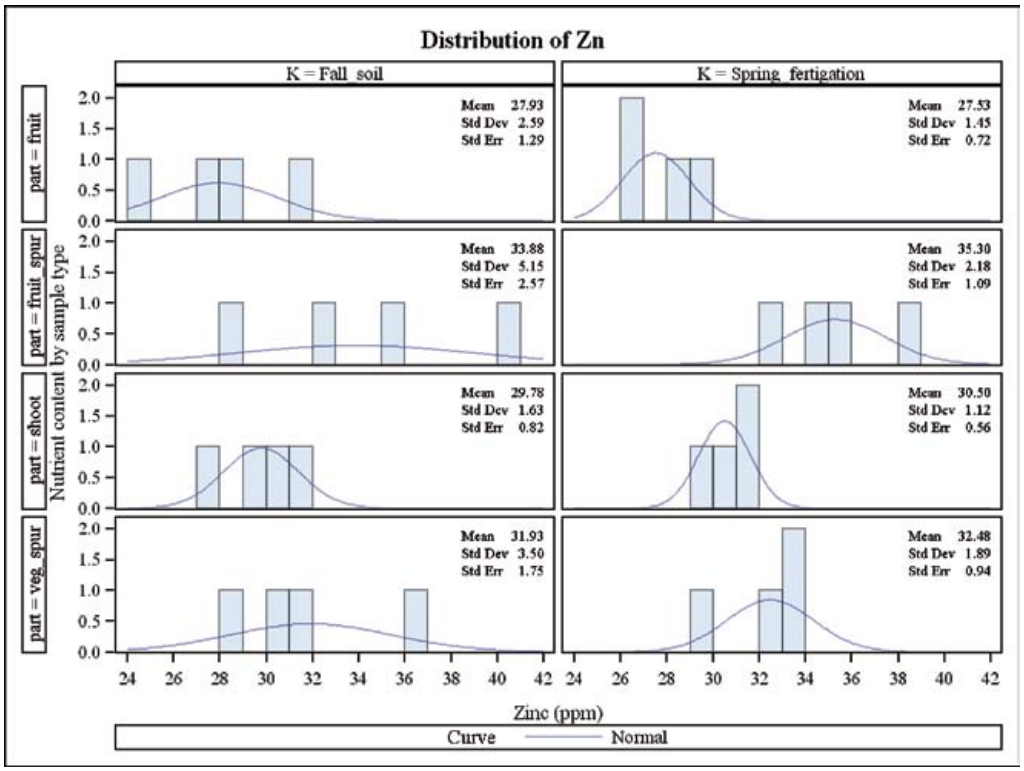


Figure 7
Distribution of potassium in fruit and leaf tissues at **Elliot2**, April, 2010.

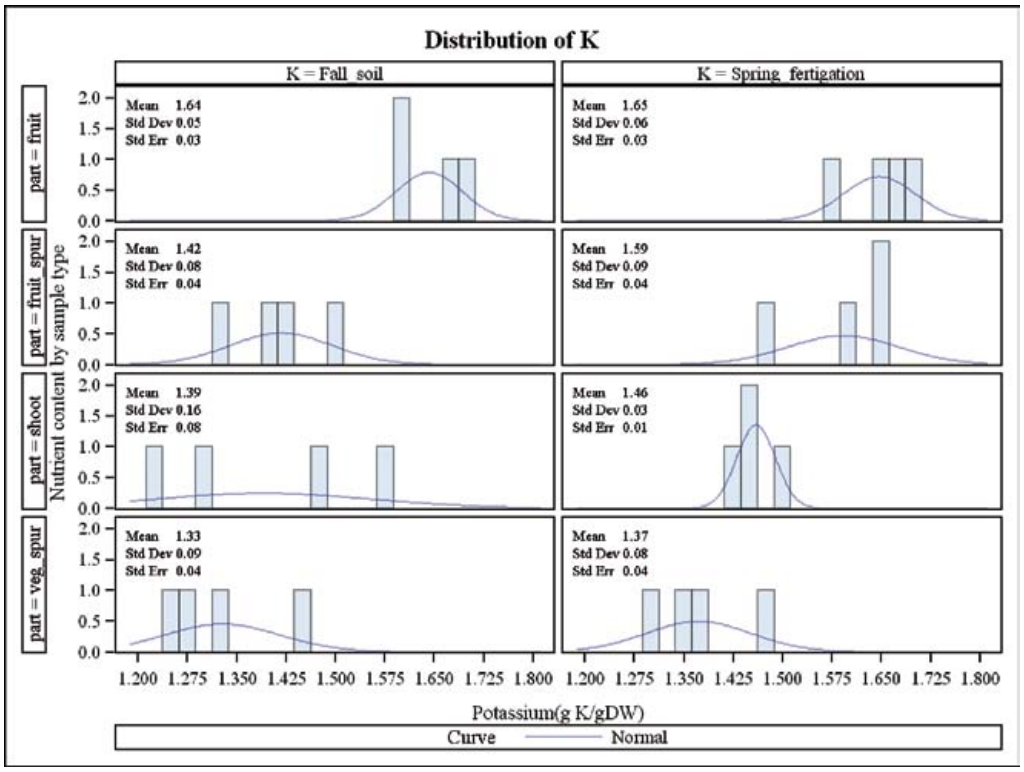
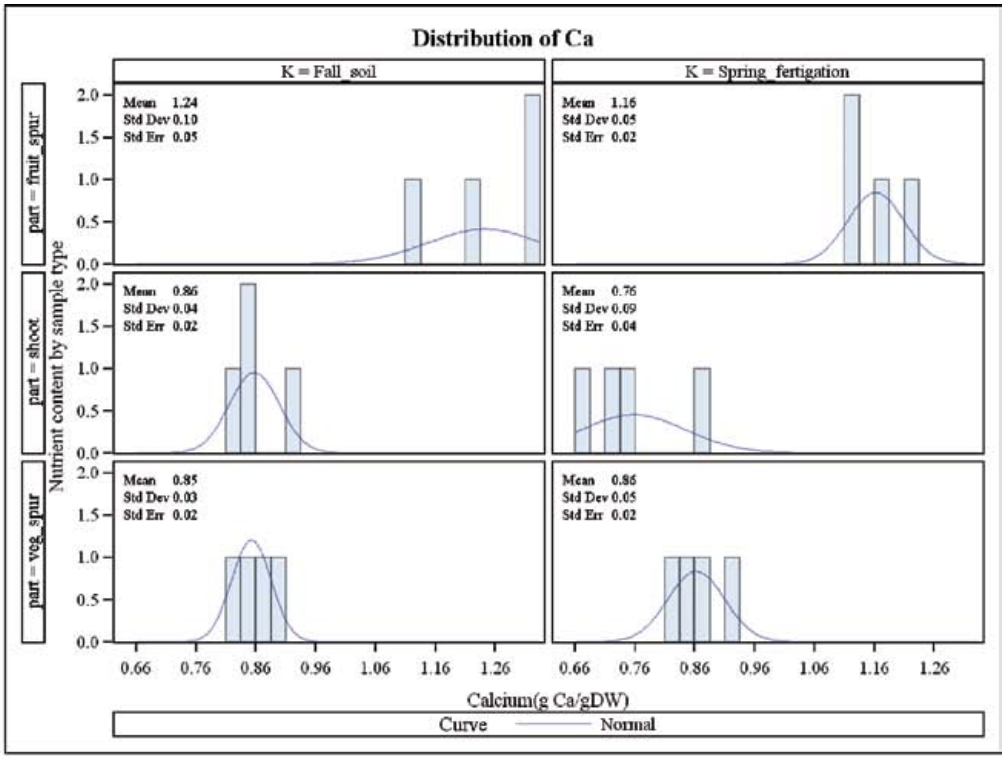


Figure 8
Distribution of calcium in fruit and leaf tissues at **Elliot2**, April, 2010.



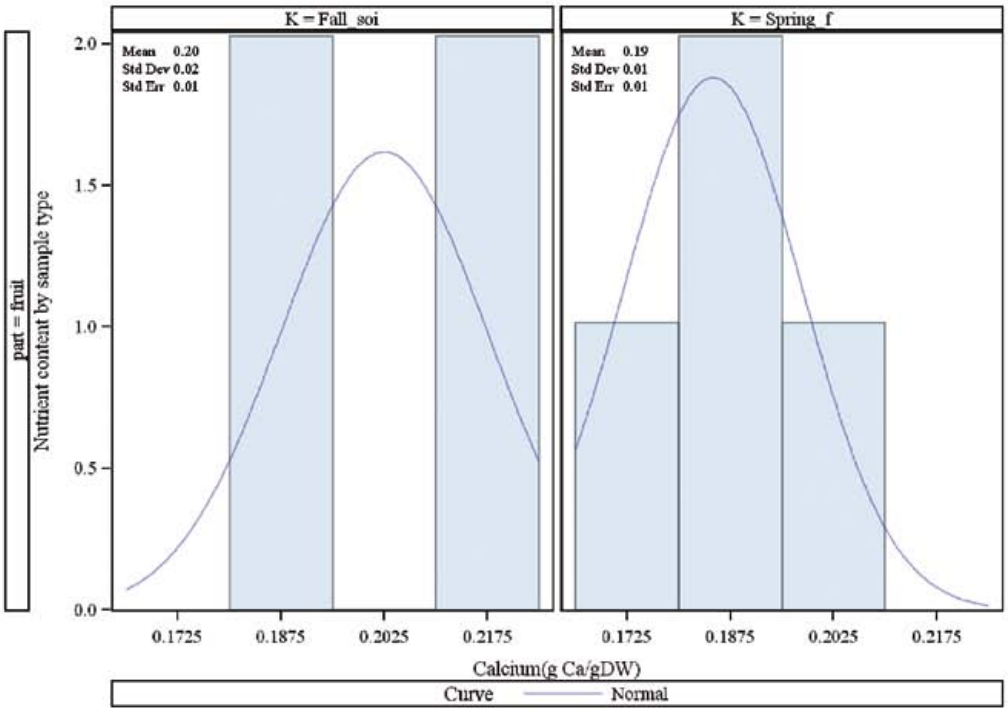
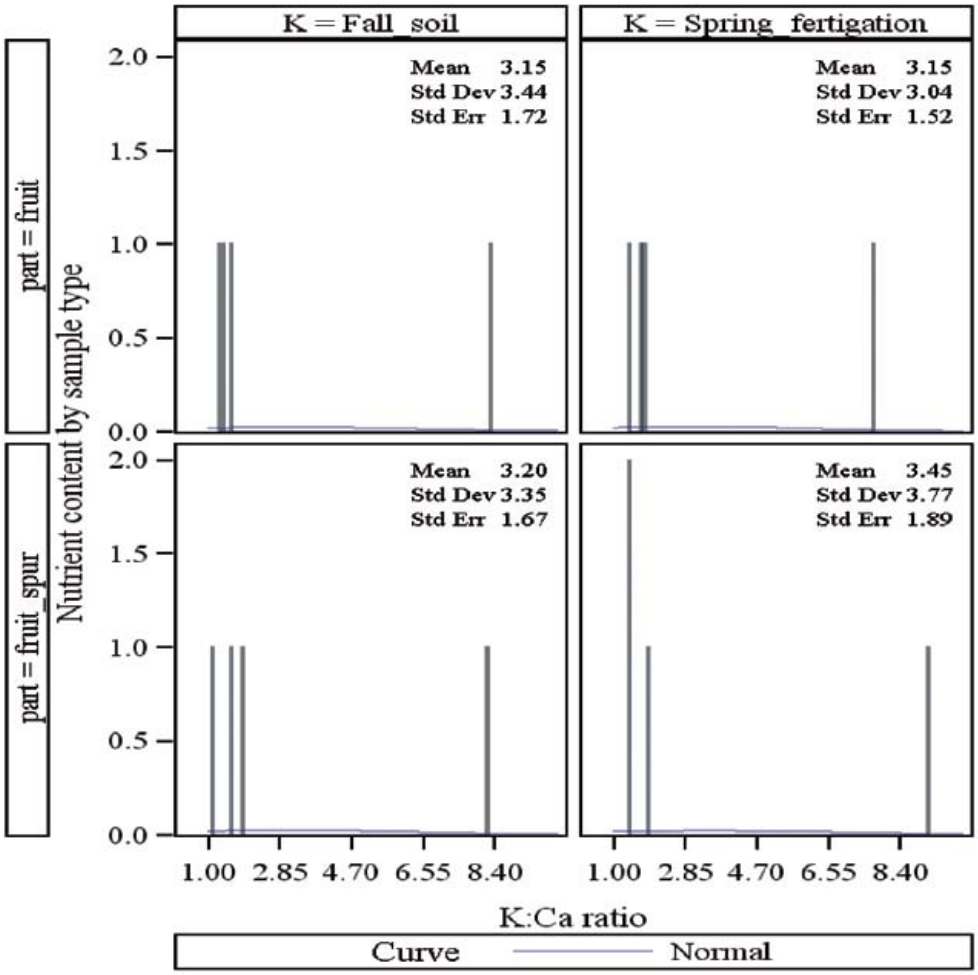


Figure 9
Binary ratio of K_Ca in fruit and leaf tissues at **Elliot2**, April 2010.



Harvest, 2010:Elliot2

We hand harvested twice, on 2 to 3 major scaffolds per 'test' tree (4 trees per treatment/block combination with 4 blocks per K treatment). The first 'pick' was to a minimum size, used by the pear industry for that purpose (2 5/8″ Grade #1). The second harvest was a 'strip pick', with all fruit removed from the scaffolds. Thus, we were able to develop baseline data for fruit size, distribution of size grades in the two harvests and in total (Figures 10 through14).

Figure 10
Elliot2 proportion of #1fruit (#1 fruit ≥ 2 5/8" diameter) harvested in the first 'pick', as part of the total harvest in 2010. The first 'pick' is entirely size-based.

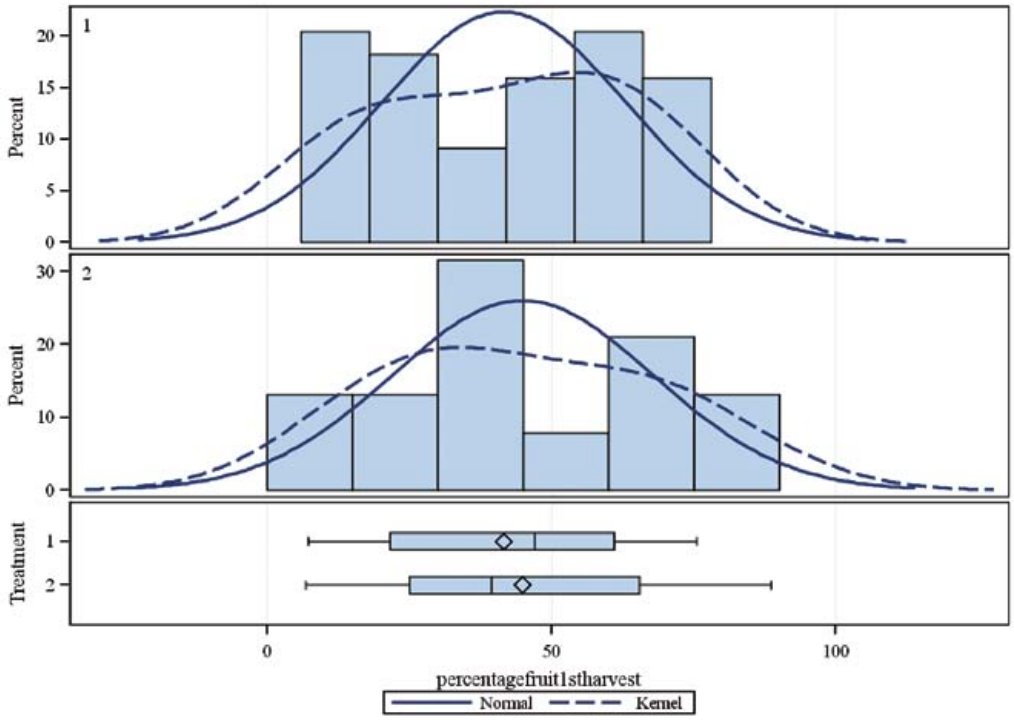


Figure 11
Percentage of #1 fruit (≥ 2 5/8" diameter) in the second 'pick' at **Elliot2**, 2010.

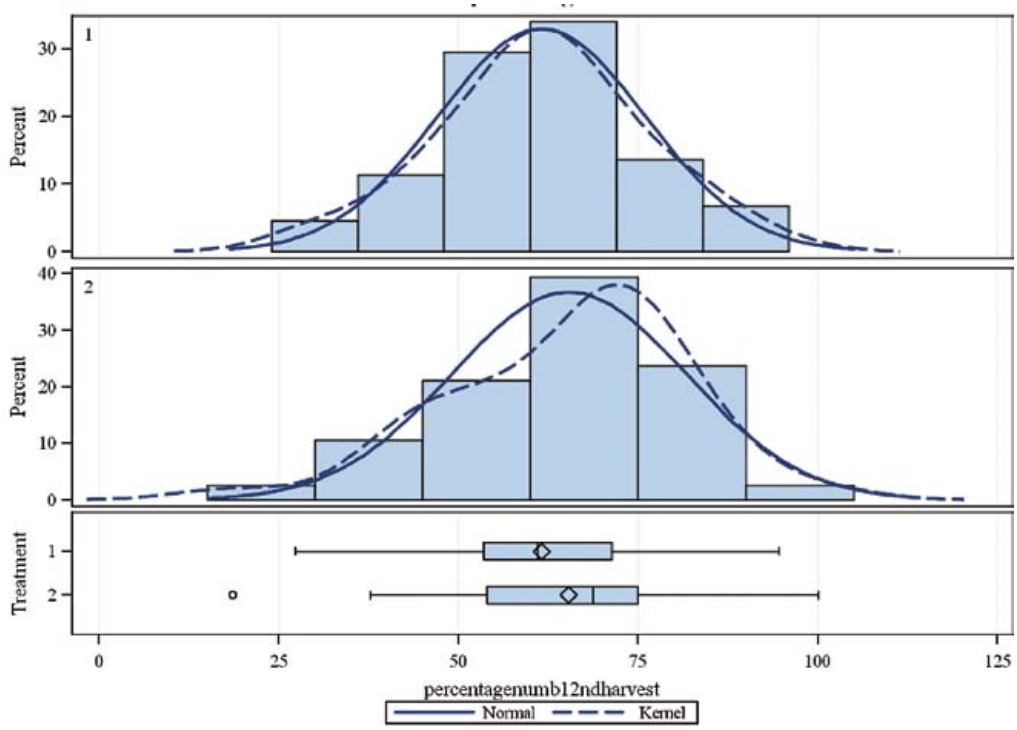


Figure 12
Percentage of the total 2010 crop at **Elliot2** which was #1 fruit (≥ 2 5/8" diameter).

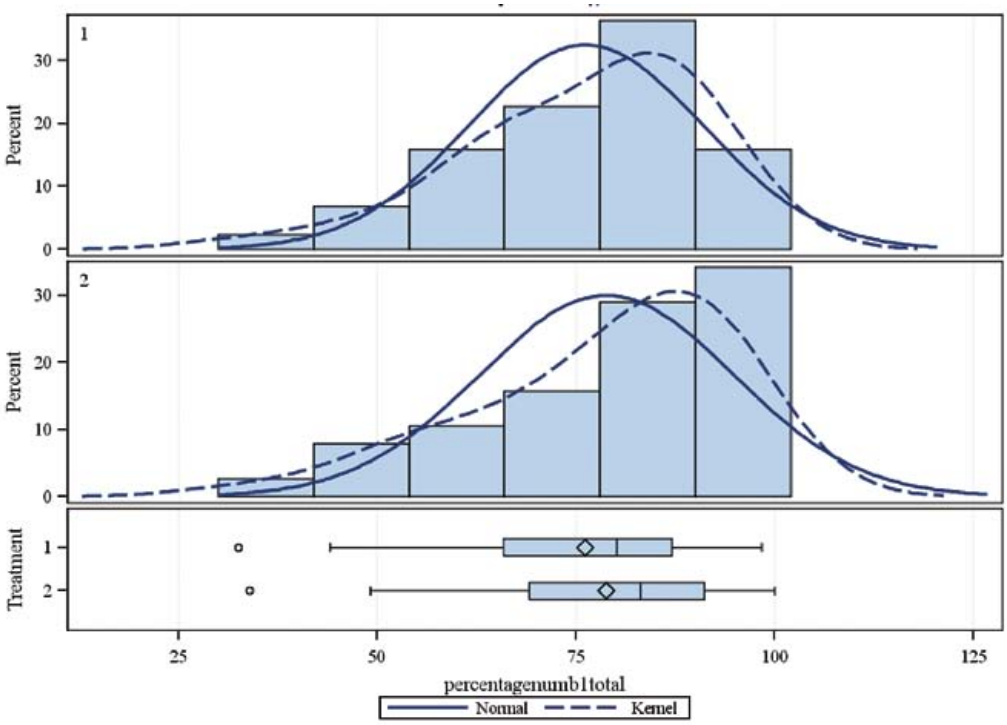


Figure 13
Fruit weight from the second harvest, 2010 at **Elliot2.**

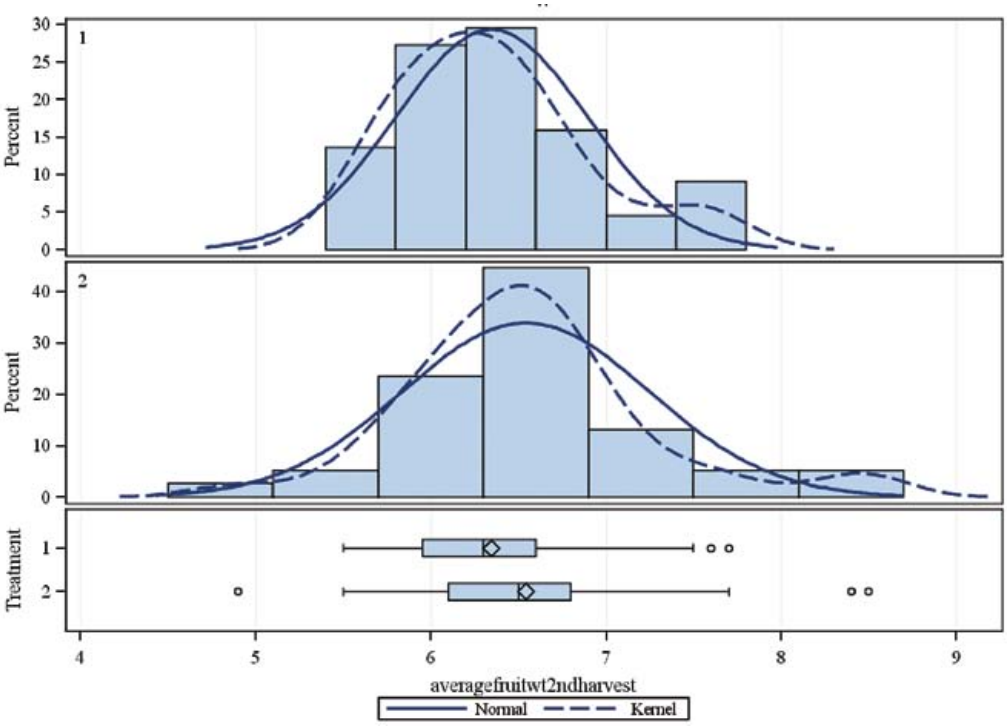
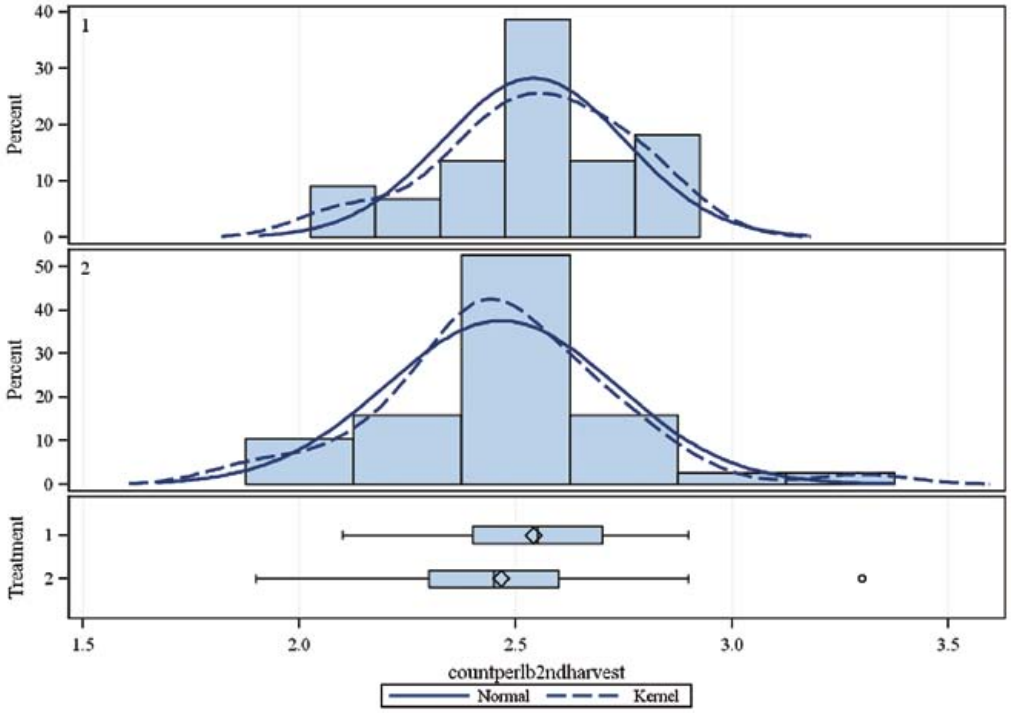


Figure 14
Fruit size, measured as 'count per pound', as affected by K treatments at **Elliot2**, 2010.



Harvest, 2010: Elliot1

Preliminary data from **Elliot1** single harvest establish baseline data (no effect of N level yet) for weight of #1 fruit (approximately 11 oz), count per lb (approximately 2.04), individual #1 fruit weight (11.07 oz), soluble solids (% Brix, 2.05), is shown in Table 2).

Table 2
Measures of fruit quality in 'Elliot1' orchard ('Low N' 60 lbs N_{act}/A/yr verses a 'HighN' treatment (120 lbs N_{act}/A/yr)

Nitrogen level	Quality	Mean	Std Error	Std Dev	Minimum	Maximum
High_N	#1 fruit weight (oz)	11.07	0.38	0.66	10.33	11.59
	Weight for unsorted fruit (oz)	7.30	0.07	0.20	7.10	7.60
	Count/lb of #1 fruit	24.43	0.84	1.46	22.80	25.60
	Soluble solids (Brix)	2.07	0.07	0.12	2.00	2.20
	Percentage of harvest as #1 fruit	79.8	2.12	6.37	65.9	85.9
Low_N	#1 fruit weight (oz)	11.09	.042	0.73	10.34	11.80
	Weight for unsorted fruit (oz)	6.86	0.10	0.30	6.30	7.30
	Count/lb of #1 fruit	24.47	0.93	1.60	22.80	26.00
	Soluble solids (Brix)	2.03	0.09	0.15	1.90	2.20
	Percentage of harvest as #1 fruit	70.63	2.86	8.58	59.80	85.90

Harvest data from **Elliot1** and **McCormack**, as well as July tissue sample analysis, are currently being conducted, and will be reported on at the annual FREP meeting.

ACKNOWLEDGEMENTS

The support of the California Department of Agriculture's FREP program and the California Pear Advisory Board for their support, as well as the growers and PCAs, whose inputs and cooperation, made this work possible.

Development of a Comprehensive Nutrient Management Web Site for the California Horticultural Industry

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INTRODUCTION

California growers of horticultural commodities are under increasing pressure to modify production practices to safeguard water quality. In the coastal vegetable and berry production areas (Salinas, Santa Maria and Ventura), three years of intensive water quality monitoring has shown that ditches, creeks and sloughs receiving runoff from irrigated agricultural land persistently average more than twice the federal limit of 10 ppm NO_3-N. In these areas groundwater is similarly impaired. Although overshadowed by the nitrate issue, surface water soluble phosphorus concentration is also above desirable levels at many of the monitoring sites. In the Imperial Valley, a major vegetable production area, a nutrient total maximum daily load (TMDL) is currently under development. The east side of the San Joaquin Valley, home to most of California's tree fruit and nut production, has widespread groundwater nitrate contamination.

In recognition of the reality that concentrated horticultural production and water quality problems are geographically linked, FREP has dedicated substantial funding to developing more agronomically efficient and environmentally sensitive fertilization and irrigation practices for vegetables, berries, tree fruits and nuts. These projects have investigated a wide range of issues, and significant advances have been made in our understanding of crop nutrient requirements, uptake patterns and monitoring techniques and the environmental fate of applied nutrients.

As the regulation to safeguard environmental water quality advances, the need for grower education will increase, and documentation of that education may become a condition for continued operation. For example, the Central Coast Region Water Quality Control Board requires growers to complete a 15 hour short course on water quality protection to qualify for an irrigation discharge waiver. The development

of a farm nutrient management plan is now a requirement in several parts of the state as a condition for continued coverage under the conditional waiver for the surface water dischargers. To meet the demand for technical service providers with nutrient management expertise, additional educational opportunities will be needed for various types of industry professionals [Pest Control Advisors (PCA), certified crop advisors (CCA), etc.]. In the increasingly busy life that such professionals lead, attendance at educational events can be a significant cost and scheduling hardship.

The internet provides a platform to collate and disseminate information about nutrient management for horticultural crop production; it also provides a convenient way to deliver continuing education for growers and associated industry professionals. This project was undertaken to develop a website containing comprehensive information on nutrient management of the important horticultural crops grown in California, and to provide online continuing education opportunities for holders of professional licenses.

OBJECTIVES

Develop an informational website on agronomically and environmentally efficient nutrient management for vegetable, fruit and nut crops.

RESULTS

The website is now operational (http://groups.ucanr.org/nutrientmanagement/index.cfm). It contains all completed FREP final reports, indexed by crop and topic. We have made several hundred items available related to mineral nutrition of horticultural commodities from UC sources, and from institutions and industry sources around the country and world. An extensive list of links to other university, industry and government resources has been assembled. We continue to add new information and links weekly.

Original educational content has also been developed for this website. Six educational modules have been created to date by the project leader, covering the following topics:

- Efficient phosphorus management for vegetable production
- Managing calcium in vegetable production
- Vegetable irrigation and nutrient management for water quality protection
- Drip irrigation scheduling of processing tomatoes
- Managing fertility in drip-irrigated processing tomatoes
- Improving fertilizer management in coastal lettuce production

These modules consist of a narrated PowerPoint presentation, paired with interactive quizzes to allow users to test their mastery of the material; examples can be viewed at http://groups.ucanr.org/nutrientmanagement/Educational_modules/

We are working with the California Certified Crop Advisor Executive Board to make these educational packets eligible for continuing education hours for CCAs. The Project Leader will create additional educational modules, and solicit modules from other UC professionals with different crop expertise. These modules may be based on a specific FREP research project, a general topic (i.e. soil quality maintenance, soil and tissue testing, etc.), or a specific crop.

We expect to have the website fully functional (including the ability for users to receive online continuing education credit) by early 2011.

Development of Certified Crop Adviser Specialty Certification and Continuing Education in Manure Nutrient Management

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INTRODUCTION

In May 2007, the Central Valley Regional Water Quality Control Board issued a General Order, (Order No. R5-2007-0035) for all existing milk cow dairy producers in the Central Valley of California. Within the Order, were a series of waste discharge requirements or (WDRs). Chief among those requirements is for a Nutrient Management Plan. The purpose of the Nutrient Management Plan (NMP) is to budget and manage nutrients applied to land, considering all sources of nutrients, crop requirements, soil types and adverse impacts to surface and groundwater. The NMPs must be developed and signed by Certified Crop Advisers (CCAs) or other certified professionals. The technical standards for the NMPs include unprecedented annual nitrogen loading limits for each field, and the Order requires a detailed monitoring and reporting program including manure, plant, soil, and water sampling and analyses. In this project, we collaborated with the California Certified Crop Adviser (CaCCA) Board to train crop management professionals in the agronomic aspects of manure management to enable them to better serve the dairy industry. Additional financial and logistical support was provided by the California Dairy Research Foundation.

OBJECTIVES

1. Produce a manure and crop nutrient management curriculum in the form of educational modules to be made available on the internet in a downloadable format.
2. Develop a set of multiple choice questions and an accompanying set of performance

objectives on manure nutrient management, suitable for use by the California Certified Crop Adviser program in the state CCA examination.

3. Conduct workshops for crop management professionals on crop nutrient management and dairy manure use in the Central Valley region. The workshops will target Certified Crop Advisers, Natural Resources Conservation Service (NRCS) Technical Service providers (TSPs) and NRCS staff who are Certified Planners of Comprehensive Nutrient Management Plans.

ACCOMPLISHMENTS

Project accomplishments were the following:

1. A half-day course was conducted at three locations (Modesto, Madera and Tulare) in May 2008. The short course was advertised by the Western Plant Health Association, the Certified Crop Adviser program/California Association of Pest Control Advisers, the California USDA/NRCS and several units within the University of California. A total of 205 persons attended, including 67 CCAs and 18 NRCS staff members. Continuing Education Units (CEUs) (3.5 units in the nutrient management category) were awarded to the Certified Crop Advisers.

2. A two-day short course was conducted in November 2008 at two locations – Modesto and Tulare. This provided 10 CEUs to CCAs. Lecturers included UC Cooperative Extension county farm advisors and specialists, Central Valley Regional Water Quality Control Board staff, and the California Dairy Quality Assurance Program (CDQAP). These workshops distributed about 30 handouts. Total attendance was 110, including 40 CCAs.

3. We produced a manure and crop nutrient management curriculum in the form of handouts and educational modules (Table 1). Workshop materials included approximately 50 handouts, of which about 20 were produced specifically for these workshops. Several technical bulletins have been posted on this website: http://manuremanagement.ucdavis.edu

4. A presentation titled "Preparing a nitrogen budget that is consistent with both crop needs and regulatory requirements" was presented at the NRCS Comprehensive Nutrient Management Planning workshop (75 attendees) in Modesto on April 17, 2008.

5. The primary investigator supported the CaCCA program's new Specialty Certification in Manure Management. This is a voluntary certification available to California CCAs in good standing. It is being offered as a tool to build clientele in the dairy industry and to demonstrate additional CCA competency in a regulated category of nutrient management. We participated in the CaCCA board's development of 32 performance objectives for the specialty certification. These are posted at: http://manuremanagement.ucdavis.edu A set of exam questions was prepared in collaboration with the CaCCA testing committee. The exam was offered in February 2010 and taken by 26 CCAs and again in August 2010 by 7 CCAs.

Table 1
Technical bulletins on the following topics are available at http://manuremanagement.ucdavis.edu

1	NRCS cost-share programs related to dairy manure recycling
2	Dairy manure properties
3	Estimating manure Nitrogen availability
4	Nitrogen cycling and losses from the soil
5	Soil testing and estimating soil Nitrogen availability
6	Crop Nitrogen Requirements and harvest removal
7	Legume Nitrogen credit for crops following alfalfa
8	Plant sampling for agronomic purposes
9	Nutrient management planning and budgeting
10	Lagoon water calculations

Development of a Nutrient Budget Approach to Fertilizer Management in Almond

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INTRODUCTION

Present nutrient management decisions in almond are based on Critical Values (CVs), in which results of leaf nutrient analysis are compared with established standard values. CVs provide only an indication of deficiency or sufficiency, but do not provide any specific information on the appropriate rate or timing of any fertilizer response. CVs are an inadequate approach to nutrient management in a high value species such as almond. Not only is the collection of a representative leaf sample difficult (because of spatial and temporal variability), and generally collected too late in the season to respond, but our degree of confidence in the existing CVs is limited and most importantly the results provide no specific information on how to respond.

An alternative approach that has been widely used in high value crops uses knowledge of growth and development to derive nutrient demand curves that guide the timing and quantity of nutrient applications. In these approaches, growth models, estimates of daily nutrient intakes, knowledge of nutrient bioavailability and the interactions between nutrients and other inputs are integrated to ensure that nutrient supply does not limit growth

and that profitability is maximized by avoiding excess applications. Almond production in California is well suited to the adoption of a nutrient budget driven approach to fertilization because crop values are at an all time high and there is an increasing interest in 'sustainable' production techniques to address customer desires and product image. Furthermore, management techniques are increasingly amenable to 'on-demand' fertilization through increased adoption of fertigation systems and fluid fertilizers.

OBJECTIVES

1. Develop a phenology and yield based nutrient model for almond.
2. Develop fertilizer response curves to relate nutrient demand with fertilizer rate and nutrient use efficiency.
3. Determine the effectiveness and nutrient use efficiency of various commercially important N and K fertilizer sources.
4. Validate current CV's and determine if nutrient ratio analysis provides useful information to optimize fertility management.
5. Develop and extend an integrated nutrient best management practice (BMP) for almond.

PROJECT DESCRIPTION

A large experimental fertilizer response trial has been set up in an eight-year-old orchard, planted 50% to Non-Pareil and 50% to Monterrey almonds. Experimental plots have been replicated under fan jet and drip irrigation systems. Fifteen individual trees and their immediate 30 neighbors are considered as a single uniformly treated unit, with all measurements taken on the central six non-pareil trees individually. A total of 128 experimental units of 15 trees have been treated; from these, 768 individual trees are being monitored for yield, nut growth and development and full nutrient status. A fertigation system has been installed and a digital flow meter has been employed to provide well-controlled doses of fertilizer during four fertigation events. Basal Sulphate of Potash (SOP) was applied in early February, and fertigation was done in February, April, June and October. The total experimental area is 100 acres.

The 12 treatments include four rates of N (UAN 32), three rates of K [SOP + Potassium Thiosulphate (KTS)], four contrasting rates of CAN17, one potassium chloride (KCl) and one SOP treatments. Descriptions of the treatments are given in Table 1. Effectiveness of each treatment will be determined by changes in leaf tissue analysis, yield, and soil residual N and K over a 3 to 5 year period.

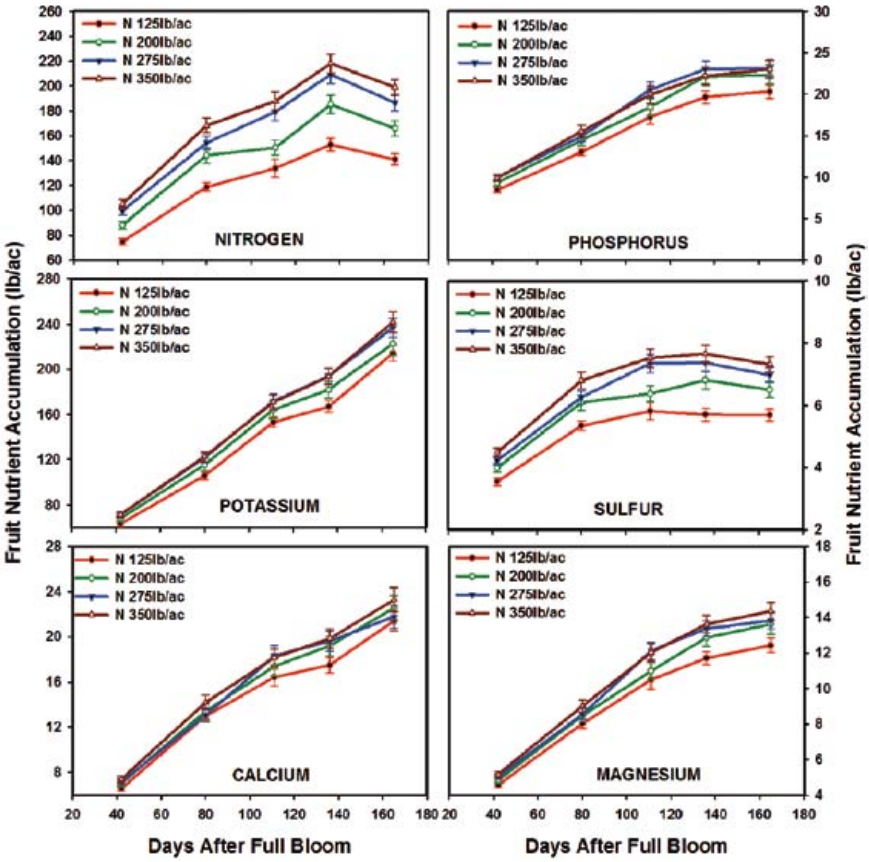
Leaf and nut samples were collected from all experimental trees starting from April through October, at a monthly interval. The nutrient concentrations of these tissues are being analyzed for N, P, K, S, Ca, Mg, B, Zn, Fe, Mn and Cu, at the Agriculture and Natural Resources (ANR) Laboratory at the University of California, Davis. Tree yield of each data tree was recorded at harvest and quality attributes of these trees are also being determined to develop a phenology and yield based nutrient model for almond.

Additionally, the project is quantifying the amount of N re-translocated from almond fruit (hull and shell) back to the perennial parts of the tree, which can be used to support the spring growth in the subsequent year. This has important implications for fertilizer management in almond fertilization program. To study the effect of the remobilized N on the spur survival and return bloom 1320 individual spurs on 32 trees were tagged in the low and the high nitrogen rate treatment. Harvest on these 92 trees will be delayed until complete loss of green color. Tagged spurs will be counted in spring 2011 at

Table 1
Detail of fertilization treatments

Treatment	N source	N amount (lbs/ac)	K source	K amount (lbs/ac)
A	UAN32	125	60% SOP / 40% KTS	200
B	UAN32	200	60% SOP / 40% KTS	200
C	UAN32	275	60% SOP / 40% KTS	200
D	UAN32	350	60% SOP / 40% KTS	200
E	CAN17	125	60% SOP / 40% KTS	200
F	CAN17	200	60% SOP / 40% KTS	200
G	CAN17	275	60% SOP / 40% KTS	200
H	CAN17	350	60% SOP / 40% KTS	200
I	UAN32	275	60% SOP / 40% KTS	100
J	UAN32	275	60% SOP / 40% KTS	300
K	UAN32	275	100% SOP	200
L	UAN32	275	100% KCl	200

Figure 1
Nitrogen, Phosphorus, Potassium, Sulfur, Calcium and Magnesium accumulation by almond fruit from nitrogen rate treatments in 2009.



full bloom to analyze for spur survival in the winter and again will be analyzed for fruit set by the end of April.

RESULTS AND DISCUSSIONS

Data from the first two years of the project has been analyzed and some results are presented in this report. The accumulation of nitrogen, phosphorus, potassium, sulfur, calcium and magnesium in the fruit for different rates of N over the season is shown in Figure 1.

Nutrient accumulation over the season (2009)

Nitrogen accumulation in the fruit was positively correlated with nitrogen supply on all sampling dates. Nitrogen accumulation increased in all treatments and maximum accumulation was observed at 136 days after full bloom (DAFB). At 165 DAFB (harvest), however, total fruit N accumulation declined for all N rate treatments, suggesting that N was remobilized back to the tree. This trend of nitrogen remobilization in 2009 was consistent with the observations in 2008. Phosphorus showed similar trend like nitrogen and increased nitrogen supply also increased phosphorus uptake. All treatments also exhibited a small but insignificant decline in P concentrations between 136 and 165 DAFB (harvest). Although, accumulation of potassium in fruit increased overtime but was not significantly influenced by K treatment,

Figure 2
Effect of different nitrogen rates (N UAN 32) on leaf nutrient concentration in 2009 (for Fan Jet Irrigation). In box plots, the central line is the median of the distribution, the edges of the boxes are the 25% and 75% quantiles, error bars, represent the 10% and 90% quantiles, and all points are outliers.

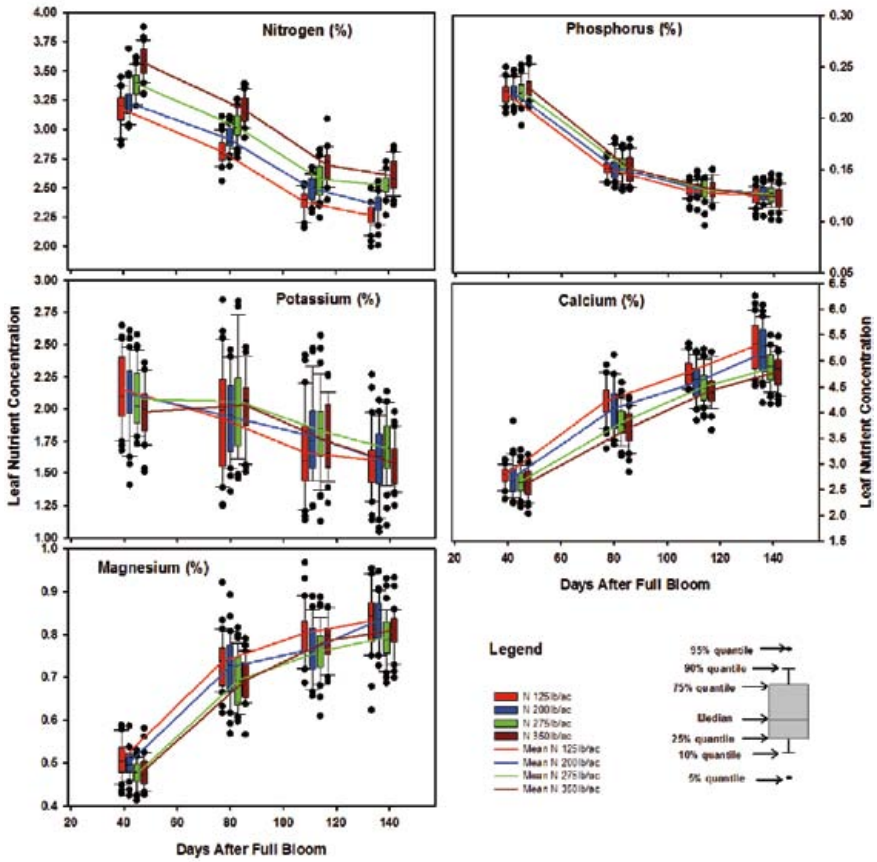


Table 2
Mean kernel yield (lb/ac) for different treatment in 2009; treatments not represented by same letter within irrigation are significantly different. (Refer to table 1 for the description of letters)

Treatment	UAN 32					CAN 17				K Rate		K Source		
	A	B	C	D	E	F	G	H	I	C	J	C	K	L
Drip Irrigation	2,689 b	2,977 b	3,327 ab	3,507 a	2,512 b	2,634 b	3,064 b	3,605 a	3,304	3,327	3,534	3,327	3,246	3,480
Fan Jet Irrigation	2,776 b	3,111 ab	3,263 ab	3,380 a	3,143	3,130	3,248	3,216	3,457	3,263	3,489	3,263	3,308	3,404

suggesting that K availability at this site was not rate limiting. Figure 1 shows nutrient accumulation in almond fruits over the entire season in 2009.

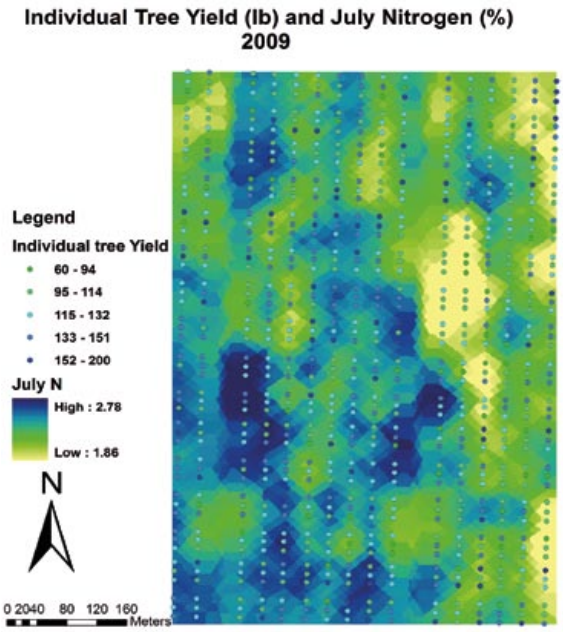
Tissue Nutrient Concentration

Leaf nitrogen, phosphorus and potassium concentrations were high in the beginning of the season and then declined as the season progressed. On the other hand, calcium and magnesium concentrations were low at the beginning of the season and then increased (Figure 2). Significant differences in leaf nitrogen concentration were observed between N rate treatments throughout the season. Current data illustrates the extreme degree of variability that exists in tree K concentrations and suggests that tissue sampling for K is extremely limited in its utility. Fruit nitrogen and phosphorus concentrations declined over time in all N rate treatments; fruit potassium showed a variable trend while there was slight decline in fruit calcium and magnesium concentration over the season (data not shown).

Yield

Data reveals great yield variability across the field in a single year that suggests how this variability has been underestimated (Figure 3). In contrast to results from first year data, significant nitrogen treatments effect was observed. The effect of different treatments on kernel yield is presented in Table 2.

Figure 3
Yield map of the experimental trees and July nitrogen concentration.



CONCLUSIONS

Effects of N rate treatments are becoming more evident in tissue nutrient and yield, while K rates have shown significant effect on tissue K only. Nitrogen remobilized from fruits to the perennial structures after kernel is maturity and may play a role in spur survival and return bloom.

ACKNOWLEDGEMENTS

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Developing Testing Protocols to Ensure the Authenticity of Fertilizers for Organic Agriculture

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INTRODUCTION

The following summary describes the first six months of activity for this project. This project was undertaken to address the growing concern about the authenticity and integrity of soil and crop amendments sold for use in organic production ("Organic farms unknowingly use synthetic fertilizer", Sacramento Bee, Dec 28, 2008; see also letter from the Executive Director of the Organic Materials Review Institute, Feb. 20, 2009, http://omri.org/OMRI_PR.html. Recent examples of the use of synthetic ammonia, which is prohibited in organic production, were found in a product derived from fish. The resulting product is very effective as a fertilizer, is much cheaper to produce, and ensures a higher profit for the manufacturer compared to fertilizers using certified organic materials. In addition, the product quality and consistency is enhanced giving the illusion the "organic fertilizer" is of a better grade than competing products on the market. Most of the organic amendment certification process is based on trust and often such adulterated products are then approved and labeled as suitable for organic agriculture. Depending on the degree of adulteration, basic laboratory tests often cannot indicate a problem. The lack of guidelines, particularly for testing of products to ensure authenticity are lacking in the industry. Analysis of nitrogen content, for example, may confirm a product label, but will not indicate the source of nitrogen. The problem has undermined public trust in the "organic" label of amendments and crops, and this inevitably negatively affects both growers and consumers of organic foods.

The development of guidelines and protocols to test organic fertilizers for their authenticity will contribute to restoring trust in producers of organic fertilizers and in fairness of the marketplace, and confidence of consumers in being offered produce that has been grown according to organic standards. These guidelines and protocols are directly related to the goals of assisting the organic fertilizer industry efforts to increase public confidence in the food supply and to provide for an equitable marketplace. The success of the guidelines and protocols will ensure that manufacturers of adulterated organic fertilizers and amendments will face the appropriate scrutiny to ensure the authenticity of their products. Legitimate producers of fertilizers will benefit by having a defined set of testing protocols to ensure the quality of their products. The guidelines and protocols will contribute to greater transparency and authenticity of fertilizer products intended for organic agriculture.

OBJECTIVES

The following objectives provide the guidelines and outcomes for this project.

1. Construct a database of materials used in organic and synthetic fertilizers and their quantifiable properties through thorough search of the literature and additional chemical and physical analyses of such materials.
2. Establish natural ranges for the chosen properties of these materials that can be used to distinguish between pure, or unadulterated, and adulterated materials.
3. Develop a stepwise protocol test that labs and regulatory agencies can follow to identify organic fertilizers that have likely been adulterated by synthetic fertilizers.
4. Carry out blind tests with collaborating test labs to evaluate the robustness of the above protocol.
5. Disseminate the results and products of the project to potential users, such as organic fertilizer test labs and regulatory agencies.

DESCRIPTION

This project will characterize the materials that can be used in the manufacturing of organic fertilizers and amendments. The major new product generated by this project will be a method of testing to detect with high probability adulteration of organic fertilizers and other amendments by synthetic fertilizer and/or other chemical nutrient sources. The following tasks will guide project activities.

Tasks

1. Conduct a literature review on the materials used in organic and inorganic fertilizer materials.
2. Analyze the collected materials for stable isotope and nutrient content.
3. Build a database.
4. Evaluate and summarize the dataset.
5. Construct usable guidelines to be used by test labs and regulatory agencies.
6. Evaluation: Measuring success.
7. Outreach.

During the first six months of the project we have completed Task 1 and begun Task 2.

RESULTS AND DISCUSSION

Previously, no systematic research has been undertaken to develop comprehensive guidelines on testing the authenticity of organic fertilizers and amendments. Important to developing guidelines and protocols is the biogeochemical literature that addresses the sources, fractionation and pathways of carbon, nitrogen and oxygen isotopes within different trophic levels of food webs and unique organismal metabolic pathways (Schimel 1993; Horwath et al. 2001). A great deal of information that can be used to develop guidelines and protocols can be found in the literature although this information is highly fragmented (Table 1).

Other properties, such as ash content, nitrogen to phosphorus ratio, phosphorus content, and content of other elements, can vary widely depending on the nature of a product and the way in which it has been processed. For example, a product made primarily from fish flesh scraps (no bones) has less ash, phosphorus, and calcium compared to a product made from whole fish or fish offal. Nevertheless, such parameters may still be used to evaluate a product if the manufacturer's claims regarding its composition are considered.

CONCLUSIONS

The evaluation and principal trends of properties of materials used to make organic fertilizers can be incorporated into a recommended course of

Table 1
The properties are the isotope ratios of carbon and nitrogen ($\delta^{13}C$ and $\delta^{15}N$), carbon content (%C), nitrogen content (%), carbon to nitrogen ratio (C:N), and phosphorus content (%P).

	$\delta^{13}C$	$\delta^{15}N$	%C	%N	C:N ratio	%P	Reference
Commercial products							
fish meal (anchovy)	-18	-13	42	11 to	3.8		Yokoyama et al. 2006
fish meal (herring)				11.5		1.7	Luzier et al. 1995
Natural materials							
fish protein	-22 to -17	10 to 16			3 to 5		Sherwood and Rose 2005
seabird guano	-20 to -18	9 to 11	22	13 to 17			Mizutani and Wada 1988
Synthetic materials							
fertilizer ammonium		-4 to 2					Freyer and Aly 1974
urea	-41	-1					Vitoria et al. 2004

action. According to our present knowledge, the C:N ratio would be an easy to measure property giving a strong indication on the authenticity of a tested product. If the C:N ratio was suspect, further tests could be recommended. Measurement of isotope ratios of C, N, and O would be recommended if multiple variables suggested that adulteration of a natural product with synthetic fertilizer might have occurred. The proposed guidelines will provide the organic industry the tools necessary to evaluate fertilizers and ensure that the trust in the organic label has integrity.

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Can a Better Tool for Assessing 'Hass' Avocado Tree Nutrient Status be Developed?

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INTRODUCTION

California avocado growers must increase yield, including fruit size, and/or reduce production costs to remain competitive in the US market, which now receives fruit from Mexico, Chile, New Zealand, Australia, Dominican Republic, Peru and Ecuador and soon South Africa and Brazil. Optimizing the nutrient status of the 'Hass' avocado (*Persea americana* Mill.) is a cost-effective means to increase yield, fruit size and quality, but the California avocado industry has no reliable diagnostic tool relating tree nutrient status with yield parameters. For the 'Hass' avocado of California, experiments for only N, Zn and Fe have been conducted to determine the optimal leaf concentration for maximum yield (Crowley, 1992; Crowley and Smith, 1996; reviewed in Lovatt and Witney, 2001). Alarmingly, leaf N concentration was not related to yield (Lovatt and Witney, 2001). Optimum ranges for nutrients other than N, Zn and Fe used for interpreting leaf analyses for the 'Hass' avocado are borrowed from citrus and, thus, are not related to *any* avocado yield parameter. The project's objective is to test the feasibility of using tissues that have frequently proven more sensitive and reliable than leaves to diagnose deficiencies of the 'Hass' avocado sufficiently early that corrective measures would have a positive effect on yield parameters during the current year, not just the following year. Based on results obtained by avocado researchers in Chile (Razeto and Granger, 2001; Razeto et al., 2003; Razeto and Salgado, 2004), it is highly likely that pedicel (the stem of the fruit) and/or inflorescence tissue will meet the criteria essential for an effective diagnostic tool for 'Hass' avocado fertility management in California. However, it must be noted that additional research would be required to develop the broader database required to have confidence in the relationship between nutrient concentrations in pedicel and/or inflorescence tissue and yield or fruit size than would be provided by the two data sets that will be obtained in this proposed 2-year study. Hence, this is a feasibility study designed to determine whether a better tool for assessing 'Hass' avocado tree nutrient status can be developed.

OBJECTIVES

The specific objectives of this project are:

1. Determine the sensitivity of inflorescences and fruit pedicels (stems) to differences in tree nutrient status
2. Determine if the nutrient concentrations of the tissues above are related to fertilizer rate and to yield parameters
3. Determine if differences in tissue nutrient concentrations related to yield can be detected sufficiently early to be corrected before they impact yield, fruit size or fruit quality in the current year.

DESCRIPTION

1. Tissues were collected as follows: entire inflorescence at the cauliflower stage and at full bloom; pedicels (stems) of young fruit in June (which is before exponential increase in fruit size and June drop of the current crop, start of mature fruit drop and transition from vegetative to reproductive growth), in September at the standard time for collecting leaves for nutrient analysis, and in November at the end of the fall vegetative flush; and pedicels of mature fruit in March at the time inflorescences at the cauliflower stage were collected and in April when inflorescences were collected at full bloom. Standard leaf collection was in September each year.
2. Tissue samples were collected from 16 individual 'Hass' avocado trees on the diagonal across orchards (with different but known rootstocks) located in Pauma Valley, Irvine, Santa Paula (high N and B site), San Luis Obispo and from trees receiving BMP N

(25 lb N/acre in July, Aug., Nov. and Apr.; 100 lb N/acre/year), BMP NPK (25 lb N, 3.75 lb P, and 22.5 lb of K in July, Aug., Nov. and Apr.; 100 lb N, 15 lb P and 90 lb K/acre/year), 0.5x N (25 lb N/acre in July and Aug.; 50 lb N/acre/year) and 0.5x NPK (25 lb N, 3.75 lb P, and 22.5 lb of K in July and Aug.; 50 lb N, 7.5 lb P and 45 lb K/acre/year) at a new research site in Santa Barbara.

3 Tissues were analyzed for N, S, P, K, Mg, Ca, Fe, Zn, Mn, B, and Cu. At harvest, yield (number and kg fruit), fruit size distribution and fruit quality were determined per tree.

RESULTS AND DISCUSSION

Relationship between tissue nutrient concentrations and yield parameters. We determined which nutrients in each tissue were significantly related to total yield and yield of commercially valuable large size fruit of packing carton sizes 60 + 48 + 40 (fruit weighing 178 to 325 g). Using stepwise regression analyses, we determined the most important combination of nutrients for each yield parameter across all orchards. ***Inflorescence tissue.*** We found significant relationships between nutrient concentrations of inflorescences at the cauliflower and full bloom stage and yield across all orchards including the trees in the fertilizer experiment in Santa Barbara. In all cases, nutrient concentrations of inflorescences collected at full bloom were more strongly related to yield and yield of commercially valuable large size fruit as both kilograms and number of fruit per tree. Cauliflower stage inflorescence tissue concentrations of Cu and Ca explained ≥ 60% of the variation in total yield (as kg/tree) and yield of fruit > 178 g per fruit (as kg and number of fruit/tree) ($P < 0.05$). Interestingly, the Cu concentration of cauliflower stage inflorescences alone predicted 54% of the variation in yield of commercially valuable large size fruit of packing carton sizes 60 + 48 + 40 (178-325 g/fruit) (as both kilograms and number of fruit per tree) ($P < 0.0001$). Cu, S, K and Zn concentrations of inflorescence tissue collected at full bloom predicted 77% of the variation in total yield, yield of fruit > 178 g per fruit and the yield of fruit in the combined pool of fruit weighing 178 to 325 g per fruit (as both Kg and number of fruit/tree) ($P < 0.01$). ***Pedicel tissue.*** P, S, B, and Ca concentrations of pedicels collected from young developing fruit in September explained 56% of the variation in yield of fruit > 178 g per fruit (packing carton size 60) as kilograms per tree ($P < 0.0009$). These nutrients plus Mg were required to predict the yield of fruit greater than packing carton size 60 as number of fruit per tree ($r^2 = 0.53$; $P = 0.0044$) and the yield of fruit in the combined pool of fruit 178 to 325 g per fruit (packing carton sizes 60 + 48 + 40) as kilograms fruit per tree ($r^2 = 0.55$; $P = 0.0039$). Note that this yield parameter as number of fruit per tree was related to P, S, B, Ca and N, not Mg ($r^2 = 0.52$; $P = 0.0138$). When pedicels of young fruit were collected in November, Zn, S, P and Mg concentrations predicted 60% of the variation in yield of fruit of packing carton sizes ≥ 40 (≥ 270 g/fruit) as both kilograms and number of fruit per tree in both years of the study ($P = 0.0244$), with Zn the most important determinant. ***Leaf tissue.*** Our results confirmed that leaf nutrient concentrations by standard leaf analyses were not related to total yield. Leaf nutrient status was also not responsive to the NPK soil fertilizer treatments. However, there was a weak, but highly significant relationship between leaf concentrations of Ca, Fe, S and Zn and yield of commercially valuable large size 'Hass' avocado fruit (packing carton sizes 60 + 48 + 40; 178-325 g/fruit) as kilograms per tree ($r^2 = 0.58$; $P = 0.0026$) and as number of fruit per tree ($r^2 = 0.51$; $P = 0.0057$) across all four orchards and the NPK soil fertilizer treatments.

Relationship between tissue nutrient concentrations and fruit quality parameters. We determined which combination of nutrients in each tissue had the most important effect on fruit quality across all orchards using stepwise regression analyses. The fruit quality parameters evaluated in each orchard were: number of days for fruit to ripen after harvest, peel color at maturity, fruit length, fruit width, width of the mesocarp (edible portion of the fruit), seed diameter, germination of the seed within the mesocarp, vascularization (presence of vascular tissue in the mesocarp), mesocarp discoloration, mesocarp decay. Fruit quality parameters were visually determined using a scale from 0 (none) to 4 (extensive, present in all four quarters of the fruit). ***Leaf tissue.*** Nutrient concentrations of leaves collected at the standard time were not related to any fruit quality parameter evaluated, with the exception that leaf Ca, Mn and Zn concentrations were significantly related to fruit length ($r^2 = 0.60$; $P = 0.0386$). ***Pedicel tissue.*** For pedicels collected from current year fruit, Zn, Fe, Mg, and Mn (September collection) and Zn and Mn (November collection) were also predictive of fruit length ($r^2 = 0.62$; $P = 0.0159$; $r^2 = 0.58$; $P = 0.0005$, respectively). ***Inflorescence tissue.*** Inflorescence tissues were the best predictors of fruit quality, including fruit length, fruit width, mesocarp width, seed germination within the fruit, and the number of days to ripen after harvest, across all four orchards and the NPK soil fertilizer treatments. All parameters were more strongly related to the nutrient concentrations of inflorescences collected at full bloom than at the cauliflower stage of inflorescence development. For inflorescences collected at full bloom, Cu and Mn predicted 82% of the variation in fruit length ($P = 0.0048$); Cu and K predicted 59% of the variation in fruit width ($P = 0.0055$); K and N predicted 57% of the variation in mesocarp width ($P = 0.0093$); K and Mg predicted 53% of the variation in the occurrence of seed germination within the mesocarp ($P = 0.0433$); and Cu alone predicted 51% of the variation in the number of days for fruit to ripen after harvest ($P < 0.0001$). Whereas all the relationships are statistically significant, fruit length was *strongly* influenced only by Cu and Mn nutrient status of full bloom inflorescences as reflected by the high r^2-value ($r^2 = 0.82$).

CONCLUSION

The results of this research identified the several key nutrient concentrations of inflorescence tissue related to total yield, yield of commercially valuable large size fruit (178-325 g/fruit, packing carton sizes 60 + 48 + 40) and fruit quality parameters that were statistically significant and explained in some cases ≥ 60% of the variation in yield or fruit quality. A unique finding was the potential importance of inflorescence tissue concentrations of Cu to yield parameters and Cu and Mn to fruit quality parameters across the orchards in this study. These relationships merit further testing to determine their potential capacity to serve as predictors of the effect of tree nutrient status on yield and fruit quality. Inflorescence tissue has the added advantage that it could be collected and analyzed sufficiently early in the season to mitigate the negative effect of nutrient deficiencies on the current crop and on the fruit quality of the mature crop.

The results confirmed that leaf nutrient concentrations were not related to yield or fruit quality parameters, with the exception of a weak, but highly significant relationship between leaf concentrations of Ca, Fe, S and Zn and yield of commercially valuable large size 'Hass' avocado fruit (packing carton sizes 60 + 48 + 40; 178-325 g/fruit) as kilograms per tree ($r^2 = 0.58$; $P = 0.0026$) and as number of fruit per tree ($r^2 = 0.51$; $P = 0.0057$) across all four orchards and the NPK soil fertilizer treatments. The value of this relationship could be studied further in orchards by using current leaf analyses and collecting yield data.

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Table 1.
Nutrient concentrations of 'Hass' avocado tissues collected in Irvine and Pauma Valley, California.

Tissue[z]	N %	P %	K %	S %	B ppm	Ca %	Mg %	Zn ppm	Mn ppm	Fe ppm	Cu ppm
	Irvine										
Y. inflorescence	3.35 a[y]	0.52 a	2.17 a	0.35 a	54.00 a	0.60 a	0.24 a	56.30 a	38.30 a	37.60 a	19.24 a
M. fruit stem 1	0.97 b	0.19 b	1.85 b	0.06 b	30.10 b	0.22 b	0.12 b	8.10 b	4.30 b	110.40 a	4.43 b
P-value	<0.0001	<0.0001	0.0158	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0845	<0.0001
M. inflorescence	2.89 a	0.38 a	2.36 a	0.37 a	57.50 a	0.59 a	0.27 a	48.90 a	31.30 a	58.90 b	15.03 a
M. fruit stem 2	1.57 b	0.29 b	1.75 b	0.07 b	19.00 b	0.20 b	0.20 b	8.50 b	5.40 b	69.20 a	3.01 b
P-value	<0.0001	0.0123	0.0039	<0.0001	<0.0001	<0.0001	0.0016	<0.0001	<0.0001	0.0426	<0.0001
M. leaf	1.85 a	0.10 a	0.88 b	0.46 a	32.80 a	1.71 a	0.82 a	37.60 a	83.60 a	69.90 a	5.96 a
Y. fruit stem	0.57 b	0.08 b	1.43 a	0.04 b	19.00 b	0.18 b	0.07 b	6.50 b	3.50 b	21.50 b	2.86 b
P-value	<0.0001	0.0461	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	Pauma Valley										
Y. inflorescence	3.11 a	0.49 a	1.81	0.29 a	45.30 a	0.55 a	0.23 a	48.90 a	38.50 a	67.00	10.08 a
M. fruit stem 1	1.71 b	0.33 b	1.81	0.07 b	20.20 b	0.20 b	0.11 b	9.50 b	3.60 b	62.40	1.81 b
P-value	<0.0001	0.0007	0.9824	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.3547	<0.0001
M. inflorescence	2.60	0.42	2.04 a	0.30 a	56.80 a	0.52 a	0.26	47.00 a	30.90 a	90.70	9.94 a
M. fruit stem 2	2.88	0.49	1.55 b	0.09 b	16.30 b	0.17 b	0.23	13.80 b	5.70 b	89.60	3.66 b
P-value	0.4232	0.1618	0.0094	<0.0001	<0.0001	<0.0001	0.1784	<0.0001	<0.0001	0.917	<0.0001
M. leaf	1.86 a	0.12 b	0.69 b	0.42 a	26.60 a	2.97 a	1.03 a	41.50 a	153.10 a	128.90 a	5.04 a
Y. fruit stem	1.23 b	0.19 a	2.04 a	0.06 b	10.90 b	0.19 b	0.08 b	9.50 b	3.20 b	22.90 b	2.20 b
P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[z] Y. inflorescence-cauliflower stage of inflorescence development (March); M. fruit stem 1-pedicel of mature fruit (March); M. inflorescence-inflorescence at full bloom (April); M. fruit stem 2-pedicel of mature fruit (April); M. leaf-mature leaf on a spring flush, non-fruiting terminal shoot (September), the standard time for leaf analysis; Y. fruit stem-pedicel of young fruit (September).

[y] Values in a vertical column followed by different letters are significantly different at *P-value* specified by Fisher's Protected LSD Test.

Table 2.
Effect of N vs. NPK fertilizer rate on tissue nutrient concentrations of 'Hass' avocado trees in Santa Barbara, California.

Tissue[z]	N %	P %	K %	S %	B ppm	Ca %	Mg %	Zn ppm	Mn ppm	Fe ppm	Cu ppm
	BMP N July, August, November and April[y]										
Y. inflorescence	3.77 a[x]	0.60 a	2.13	0.35 a	44.25 a	0.55 a	0.33 a	62.75 a	161.13 a	63.00 a	27.69 a
M. fruit stem 1	1.37 b	0.22 b	1.83	0.07 b	18.75 b	0.22 b	0.14 b	7.38 b	20.50 b	51.88 b	2.41 b
P-value	<0.0001	<0.0001	0.2368	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0014	0.0307	<0.0001
M. inflorescence	3.01 a	0.46 a	1.84	0.31 a	43.13 a	0.51 a	0.32 a	43.13 a	140.25 a	105.75 a	19.40 a
M. fruit stem 2	1.60 b	0.28 b	1.87	0.08 b	18.75 b	0.22 b	0.16 b	8.50 b	29.75 b	58.75 b	3.23 b
P-value	<0.0001	<0.0001	0.8978	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	0.0093	<0.0001	<0.0001
M. leaf	1.91 a	0.12 a	0.73	0.31 a	17.38 a	1.38 a	0.71 a	18.13 a	240.25 a	70.50 a	5.70 a
Y. fruit stem	0.59 b	0.08 b	1.04	0.04 b	13.00 a	0.18 b	0.08 b	5.20 b	11.60 b	29.40 b	2.48 b
P-value	<0.0001	<0.0001	0.176	<0.0001	0.0663	<0.0001	<0.0001	0.0012	0.0106	0.0007	<0.0001
	BMP NPK July, August, November and April										
Y. inflorescence	3.65 a	0.58 a	2.16 a	0.34 a	49.38 a	0.56 a	0.29 a	59.25 a	142.88 a	60.25 a	25.46 a
M. fruit stem 1	1.20 b	0.19 b	1.61 b	0.07 b	21.13 b	0.23 b	0.14 b	7.13 b	20.25 b	50.50 b	2.51 b
P-value	<0.0001	<0.0001	0.0305	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0055	0.0257	<0.0001
M. inflorescence	2.87 a	0.45 a	1.95 a	0.30 a	47.13 a	0.48 a	0.28 a	39.63 a	107.00 a	103.38 a	18.14 a
M. fruit stem 2	1.36 b	0.28 b	1.46 b	0.07 b	17.88 b	0.22 b	0.16 b	7.38 b	25.38 b	55.75 b	2.75 b
P-value	<0.0001	0.0017	0.0126	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	0.0075	<0.0001	<0.0001
M. leaf	1.72 a	0.11	0.62 b	0.32 a	16.75	1.42 a	0.71 a	16.25 a	252.00 a	74.50 a	5.16 a
Y. fruit stem	0.57 b	0.10	1.37 a	0.04 b	15.25	0.17 b	0.07 b	6.00 b	7.00 b	23.50 b	2.93 b
P-value	<0.0001	0.6	<0.0001	<0.0001	0.3959	<0.0001	<0.0001	<0.0001	0.0121	<0.0001	0.0057
	0.5x N July + August										
Y. inflorescence	3.74 a	0.60 a	2.20 a	0.36 a	44.00 a	0.53 a	0.32 a	59.50 a	156.00 a	64.38 a	25.96 a
M. fruit stem 1	1.41 b	0.21 b	1.62 b	0.07 b	20.13 b	0.24 b	0.14 b	7.25 b	27.88 b	51.75 b	2.65 b
P-value	<0.0001	<0.0001	0.0041	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0005	0.0088	<0.0001
M. inflorescence	2.87 a	0.45 a	1.91	0.30 a	44.00 a	0.49 a	0.29 a	40.00 a	138.50 a	100.50 a	18.04 a
M. fruit stem 2	1.51 b	0.25 b	1.77	0.08 b	16.38 b	0.24 b	0.15 b	8.13 b	25.00 b	55.25 b	3.26 b
P-value	<0.0001	<0.0001	0.5153	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001
M. leaf	1.85 a	0.11 a	0.67 b	0.29 a	17.00 a	1.38 a	0.74 a	15.88 a	208.75 a	78.50 a	5.58 a
Y. fruit stem	0.60 b	0.08 b	1.20 a	0.04 b	12.88 b	0.16 b	0.08 b	5.00 b	10.00 b	25.38 b	2.29 b
P-value	<0.0001	<0.0001	0.0025	<0.0001	0.0021	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	0.5x NPK July + August										
Y. inflorescence	3.82 a	0.61 a	2.25 a	0.35 a	52.38 a	0.64 a	0.31 a	61.25 a	194.75 a	62.50 a	27.26 a
M. fruit stem 1	1.23 b	0.22 b	1.72 b	0.07 b	23.75 b	0.24 b	0.13 b	7.00 b	25.13 b	47.25 b	2.46 b
P-value	<0.0001	<0.0001	0.0444	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0033	0.0007	<0.0001
M. inflorescence	2.90 a	0.47 a	1.97	0.31 a	44.63 a	0.51 a	0.29 a	41.63 a	126.88 a	104.50 a	19.08 a
M. fruit stem 2	1.55 b	0.30 b	1.74	0.07 b	21.38 b	0.23 b	0.15 b	7.38 b	27.38 b	54.00 b	2.76 b
P-value	<0.0001	0.0039	0.3576	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0008	<0.0001	<0.0001
M. leaf	1.76 a	0.11 a	0.73 b	0.31 a	18.25	1.48 a	0.66 a	16.50 a	187.50 a	73.88 a	5.73 a
Y. fruit stem	0.58 b	0.09 b	1.28 a	0.04 b	14.00	0.18 b	0.07 b	5.25 b	11.50 b	26.75 b	2.38 b
P-value	<0.0001	0.0002	0.0007	<0.0001	0.155	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001

[z] Y. inflorescence-cauliflower stage of inflorescence development (March); M. fruit stem 1-pedicel of mature fruit (March); M. inflorescence-inflorescence at full bloom (April); M. fruit stem 2-pedicel of mature fruit (April); M. leaf-mature leaf on a spring flush, non-fruiting terminal shoot (September), the standard time for leaf analysis; Y. fruit stem-pedicel of young fruit (September).

[y] BMP N (25 lb N/acre in July, Aug., Nov. and Apr.; 100 lb N/acre/yr), BMP NPK (25 lb N, 3.75 lb P, 22.5 lb K in July, Aug., Nov. and Apr.; 100 lb N, 15 lb P, 90 lb K/acre/yr), 0.5x N (25 lb N/acre in July and Aug.; 50 lb N/acre/yr), 0.5x NPK (25 lb N, 3.75 lb P, 22.5 lb K in July and Aug.; 50 lb N, 7.5 lb P, 45 lb K/ acre/yr).

[x] Values in a vertical column followed by different letters are significantly different at P-value specified by Fisher's Protected LSD Test.

Figure 1.
Nutrient concentrations of pedicels of young fruit (Oct., Nov., June, Sept.) and mature fruit (Mar., Apr.) from 'Hass' avocado trees in Santa Barbara, California, receiving soil-applied fertilizer: BMP N (-•-) (25 lb N in July, Aug., Nov. and Apr. /acre/yr); BMP NPK (-○-) (25 lb N, 3.75 lb P, 22.5 lb K in July, Aug., Nov. and Apr./acre/yr); 0.5x N (-▲-) (25 lb N in July and Aug./acre/yr); 0.5x NPK (-△-) (25 lb N, 3.75 lb P, 22.5 lb K in July and Aug./acre/yr).

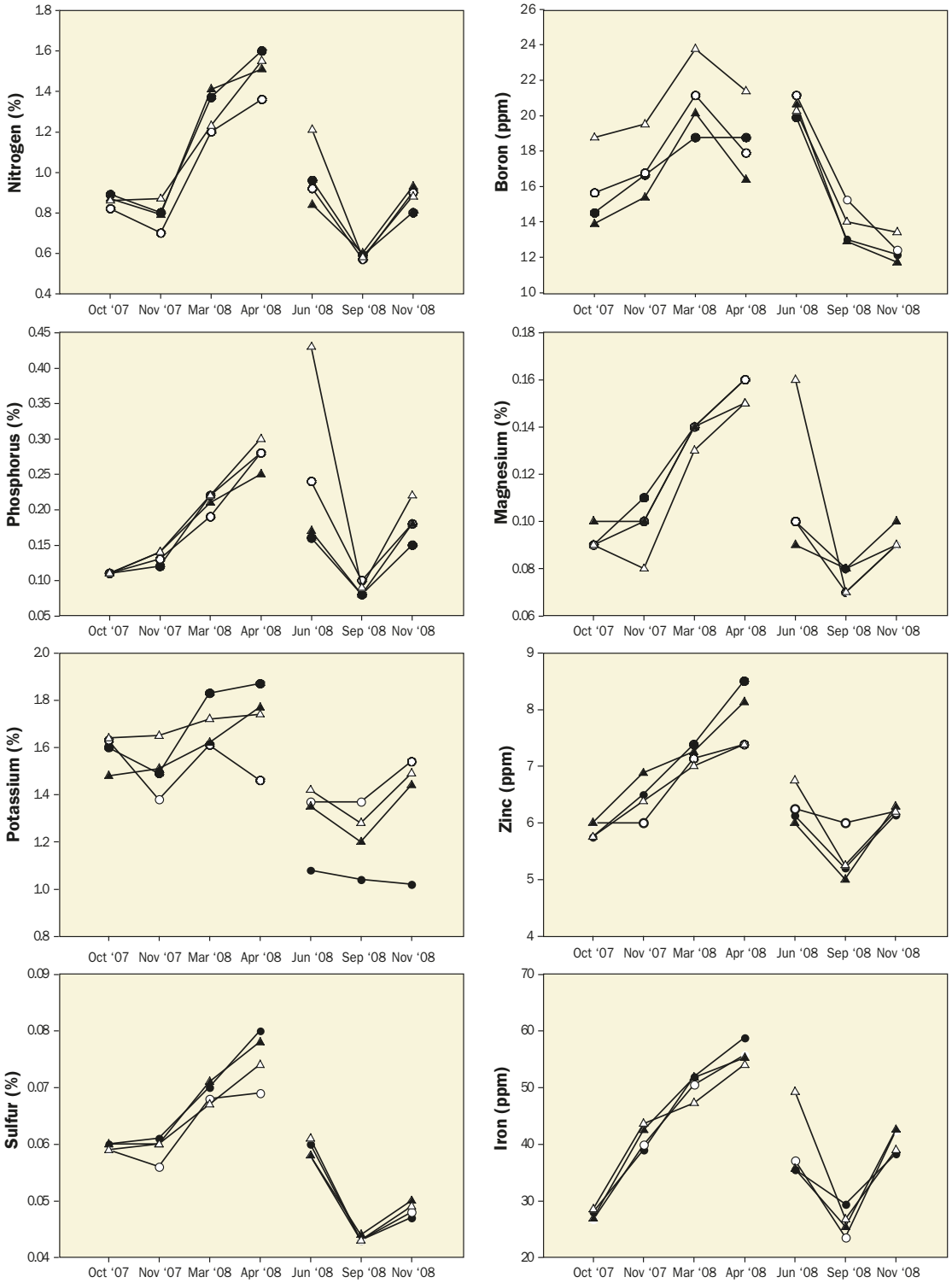
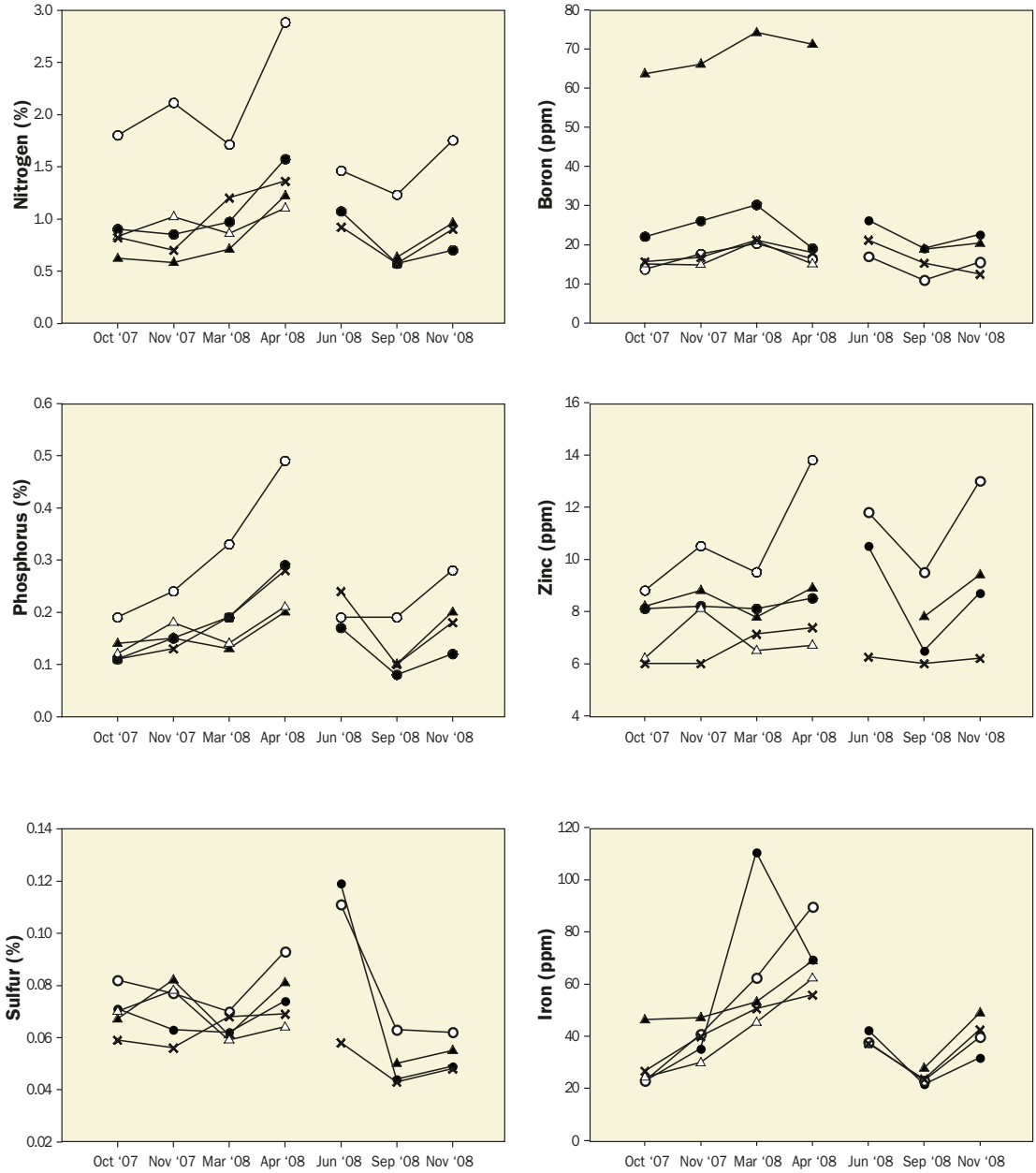


Figure 2.
Nutrient concentrations of pedicels of young fruit (Oct., Nov., June, Sept.) and mature fruit (Mar., Apr.) from 'Hass' avocado trees in Irvine (-•-), Pauma Valley (-○-), Santa Paula (-▲-), San Luis Obispo (-△-), and Santa Barbara (-X-) in the BMP NPK treatment (25 lb N, 3.75 lb P, 22.5 lb K July, Aug., Nov. and Apr./acre/yr).



Summaries of Other Ongoing FREP Research Projects

Citrus Yield and Fruit Size Can Be Sustained for Trees Irrigated with 25% or 50% Less Water by Supplementing Tree Nutrition with Foliar Fertilization – *Comparison of Conventional Irrigation and Partial Root Zone Drying at the Same Reduced Irrigation Rates Supplemented with Equal Foliar Fertilization*

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INTRODUCTION

For California citrus growers, the cost of irrigation water is a major expense. Irrigation water is nearing $200/acre-foot in the San Joaquin Valley. Moreover, the future availability of water necessary for crop production is in question; growers may have to produce their crops with 30% less water. Micro-jet and drip irrigation systems have contributed significantly to increasing water use efficiency and reducing the amount of water used annually in citrus orchards. Regulated deficit irrigation (RDI) and partial root zone drying (PRD) were developed to further improve water use efficiency in perennial fruit tree crops to further reduce water use and expense (Kriedemann and Goodwin 2003). Both methods limit the vigor of vegetative shoot growth in favor of crop development with the goal that neither the current nor return yield is negatively affected. Reduced flushing of vegetative shoots is considered an important factor in controlling Asian Citrus Psyllid populations and the spread of Huanglongbing in citrus. With RDI, water deficit is applied in an orchard in a carefully controlled manner during a specific period in the phenology of the tree. When using RDI, timing is critical. RDI was shown to have limited utility in navel orange production in California (Goldhamer 2003). In contrast, PRD is the practice of alternately wetting and drying the root zone on two sides of the tree. With PRD, timing is flexible and PRD

is employed year-round. PRD is being used over RDI in commercial sweet orange production in Australia. In a 4-year field study, 40% less water was applied by PRD than the fully irrigated control. Reduced water application resulted in significant savings in water use (32%-43% less than the district average for citrus orchards) with no significant effect on fruit number, size or quality, with the exception that the ratio of solids to acid in the juice was lower than that of the control in the first year of the experiment (Loveys et al. 1999).

Our research goal is to meet the challenge of California's water shortage crisis by demonstrating that yield of commercially valuable large-size navel orange fruit can be sustained despite irrigating citrus trees with 25% or 50% less water. The proposed research will test the feasibility of using partial root zone drying (PRD) to reduce the amount of water and soil (irrigation-applied) fertilizer used in citrus production combined with foliar fertilization to sustain the yield of commercially valuable large fruit (Boman 2002, Lovatt 1999). An increase in grower net profit should be expected, given reduced water costs and fertilizer application. Our approach increases water and nutrient use efficiency (WUE and NUE). Our research goal of testing PRD to reduce water use in citrus production and to increase grower net income is not only timely, it might be critical to the sustainability of California's citrus industry.

OBJECTIVES

1. To reduce annual water use in a commercial navel orange orchard, by alternately wetting and drying the root zone on two sides of the tree, using irrigation rates that are 25% and 50% less than the well-watered control under conventional irrigation (CI).
2. To compare the PRD treatments with CI at the reduced rates (CI-RR) of 25% and 50% less than the well-watered control.
3. To determine the effect of supplementing PRD and CI-RR treatments with foliar fertilization (especially N and K to ensure adequate nutrition to sustain yields of large-size fruit) on yield, fruit size and quality and on return bloom for two crop-years compared to the well-watered control receiving soil fertilization.
4. To provide a cost:benefit analysis of the results to the growers.

DESCRIPTION

1. To reduce annual water use in a commercial navel orange orchard by alternately wetting and drying the root zone on two sides of the tree using irrigation rates that is 25% and 50% less than the well-watered control under conventional irrigation (CI).
2. To compare the PRD treatments with CI at the reduced rates (CI-RR) of 25% and 50% less than the well-watered control.
   (1) well-watered control (based on evaporative demand) – trees have an emitter on each side of the five trees within the row so that both sides of the tree are wet. Evaporative demand based on the California Irrigation Management Information System (CIMIS) is used to set the amount of water to be applied to the well-watered control. We are using historical and real time weather data CIMIS to predict the amount of water the trees will need in the up-coming 4-day period. Treated trees receive 25% or 50% less than this amount. All treatments are irrigated when soil moisture content is 30 cb at a depth of 30 cm, which may occur before the end of 4 days.

(2) 25% PRD – 25% less water than well-watered control – trees have an emitter on each side of the five trees within the row, which alternate in delivery of the tree and then the other.

(3) 50% PRD – 50% less water than well-watered control – trees have an emitter on each side of the five trees within the row that alternate in delivery to one side of the tree and then the other.

(4) 25% CI-RR – 25% less water than well-watered control – trees have an emitter on each side of the fives trees within the row so that both sides of the tree are wet.

(5) 50% CI-RR – 50% less water than well-watered control – trees have an emitter on each side of the five trees within the row so that both sides of the tree are wet.

3 To determine the effect of supplementing PRD and CI-RR treatments with foliar fertilization (especially N and K to ensure adequate nutrition to sustain yields of large-size fruit) on yield, fruit size and quality and on return bloom for two crop years compared to the well-watered control receiving soil fertilization.

(1) a winter pre bloom foliar application of low biuret urea (46% N, 0.25% biuret, 23 lbs N/acre) in mid January to increase floral intensity to sustain yield (Albrigo 1999, Ali and Lovatt 1992, 1994, Lovatt et al. 1988);

(2) foliar applied potassium nitrate (25 lbs KNO3/acre) applied at dormancy (February) and post bloom (approximately April) to increase the yield of commercially valuable large size fruit (Boman 2002); the second potassium nitrate application post-bloom (approximately April) will target 75% petal fall in the northeast quadrant of the tree, which typically occurs at the end of April or beginning of May

(3) application of low biuret urea (46% N, 0.25% biuret, 23 lbs N/acre) at maximum peel thickness (early to mid-July) to increase yield of commercially valuable large size fruit (transverse diameters of 6.9-8.8 cm, respectively) (Lovatt 1999).

RESULTS AND DISCUSSION

Due to a problem we encountered during April to June, trees in all reduced irrigation treatments received an over application of irrigation. Trees in the 75% PRD and 75% CI-RR treatments received only 15% less water than well-watered control trees and those in the 50% PRD and 50% CI-RR treatments received 30% and 36% less water than well watered control trees, respectively. By the end of August, average fruit diameter (measured on tree) was significantly reduced for trees in all reduced irrigation treatments compared to the well-watered control (Table 1). Average fruit size was significantly smaller for trees in the 50% CI-RR treatment, which received 6% less water than trees in the 50% PRD treatment. Thus, it is of interest that there was no significant difference in fruit size for trees in the 75% PRD treatment compared to the 50% PRD treatment, despite the fact that the trees in the 50% PRD treatment received 16% less water. It is noteworthy that the smallest fruit (50% CI-RR) were only 10 mm (0.4 inches) smaller than fruit of well-watered control trees, despite receiving 36% less water.

CONCLUSIONS

The harvest for the first year of this project will occur in January 2011. Thus, no conclusions can be drawn at this time.

ACCOMPLISHMENTS

The primary investigator made presentations related to this project to educate growers, allied industry partners and other researchers regarding the need to reduce soil applied fertilizers and the benefits that can be attained using properly timed foliar fertilization at the following venues:

1. "Phenology and Physiology of Citrus Productivity" at the Tulare County Citrus Growers Meeting, October 7, 2009;
2. "Phenology and Physiology of Citrus Productivity - *The basis for developing and using plant growth regulators and foliar fertilizers in commercial citrus production*" at the Friends of Citrus meeting, February 17, 2010;
3. "Effect of Climate Change on Citrus and Avocado Flowering and Productivity," to researchers at INIFAP, Tepic, Nayarit, Mexico, March 12, 2010; and
4. "Phenology and Physiology of Citrus and Avocado Productivity", University of Arizona, April 28, 2010.
5. "Phenology and Physiology of Citrus Productvity – *The basis for developing and using PGRs and foliar fertilizers in commercial citrus production*" to Australian visitors in citrus research and production at UCR, August 26, 2010.

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Table 1.
Effect of a reduction in irrigation rate[z] by partial root zone drying (75% PRD and 50% PRD, respectively) or conventional irrigation (75% CI-RR and 50% CI-RR, respectively) on average fruit size compared to well-watered control trees as of August 2010.

Treatment	Whole tree	Tree quadrant			
		North	East	South	West
	fruit diameter (mm) [y]				
Control	49.97 a [x]	50.76 a	51.29 a	49.15 a	48.69 a
75% CI-RR	46.47 b	46.41 b	45.94 b	47.40 ab	46.14 ab
50% CI-RR	39.96 c	40.90 c	40.05 c	40.16 d	38.71 c
75% PRD	45.34 b	45.54 b	46.28 b	45.65 bc	43.98 b
50% PRD	43.81 b	43.58 bc	44.22 bc	42.83 cd	44.62 b
P-value	<0.0001	<0.0001	0.0002	<0.0001	<0.0001

[z] Trees in the 75% PRD and 75% CI-RR treatments received 15% less water than well-watered control trees; trees in the 50% PRD and 50% CI-RR treatments received 30% and 36% less water than well watered control trees, respectively.

[y] 25.4 mm = 1 inch.

[x] Values in a vertical column followed by different letters are significantly different at specified P-value by Fisher's Protected LSD Test.

Development of Leaf Sampling and Interpretation Methods for Almond and Pistachio

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INTRODUCTION

Results of a survey of almond growers, pistachio growers, and consultants in California, suggested that the existing leaf sampling protocol and comparison of the tissue results with the established standards does not provide sufficient guidance for nutrient management. Two explanations for this observation are possible:

1. The current critical values (CVs) are incorrect or not useful for the decision-making process due to lack of sensitivity or inappropriate timing.
2. There are systematic errors in the manner in which critical values are used.

While it is not known if UC CV's are incorrect (this will be verified), it is known that they have not been validated for early season use and it is clear that there has been a systematic error in the way leaf sampling and CV's have been used. We conclude that the 'problem' with current CV's is not that they are necessarily wrong, but that they do not account for within field, within canopy, between season or within season variability. A vast majority of growers have also noted that the credibility of the current CV's have not been validated for early season fertilizer adjustments and many noted that even if a sound leaf sample is taken that the analysis cannot be used to determine a specific fertilization response. Additionally, another constraint with current leaf sampling is that leaves are not collected until late July and frequently are not analyzed prior to fall. This late sampling provides the grower with no ability to make in-season fertilizer adjustments.

SPECIFIC OBJECTIVES

Therefore, the aim of almond and pistachio projects is to correct this situation by developing new approaches and interpretation tools that better quantify field and temporal variability, which are sensitive to yield and provide for in season monitoring and fertilizer optimization in almond and pistachio across different locations. These projects also offer the unique opportunity to verify the current CV's and determine the utility of nutrient ratios as a diagnostic tool. Therefore, the integrated objectives of these research projects are to:

1. Determine the degree to which leaf nutrient status varies across a range of representative orchards and environments.
2. Determine the degree to which nutrient status varies within the canopy and within the year.
3. Validate current CV's and determine if nutrient ratio analysis provides useful information to optimize fertility management.
4. Develop and extend an integrated nutrient best management practice (BMP) for almond and pistachio.

PROJECT DESCRIPTION

A large scale and long-term survey of within field, between field, within tree and between organ nutrient concentration and variance is conducted in mature almond and pistachio orchards. The interaction between yield and nutrient status will be determined at four almond orchards (on >600 individual trees), and at four pistachio orchards (on >400 individual trees). All almond and pistachio trials have been initiated in eight or nine year old almond orchards and 10 to 15 year old pistachio orchards of good to excellent productivity planted to non pareil (50%) and Kerman (97%) respectively. Both, almond and pistachio orchards are in soils representative of the major production regions.

The four experimental sites for almond project are located in Arbuckle, Modesto and Madera (2) and four pistachio sites are located at Fresno County, Madera County, Kern County and Kings County. At 54 grid points uniformly distributed across a 10 acre block of trees, leaf nutrient status throughout the year (May through August) (N, P, K, S, Ca, Mg, B, Zn, Fe, Mn, Cu), light interception, trunk diameter and tree yield are being determined in each tree. Further, in almond trees, three different kinds of leaves and nut samples are being collected at five times during the growing season to explore different sampling methods. Similarly, in pistachio trees, leaf and nut samples are being collected at various times throughout the season to determine the degree of variability in tissue nutrient concentrations over time, space and within tree canopies to validate the established standards and develop nutrient budget models for important major nutrients. Samples will be collected from 54 trees in each site for a period of 3 to 5 years. Sample collection is spaced evenly over time from full leaf expansion to one month post harvest. As a phenological marker, days past full bloom and stage of nut development are monitored.

All tissues that are collected are being dried, weighed, ground to pass a 30 mesh screen and analyzed for nutrient concentration of N, P, K, Ca, S, Mg, B, Zn, Cu, Mn and Fe by standard methods at the Agriculture and Natural Resources (ANR) Laboratory at the University of California Davis.

RESULTS AND DISCUSSION

Almond

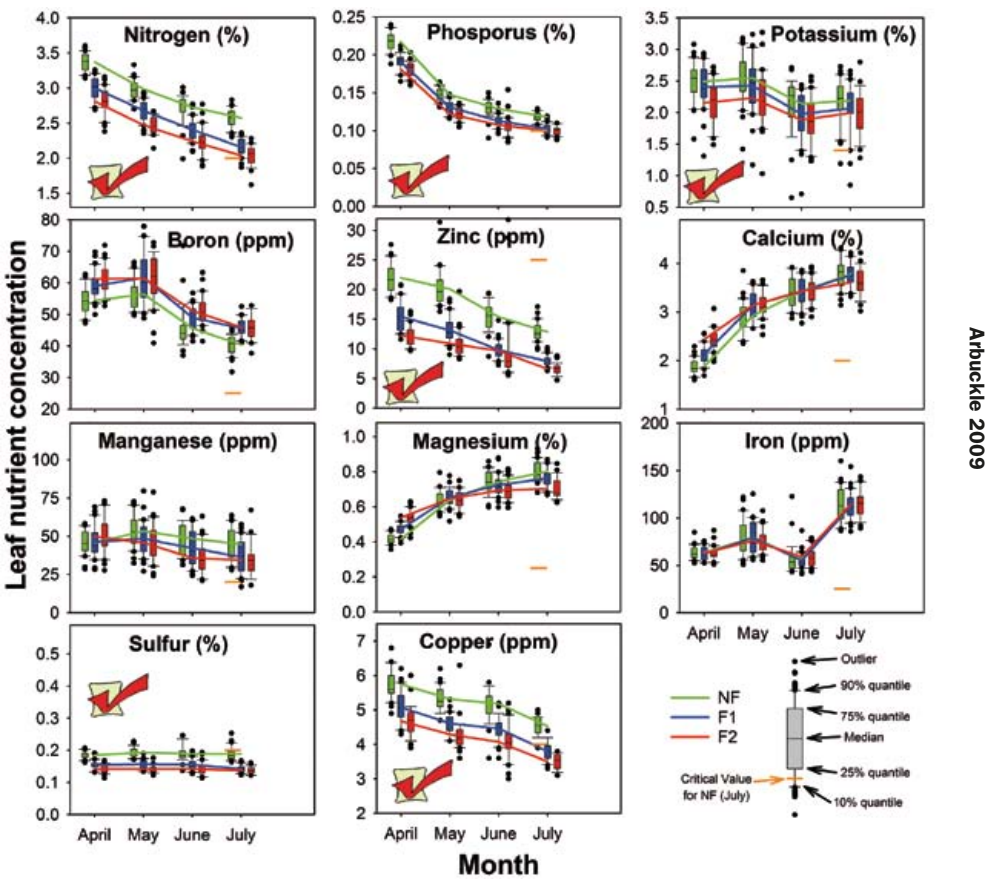
By the end of July 2010, all 2008 and 2009 data was received from the lab. Statistical analyses on these dataset are currently being run and some preliminary results are described below.

Almond Kriging interpolation analysis in 2008 and 2009 data shows that the majority of nutrients are not spatially auto correlated (Figure 2A). Therefore, almond trees that are close to each other are not codependent with regard to their nutrient status. On the other hand, yield of almond trees seems to be spatially autocorrelated (Figure 2B). There are several different reasons which could explain why yield is spatially correlated and why nutrients are generally not; this will be resolved with the subsequent year's data. These factors are currently being assessed through light interception analysis and soil nutrient movement analysis among other techniques. The discovery of spatial independence or dependence from one tree to another is valuable information in correctly estimating sample size and then obtaining a reliable sampling protocol for almond trees.

Robust data collected over the preceding two years suggests that leaves with local fruit (leaves on fruiting spurs) show a relative deficit of N, P, K, Zn, S, and Cu in comparison with non fruiting spur leaves. This phenomenon has been observed during the season, between seasons and between all the locations under study. Thus, a local deficit of these six elements may be a key factor determining spur longevity and consequently alternate bearing (Figure 1).

Figure 1 shows nutrient behavior throughout 2009 season in leaves from non fruiting spurs (NF), spurs with one fruit (F1), and spurs with two fruits (F2). The graphs show data collected from the Arbuckle orchard and the check marks symbolize nutrients that are relatively deficient.

Figure 1
Nutrient behavior throughout 2009 season in Arbuckle site.



GEOSTATISTICAL ANALYSIS

Two years of consistent results (2008-2009) in almond have determined that the planed statistic design (cluster grid) was not substantially better than the simple grid design. Therefore, cluster trees were eliminated from both projects and the amount of trees under study was reduced to the half in the present season. The power of the experiment as well the interpolation/extrapolation ability is statistically unaffected.

Figure 2 (A) and (B) show spatial correlation of nitrogen and yield in Arbuckle and Belridge site respectively in July 2009. Variogram of N shows pure nugget (no correlation is observed in the data). Figure 2 (B) shows yield variogram of spatial correlation of 2009 in Belridge site. Spatial correlation for yield is appreciated until 40 meters away. Distance is scaled in meters in both variograms and the variogram was estimated using ordinary Kriging, spherical model.

Pistachio

Like almond, the overall goal of the pistachio project is to develop the best integrated nutrient management practices for pistachio across different ranges of environments. The study involved gathering nutrient and nut yield information from pistachio trees. By the end of July 2010, all 2009 data was received from the lab. Data from all leaf samples, across site and time, are currently being analyzed to validate and optimize current critical values and management strategies. Although, complete assessment of the data requires data collection over several years; some preliminary results are presented in this report. Detailed analysis of the data for the year 2009 is currently being underway.

RESULTS AND DISCUSSION

Figure 3 shows changes in N, P and K and other nutrient concentrations in leaf in pistachio trees during different biological phases and across different locations. The pattern of nutrient change over time varies from nutrient to nutrient. For example, N and P concentrations consistently decreased with time. On the other hand, B, Fe and K accumulated as the season progressed. A precise understanding of these changes is essential for interpretation of leaf and nutrient analysis.

In general, we report an average leaf N concentration of (2.44%, 2.31%, 2.64% and 2.56%) for the month of August in Paramount, Madera, KammAvenue and Buttonwillow respectively. On the other hand, the University of California, recommended value for N is 1.8% which is lower than the current values for N in all sites.

Figure 2
Figure 2 (A) and (B) shows spatial correlation of nitrogen and yield in Arbuckle and Belridge site respectively in July, 2009.

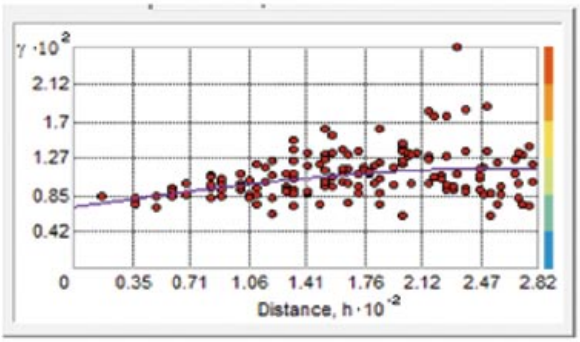


Figure 2 (A)

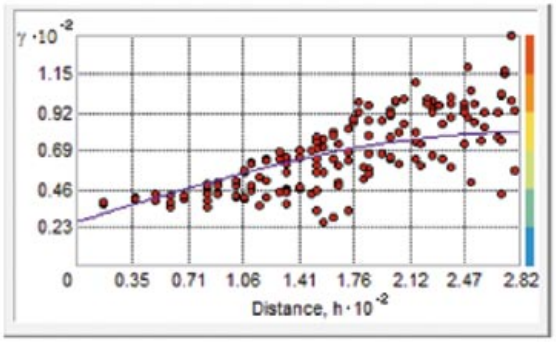


Figure 2 (B)

GEOSTATISTICAL ANALYSIS

In pistachio the geostatistical analysis of the data suggests that a regular grid sampling is generally better than cluster based sampling. For this reason, the sampling strategy was adjusted and the neighboring trees were eliminated from sample collection which reduced the sampling trees to half for the current season (2010).

Figures 4 (A) and (B) show the variograms of spatial correlation of leaf N in Kamm Avenue (Fresno County) and Kettleman City (Kings County) sites respectively. Distance is scaled in meters and variograms were estimated using ordinary Kriging, exponential and J-Bessel model respectively. Variograms of (N) show pure nugget (no correlation is observed in the data).

Results from 2009 demonstrate a great deal of variability across the orchard. This large variation (in these orchards which were thought to be relatively uniform), indicates how greatly tree variability has been underestimated. It also suggests that management practices should not be applied uniformly across large areas of orchards as they are now, but rather must be optimized at a far more local scale.

Figure 3
Leaf nutrient dynamic over the growing season (2009). Data represents four research sites. Values represent means ± SD of 114 replicates.

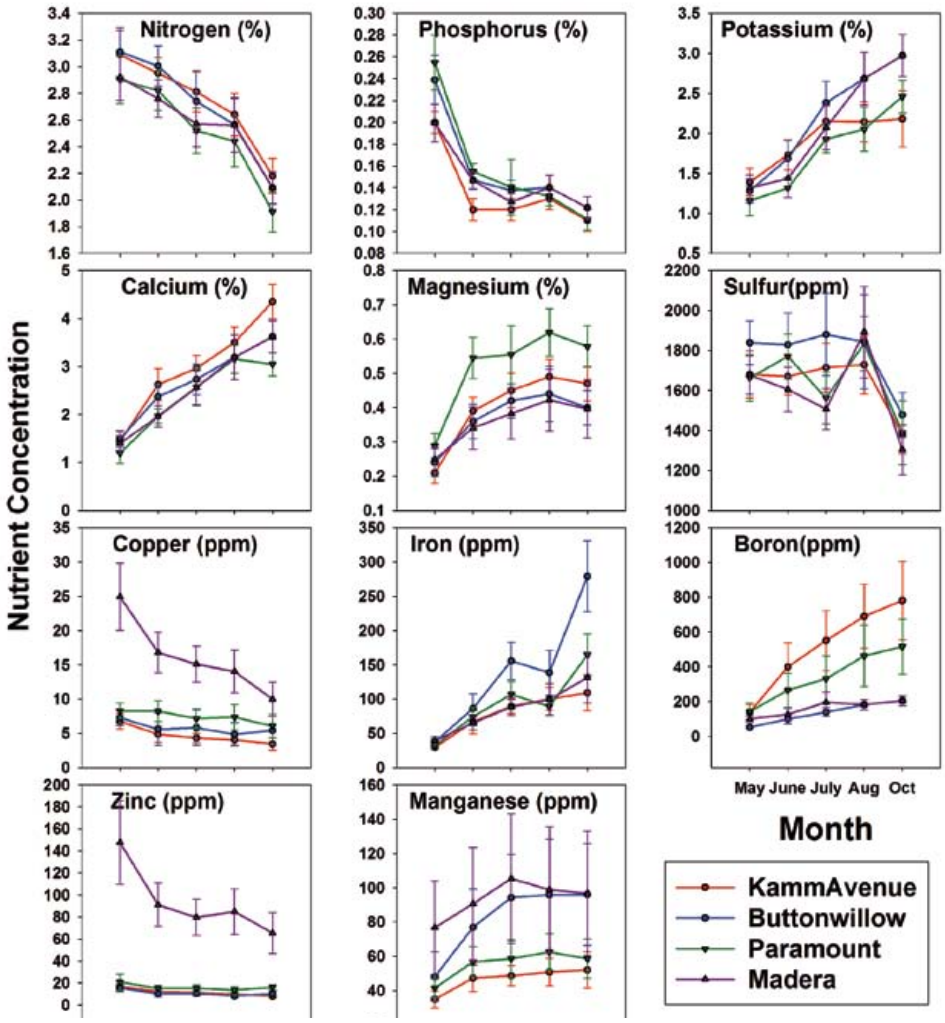


Figure 4
Figures 4 (A) and (B) show variograms for July leaf (N) for KammAvenue and Paramount (Kettleman City) sites respectively for the year 2009.

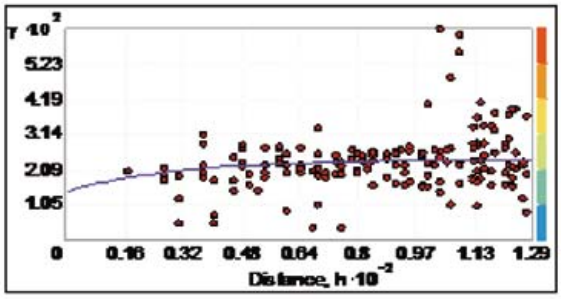


Figure 4 (A)

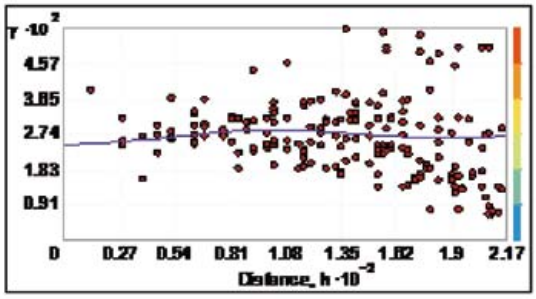
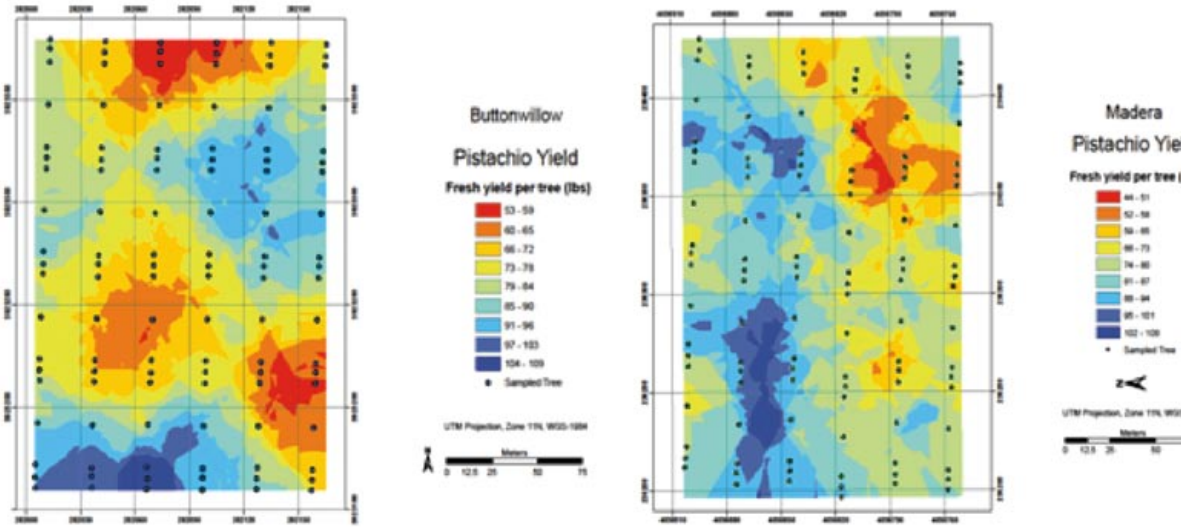


Figure 4 (B)

Figure 5
Tree yield variability at Buttonwillow and Madera research sites. Data represents 114 individual trees at each site. Using Arc GIS version 9.3, these maps were generated to observe how yield is variable across the field in a single year.



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The primary investor greatly appreciates the help and financial support from CDFA that enabled us to establish these nutrient optimization projects to develop the best management practices for almond and pistachio growers. Furthermore, we appreciate Paramount and Agri-World for their great support.

Measuring and Modeling Nitrous Oxide Emissions from California Cotton, Corn, and Vegetable Cropping Systems

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INTRODUCTION

The effects of the anthropogenic increase in atmospheric greenhouse gas (GHG) concentrations on climate change are beyond dispute (IPCC, 2007), and agriculture does play a key role in this issue, both as a source and a potential sink for GHG (California Energy Commission, CEC, 2005). Of the three biogenic GHGs (CO_2, CH_4, and N_2O) contributing to radiative forcing in agriculture, N_2O is the most important GHG to be considered, researched, and eventually controlled within intensive and alternative cropping systems. It is estimated that in California, agricultural soils account for 64% of the total N_2O emissions, and N_2O may contribute as much as 50% to the total net agricultural greenhouse gas emissions (CEC, 2005). However, the reliability of these estimates is highly uncertain, which stems, in part, from a lack field measurements in California (CEC, 2005; EPA 2004), and in part, from the inherently high temporal variability of N_2O flux from soils. In a statistical analysis of 1,125 N_2O studies from all over the world, the average 95% confidence interval was -51% to +107% (Stehfest and Bouwman, 2006). Among California's statewide greenhouse gas emissions, the magnitude of N_2O emissions is the most uncertain (CEC 2005).

Episodes of high N_2O fluxes are often related to soil management events like N fertilization, irrigation, or incorporation of crop residue, but the magnitude of the responses to such field operations also depends on soil physical and chemical factors, climate and crop system. Meta-analyses based on over 1,000 studies found that fertilizer N application rates have significant effects on N_2O emissions, in addition to other factors like fertilizer type, crop type, or soil texture (Bouwman et al., 2002 a and b; Stehfest

and Bouwman, 2006). Many of California's high-value crops are intensively managed in terms of N fertilizer use and irrigation, which are factors that have the potential to contribute to substantial N_2O emissions. Furthermore, California's mild winter temperatures and erratic rainfall patterns may be conducive to sporadic high N_2O emissions in the winter. The intensive management of cropland and the dependence on irrigation might also present opportunities to optimize management practices in order to mitigate N_2O emissions. However, the establishment of an improved estimate of N_2O emissions based on field measurements that capture both the temporal variability of N_2O emissions and a range of environmental conditions representative for California's main crop systems must precede any mitigation strategies.

OBJECTIVES

The overall goals of this project are to:

1. Determine detailed time series of nitrous oxide (N_2O) fluxes and underlying factors at crucial management events (irrigation, fertilization, etc.) in representative agro ecosystems in Central Valley of California; and,
2. Utilize the intensive data on N_2O fluxes to calibrate and validate processed based biogeochemical De-Nitrification - De Composition model (DNDC).

Specific objective of this phase of the project is to:

1. Determine N_2O flux measurements for cotton and silage corn systems grown in the central San Joaquin Valley (SJV).

DESCRIPTION

Given the interest in the suitability of current emission factors for estimating N_2O emission, the percentage of N lost to the atmosphere as N_2O from added N fertilizer will be determined for corn and cotton cropping systems. A system's approach that considers N fertilization, crop N use, N loss as N_2O, and the soil physical and chemical environment will be employed. Through intensive measurements of N_2O flux in the field for two consecutive years during periods with high N_2O emission potential, and less frequent, but regular monitoring of N_2O emissions when fluxes are low, baseline and event related N2O emission will be calculated for each N addition treatment and crop system. Yield data will also be assessed to test the hypothesis that N_2O emissions increase mainly in response to N additions exceeding crop needs. Data of ancillary variables, such as soil moisture, temperature, and soil chemical parameters that are known to affect N_2O emissions will be collected to characterize patterns of N_2O emissions and for model validation.

The project's success depends on the robustness of the N_2O emission data that will be collected and the success of the model calibration and validation. The success of the model calibration and validation will be evaluated in comparison with numerous other studies from all over world. This research will benefit state agencies (CDFA, ARB and CEC) and the Fertilizer Research Education Program (FREP) by providing (a) California specific data for establishing baseline and event related N_2O estimates in response to N fertilization and irrigation in the Central Valley and (b) validated modeling tools to estimate nitrous oxide budgets of current and future conventional and alternative cropping systems in California

RESULTS AND DISCUSSION

Significant Progress Against Objectives:

1. Corn and cotton experimental sites have now been identified in Hanford. The cooperators have agreed to let us collect data during any rotation over next 2 years.

2 Relatively smaller research plots on the Fresno State campus farm have also been identified. These will be used primarily of methodology and protocol development, and sampling under more controlled conditions than what may be possible out on the farmer's fields.

3 We have completed the construction of 16 of the sampling chambers, and will be installing these at the Hanford sites in early October 2010.

4 At the Fresno State sites, we have conducted measurements with the 2nd sampling device, the INNOVA. This has allowed us to improve our expertise with the calibration and field operation of the INNOVA auto sampling device. Data obtained with this device will be compared with the data from the flux chambers.

5 We have identified the following parameters should be measured in order to have sufficient data for the calibration and application of the DNDC model:

-Soil: Moisture profile, Bulk density, Texture, pH, EC (ds/m) and Organic matter;

-Plant: Biomass (destructive biomass), N tissue analysis for root, stalk, leaves, and after harvest, determine the C:N ratio of root and leaves;

-Agronomic Practices: Tillage operations (date and frequency); Fertilizer application rates and frequency; harvest data

Future Work Plan

1 We will continue to coordinate with the UC Davis collaborating scientists to guarantee that similar methodologies and monitoring equipments are used for collecting the N_2O data. This will ensure that any data collected by the both research groups are interchangeable and can be used for comparison and computer modeling purposes.

2 Nitrous oxide measurements and related soil and climatic data will be conducted at sites located on the Fresno State campus and at the farmer's fields starting in the first week of October 2010 (Table 1).

3 Preliminary calibration of the DNDC model for determination of N_2O emissions from corn and cotton subjected irrigation and fertilizer practices typical of those being used by the collaborating growers. Soil, fertilizer, climatic and irrigation data collected will used as input parameters for the various algorithms inherent in the DNDC model.

Table 1
Proposed tasks and timeline for October 2010 to July 3013

		2011				2012				2013	
	Oct to Dec 2010	Jan to Mar	Apr to Jul	Aug to Oct	Nov& Dec	Jan to Mar	Apr to Jul	Aug to Oct	Nov& Dec	Jan to Mar	Apr to Jul
Task 1: N2O Measurements											
Task 2: Model Validation											
Task 3: Regional Modeling											
Task 5: Reporting and Dissemination											

CONCLUSIONS

Since no actual field measurement have been conducted to date, no scientific conclusions are possible at this time. Based on extensive discussions and re evaluation of the potential costs associated with conducting sufficient measurements at the research sites, it was concluded that for the off campus measurements, we will limit our experiments to two cotton site and one corn site. Additional sites and crops will be determined as more matching funds become available from sources such as the California State University Agricultural Research Initiative (CSU ARI) and other sources.

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In addition to FREP, matching funds for this research are provided California State University Agricultural Research Initiative (CSU ARI) program.

Comparing the Efficiency of Different Foliarly-Applied Zinc Formulations on Peach and Pistachio Trees by Using ^{68}Zn Isotope

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INTRODUCTION

This is the final year of a three year project funded by FREP. Therefore, this report will summarize results from all three years and thus some points from previous reports will be repeated. Since Zn deficiency is common in California fruit and nut orchards, many different approaches and materials have been tried by growers. Our first FREP project (see 2005 to 2007 reports) took a broad look at various approaches and we concluded that foliar applications are the most cost effective method of supplying Zn to trees. Therefore, this second FREP project has focused on evaluating the effectiveness of different foliar applied materials, additives and timings. There are literally hundreds of zinc formulations that vary greatly in cost, solubility, chemistry and phytotoxicity. Since we have not been able to test all materials, our emphasis has been on cost effectiveness. Thus our research has focused first on the less expensive formulations, but has expanded from there to include many of the other commonly used materials. Even though we determine biological effectiveness of each treatment, our eventual selection criteria has depended much more on cost effectiveness. The project has relied heavily on using labeled 68Zn, an expensive approach, but very precise at measuring uptake efficiency.

OBJECTIVES

1. Incorporate the ^{68}Zn isotope into some commonly used zinc formulations such as sulfate, Ethylenediaminetetraacetic acid (EDTA) chelate, oxide, amino acid or poly amine complex, citrate, lignosulfonate, fulvic acid, neutral-52%, nitrate etc.
2. Test the foliar uptake efficiency of these formulations on peach and pistachio seedlings with and without different types of surfactants.

3 Using the best treatments from objective 2, treat young peach and pistachio trees with ^{68}Zn in the field.

4 Test the most efficient Zn treatments in commercial peach and pistachio orchards.

DESCRIPTION

Before incorporating the ^{68}Zn label into different formulations, we developed a greenhouse procedure for evaluating the effectiveness of zinc formulations (without the 68Zn label) using peach and pistachio seedlings. Briefly, the procedure involves Nemaguard peach seedlings and Kerman pistachio seedlings grown under conditions that induce noticeable zinc deficiency. Foliar sprays of zinc formulations then overcome these symptoms within 20 to 30 days. The degree of recovery demonstrates the relative effectiveness of the material (for details of this procedure, see the 2008 and 2009 FREP reports).

The ^{68}Zn label has now been incorporated into five different zinc formulations. At the beginning of the project, we already had ^{68}Zn oxide and ^{68}Zn sulfate. Once we started getting results with the greenhouse seedling experiments, the chemist at Monterey AgResources produced ^{68}Zn EDTA in June 2008 and ^{68}Zn nitrate and ^{68}Zn chloride in July 2009. These different formulations have now been used to confirm results from the seedling experiments. In 2009 these formulations were also used to compare zinc uptake from ^{68}Zn sulfate and ^{68}Zn nitrate sprays applied to nectarine trees in the fall. The procedure involved spraying 100 ml of solution to a section of leaves on full sized trees in an orchard. The next spring, flowers and new leaves were collected from the same section of the trees and analyzed for 68Zn.

Table 1
Ranking of effectiveness of zinc formulations based on peach seedling experiments. Phytotoxicity was evaluated on both peach seedlings and in stone fruit orchards sprayed with solutions containing 500 to 1,000 ppm zinc.

Ranking	Formulation	Anion Size (mol wgt)	Solubility (g/100 H_2O)	Phytotoxicity
Most Effective	Zinc Chloride	35	432	High (58*)
Almost As Good	Zinc Nitrate	62	324	High (54)
	Zinc Nitrate Mix	62 & 96	324	High (59)
Next Best	Zinc Sulfate	96	50	Moderate (12)
	Zinc Carbohydrate	96 & ?	High	Moderate
	Zinc Polyamine	96 & 75-204	High	Moderate
	Zinc Glycine	96 & 75		Moderate (15)
Less Effective	Zinc EDTA	292	High	Low
	Zinc Leonardite	1000+	High	Low
	Zinc Oxysulfate	16 & 96	1.3	None
Least Effective	Zinc Phosphite	79	?	Low (17)
	Zinc Oxide Suspension	16	Insoluble	None

* Percent of leaves showing obvious phytotoxicity in a controlled experiment on Summer Fire nectarine.

RESULTS AND DISCUSSION

Over the three years of this project we have conducted numerous experiments comparing different zinc formulations on both peach and pistachio seedlings. Details of these experiments were reported in previous FREP proceedings. The summary ranking of the formulations is shown in Table 1. These are based on the original peach seedling experiments with non-labeled formulations as well as follow-up experiments with ^{68}Zn. The experiments with pistachio were not as extensive, but the same general ranking was been obtained.

We conclude that soluble formulations are considerably more effective than insoluble materials. Experiments with labeled 68Zn showed three to ten times more uptake of Zn with Zn sulfate compared to Zn oxide. Therefore, even though Zn oxide can be somewhat less expensive than sulfate, the Zn sulfate formulation is still much more cost effective. Among the soluble formulations, we conclude that the greater the solubility and the smaller the anion size (molecular weight), the greater the uptake of Zn (Table 1). Thus, the ranking of the best formulations goes in the order of chloride, nitrate, sulfate and EDTA. Experiments with 68Zn showed sulfate to be much more effective than EDTA and it is also less expensive per unit of Zn. The same argument can be made for all the other formulations below Zn sulfate in the table. For the most effective formulations in the table (chloride, nitrate and sulfate), separation among them was not always clear. In some of the ^{68}Zn experiments there were no statistical differences among the three. In the field experiment comparing ^{68}Zn sulfate to ^{68}Zn nitrate, there was no difference between these two formulations (Table 2). Therefore, as we take these results to the field, our conclusion is that Zn sulfate is the most cost effective material to use. Both Zn nitrate and Zn chloride may be slightly better under some conditions, but are generally much more expensive than Zn sulfate and thus less cost effective.

Table 2
Recovery of 68Zn applied to Summer Fire nectarine trees in early October, 2009. Labeled 68Zn applied as either sulfate or nitrate in a 864 ppm Zn solution at 100 ml/tree. Recovery measured in flowers and new growth collected in March, 2010.

Parameter	Treatments			Significance
	Untreated Control	^{68}Zn Sulfate	^{68}Zn Nitrate	
^{68}Zn in Flowers (µg)	0 b*	18.0 a	17.8 a	.001
^{68}Zn in Young Leaves (µg)	0 b	7.3 a	5.5 a	.0001
Total ^{68}Zn Recovered (µg)	0 b	25.2 a	23.3 a	.0004
Percent of Applied (%)	0 b	0.03 a	0.03 a	.0004

*Different letters in a row indicate significantly different values at the significance level indicated.

The final step of this project will be foliar applications of ^{68}Zn sulfate to mature trees in the field. Experiments with young potted peach trees growing in a lath house indicated that early fall was more effective than the currently accepted practice of late fall. In 2010 this experiment will be repeated on mature trees in the field since leaf characteristics could be different from the potted trees. We will also attempt to evaluate the addition of a surfactant that showed slight improvements in Zn uptake on greenhouse seedlings.

The emphasis of this project has been on peach but similar experiments were conducted on pistachio along the way. The biggest difference between the two was that Zn was much more difficult to get into a pistachio plant. Often two to three times more Zn was taken up by peach compared to similar experiments on pistachio. Also, Zn seems to be less mobile in a pistachio plant. However, other aspects of the research such as response to formulations, timing and surfactants, were comparable between the two. Therefore, the final experiments on pistachio will be similar to those planned for peach.

CONCLUSIONS

Research during the three years of this project has shown that Zn sulfate is the most cost effective material to use for foliar applications that supply Zn to peach and pistachio trees. Most other formulations tested were both less effective and more expensive. Zn oxide is less expensive but much less effective than Zn sulfate. Zn chloride and Zn nitrate were more effective in some tests but not enough to justify the increased cost. The final step that will be conducted in the fall of 2010 will be an evaluation of the optimum timing for a Zn sulfate spray and whether the addition of a surfactant might improve uptake efficiency.

ACKNOWLEDGEMENTS

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New Standard for the Effectiveness of Foliar Fertilizers

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INTRODUCTION

Foliar fertilization can meet a plant's demand for a nutrient at times when soil conditions (i.e. low temperature, low moisture, pH, salinity) render soil-applied fertilizers ineffective. Thus, foliar fertilization is an effective method for correcting soil deficiencies and overcoming the soil's inability to transfer nutrients to the plant. Nutrients, especially phosphate, potassium and trace elements can become fixed in the soil and unavailable to plants. Applying nutrients directly to leaves, the major organ for photosynthesis, ensures that the plant's metabolic machinery is not compromised by low availability of an essential nutrient. It is important to note that foliar applied fertilizers of phloem-mobile nutrients are translocated to all parts of the tree, including the smallest feeder roots. Foliar fertilizers reduce the potential for accumulation of nutrients in soil, run off water, surface water (streams, lakes and the ocean), and groundwater (drinking water supply), where they can contribute to salinity, eutrophication and nitrate contamination; all of these have serious consequences on the environment and human health. Therefore, foliar fertilization provides advantages over traditional soil applied fertilizer and should replace soil-applied fertilizer, at least in part, in crop best management practices (BMPs).

Three problems impede adoption of foliar fertilizers:

(1) Not all nutrients are taken up through the foliage and, even if taken up, some nutrients are not phloem-mobile. Thus, *a priori* knowledge (research) is necessary to know which nutrients are taken up through the leaves of a specific crop in order to develop a foliar fertilization program. This information is not always available to growers and the lack of information compromises a grower's ability to discern which foliar fertilizers are worth using and when to apply them.

(2) Standard leaf analyses do not always show the expected increase in nutrient concentration. This can be due to poor nutrient uptake, but also can result from excellent uptake and utilization by tissues not sampled (new shoots, stems, roots and especially fruit). Conversely, leaf analyses can give false positive information regarding foliar fertilization. Some foliar applied nutrients persist in the wax of the leaf cuticle. Thus, if the leaves analyzed are not washed properly, a false

high reading will be obtained. Frequently, it is considered sufficient to merely demonstrate that a nutrient applied as a foliar fertilizer is taken up. To do this, leaves are typically analyzed within a short period of time after the fertilizer is applied to the foliage. Whereas this approach may confirm that uptake has occurred, benefits of the application are largely presumed.

(3) Rates of foliar fertilizer are typically lower than soil applied fertilizer, but application of foliar fertilizer can be more expensive, especially if a grower does not own his own sprayer. Tank mixing multiple fertilizers and/or pesticides to save a trip through the orchard can cause negative interactions that reduce efficacy or cause negative effects on plant metabolism, such as the negative effect on yield of the avocado, due to the interaction between foliar-applied N and B (Lovatt, 1999).

Growers have been proactive in protecting the environment, but with the high cost of fertilizer in general, foliar fertilizers must be proven to be effective for growers to be willing to incur the expense of using them. An improved methodology to evaluate the effectiveness of foliar fertilizer is required. The primary investigator proposes that the only acceptable standard by which to measure effectiveness of foliar fertilizer is a resultant yield benefit and net increase in grower income. The key to achieving a yield benefit and net increase in grower income is properly timing the foliar application of fertilizer to key stages of crop phenology when nutrient demand is likely to be high or when soil conditions are known to restrict nutrient uptake. For citrus and avocado tree crops, this approach is in contrast to applying foliar fertilizers at the standard time of 1/3 to 2/3 leaf expansion (in March), which targets foliage with a thin cuticle and large surface area and only resulted in yields equal to those attained with soil applied fertilizer (Embleton and Jones, 1974; Labanauskas et al., 1969).

By demonstrating that foliar fertilization strategies can be used to increase yield parameters and grower net income, by properly timing their application (Lovatt 1999), growers have replaced soil-applied fertilizer, at least in part, with foliar fertilizer, improving fertilizer efficiency and protecting the environment. This theory is being tested with Clementine mandarin (Citrus reticulata Blanco), for which little fertilizer research has been conducted in California. Thus, the results of this project will not only establish the feasibility of using a yield benefit and net increase in grower income as a new methodology for evaluating the effectiveness of foliar fertilizers, but will also provide California Clementine mandarin growers with fertilization practices to improve crop production that are efficient and protect the environment. In addition, CDFA FREP provides the visibility required to make the benefits of this approach known to researchers and growers of other crops.

OBJECTIVES

1. Test the efficacy of properly timed foliar applied $ZnSO_4$, Solubor B, urea N and phosphate P+K fertilizers to increase Clementine mandarin fruit number, size, and/or quality and increase grower net income.
2. Demonstrate that a yield benefit and net increase in grower income should be the only acceptable standard for evaluating the effectiveness of foliar applied fertilizers.

DESCRIPTION

1. Test the efficacy of the following fertilizers applied to the foliage at the times specified below in comparison with fertilizers applied at 2/3 leaf expansion:

   (1) N [23 lb/acre, urea (46% N, 0.25% biuret)] with K and P [0.64 gal/acre, potassium phosphite (0-28-26)] applied winter prebloom to increase flower

number, fruit set and yield, without reducing fruit size, and to increase total soluble solids (TSS) and TSS:acid.

(2) Zn [1 lb/acre, $ZnSO_4$ (36% Zn)] at 10% anthesis in the southwest tree quadrant (SWTQ) to increase fruit set and yield, without reducing fruit size.

(3) B [1.3 lb/acre, Solubor (20.5% B)] at 10% anthesis in the SWTQ to increase total yield and yield of commercially valuable large size fruit.

(4) K and P [0.49 gal/acre, potassium phosphite (0-28-26)] in May and July to increase yield of commercially valuable large size fruit, without reducing total yield, and to increase TSS and TSS:acid.

(5) N [23 lb/acre, urea (46% N, 0.25% biuret)] at maximum peel thickness to increase yield of commercially valuable large size fruit, without reducing yield, and to increase TSS and TSS:acid.

(6) K (25 lb KNO3/acre) at dormancy (February), post bloom (approximately April) and summer fruit growth (July to August) to increase the yield of commercially valuable large size fruit (Boman 2002).

(7) N [23 lb/acre, urea (46% N, 0.25% biuret)] with K and P [0.64 gal/acre, potassium phosphite (0-28-26)] applied at 2/3 leaf expansion.

(8) Zn [1 lb/acre, ZnSO4 (36% Zn)] at 2/3 leaf expansion.

(9) B [1.3 lb/acre, Solubor (20.5% B)] at 2/3 leaf expansion.

2 Determine the best time to apply the winter prebloom treatments to Clementine mandarin in the San Joaquin Valley, the winter prebloom foliar-applied urea-N and winter prebloom foliar-applied phosphite-P+K were expanded to five treatments as follows:

(1) N [23 lb/acre, urea (46% N, 0.25% biuret)] in November.

(2) N [23 lb/acre, urea (46% N, 0.25% biuret)] in December.

(3) N [23 lb/acre, urea (46% N, 0.25% biuret)] in January.

(4) N [23 lb/acre, urea (46% N, 0.25% biuret)] with K and P [0.64 gal/acre, potassium phosphite (0-28-26)] in November.

(5) N [23 lb/acre, urea (46% N, 0.25% biuret)] with K and P [0.64 gal/acre, potassium phosphite (0-28-26)] in December.

3 In all treatments, fertilizer rates are based on application in 250 gallons water per 100 trees per acre so that they can be adjusted for application to individual trees.

RESULTS AND DISCUSSION

The first harvest for our CDFA FREP project was in December 2009. All trees produced uniformly heavy on-crop yields (an average of 207 lbs of fruit per tree, with a range of 196 to 220 lbs of fruit per tree and an average of 950 fruit per tree, with a range of 863 to1016 fruit per tree) (Tables 1 and 2). No treatment significantly increased total yield above that of the untreated control trees. The highest yields by lb and number of fruit per tree were obtained with foliar applications of low biuret urea in November or January (220 lbs per tree and 1016 and 1010 fruit per tree, respectively, compared to 206 lbs and 921 fruit per tree for the untreated control trees).

Fruit size peaked on packing carton sizes 28 to 24 (fruit 2.28 to 2.5 inches in transverse diameter). The three pre bloom foliar applications of low biuret urea (November, December and January), the pre bloom application of low

biuret urea combined with potassium phosphite (November), and zinc applied to the foliage at 10% anthesis in the SWTQ significantly increased the yield of fruit in these two size categories; as lb per tree compared to trees receiving foliar applied urea combined with potassium phosphite in December, foliar applied potassium nitrate at dormancy (February), post bloom (75% petal fall in the NETQ) (approximately May) and during summer fruit growth (July-Aug.), and boron applied to the foliage at 10% anthesis in the SWTQ (P = 0.0223) (Table 1). All other treatments had an intermediate effect on the yield of fruit of packing carton sizes 28 + 24 that was not significant. Interestingly, only the pre bloom foliar application of low biuret urea (November, December and January) and foliar zinc applied at 10% anthesis in the SWTQ increased the number of fruit of packing carton sizes 28 + 24 per tree.

The result is compared to trees receiving foliar-applied urea combined with potassium phosphite in December, foliar potassium nitrate applied at dormancy (February), post bloom (approximately May) and during summer fruit growth (July to Aug.), and foliar boron applied at 10% anthesis in the SWTQ (P = 0.0214) (Table 2). Despite the significant positive effect of several treatments on the yield of fruit of packing carton sizes 28 + 24, there was no concomitant effect on the yield of commercially valuable large size fruit in the combined pool of fruit of packing carton sizes 28 to 15 (2.25 to 2.95 inches in transverse diameter). Although not significant, the highest yield of fruit of packing carton sizes 28 to15 was achieved with the foliar application of low biuret urea in November (150 lbs fruit per tree, 608 fruit per tree) (Tables 1 and 2). The lowest yield of fruit of packing carton sizes 28 to15 resulted from foliar application of potassium nitrate at dormancy (February.), post bloom (approximately May) and during summer fruit growth (July through Aug.).

All fruit were of excellent quality and had a high sugar to acid ratio (approximately 14). There were no significant treatment effects on any fruit quality parameter analyzed, including rind thickness, average fruit weight, average juice weight per fruit, average juice volume per fruit, total soluble solids (TSS as °brix), acidity (%), or the ratio of TSS:acidity (Table 3).

CONCLUSIONS

The pre bloom foliar application of low biuret urea in November not only resulted in the highest total yield, but also the highest yield of commercially valuable large size fruit in the combined pools of fruit of packing carton sizes 28 and 24 and 28 to 15 both as lb and number of fruit per tree, but the month (November, December and January), in which the winter pre bloom low biuret urea application was made did not have a significant effect on yield or fruit size. The November low biuret urea application, resulted in total yields and yields of commercially valuable large size fruit that were significantly greater than those produced by trees receiving several other treatments, but not the untreated control trees. Yield and fruit size of the untreated control trees were not significantly different from those of any treatment.

The yield results for the harvest of December 2010 will be very important to determine. Of key importance is the following: (1) whether November is really a better time to apply low biuret urea and especially low biuret urea combined with potassium phosphite rather than December as the Year 1 data suggest; (2) whether application of potassium nitrate applied at dormancy (February), post bloom (75% petal fall in the NETQ) (approximately May) and during summer fruit growth (July to Aug.) or boron at 10% anthesis in the SWTQ reduce fruit size of 'Nules' Clementine mandarin in California; and (3) whether treatments having a positive effect on total yield this year will have

Table 1
Effect of applying foliar fertilizers at key stages of tree phenology on yield (kg per tree) of 'Nules' Clementine mandarin trees. Application times refer to the following phenological stages: November, December, and January-pre bloom; February-dormancy; April-10% anthesis or 2/3 leaf expansion as indicated; May-post bloom (75% petal fall in the Northeast tree quadrant); and July-exponential increase in fruit growth (Stage II of fruit development, the start of which is identified by maximum peel thickness). (Year 1: 2008-2009; the orchard is located in Fresno, CA)

Treatment	Application time	Total	Packing carton size							
			≤ 32 ≤ 2.2 in	28 2.3-2.4 in	24 2.4-2.5 in	21 2.5-2.6 in	18 2.7-2.8 in	15 2.8-3.0 in	28-24 2.3-2.5 in	28-15 2.3-3.0 in
		lbs. per tree								
Urea	Nov	220.02	68.78	51.37 a[z]	38.80	37.48	14.33	6.83	90.17 a	148.81
Urea + Potassium phosphite	Nov	206.57	67.24	40.79 abcd	41.01	32.41	14.55	7.94	81.57 ab	136.46
Urea	Dec	212.74	60.19	41.45 abcd	42.77	35.71	16.98	8.60	84.22 a	145.50
Urea + Potassium phosphite	Dec	192.24	62.61	35.27 cd	29.76	33.51	16.75	9.92	65.04 d	125.22
Urea	Jan	220.24	69.67	49.82 a	38.80	39.24	12.57	6.17	88.40 a	146.39
Potassium nitrate	Feb + May + Jul	207.67	80.91	37.92 bcd	28.44	31.53	16.75	5.07	66.14 cd	119.49
Zinc	Apr 24									
(10% anthesis)	209.88	73.19	48.06 ab	37.92	32.63	11.46	4.19	85.98 a	134.04	
Zinc	Apr 13									
(2/3 leaf expansion)	208.78	69.44	45.41 abc	35.05	34.39	13.89	5.73	80.25 abc	134.26	
Boron	Apr 24									
(10% anthesis)	201.50	68.34	34.17 d	34.61	38.14	15.87	5.07	69.00 bcd	127.65	
Boron	Apr 13									
(2/3 leaf expansion)	214.51	70.99	42.99 abcd	33.95	38.80	14.77	8.16	76.94 abcd	138.67	
Urea + Potassium phosphite	Apr 13									
(2/3 leaf expansion)	196.21	51.37	41.23 abcd	39.90	32.41	16.53	10.14	81.13 abc	139.99	
Potassium phosphite	May + Jul	207.23	71.87	41.23 abcd	36.82	30.42	18.08	5.51	78.04 abcd	132.06
Urea	Jul	199.08	61.29	41.01 abcd	37.48	31.31	17.42	5.51	78.48 abcd	132.72
Control		205.69	56.00	40.56 abcd	38.36	39.68	18.08	8.82	78.92 abcd	145.28
P-value		0.4956	0.8149	0.0931	0.2931	0.9092	0.9343	0.7116	0.0223	0.4204

[z] Values in a column followed by different letters are significantly different by Fisher's Protected LSD test at $P = 0.05$.

Table 2
Effect of applying foliar fertilizers at key stages of tree phenology on yield (number of fruit per tree) of 'Nules' Clementine mandarin trees. Application times refer to the following phenological stages: November, December, and January pre bloom; February-dormancy; April-10% anthesis or 2/3 leaf expansion as indicated; May post bloom (75% petal fall in the Northeast tree quadrant); and July exponential increase in fruit growth (Stage II of fruit development, the start of which is identified by maximum peel thickness). (Year 1: 2008-2009; the orchard is located in Fresno, CA)

Treatment	Application time	Total	Packing carton size							
			≤ 32	28	24	21	18	15	28-24	28-15
			≤ 2.2 in.	2.3-2.4 in.	2.4-2.5 in.	2.5-2.6 in.	2.7-2.8 in.	2.8-3.0 in.	2.3-2.5 in.	2.3-3.0 in.
		no. of fruit per tree								
Urea	Nov	1016	402	237 a[z]	164	141	47	19	402 a	608
Urea + Potassium phosphite	Nov	946	386	188 abcd	173	122	47	23	362 ab	553
Urea	Dec	950	345	192 abcd	181	134	55	25	373 a	587
Urea + Potassium phosphite	Dec	882	374	163 cd	126	126	54	28	289 c	498
Urea	Jan	1010	400	230 a	164	147	40	18	394 a	600
Potassium nitrate	Feb + May + Jul	980	479	175 bcd	120	118	54	15	295 bc	482
Zinc	Apr 24									
(10% anthesis)	980	420	222 ab	160	123	37	12	382 a	554	
Zinc	Apr 13									
(2/3 leaf expansion)	970	409	210 abc	148	129	45	17	358 ab	548	
Boron	Apr 24									
(10% anthesis)	926	399	158 d	147	143	51	14	305 bc	513	
Boron	Apr 13									
(2/3 leaf expansion)	991	420	199 abcd	144	146	48	24	342 abc	560	
Urea + Potassium phosphite	Apr 13									
(2/3 leaf expansion)	863	288	191 abcd	168	122	53	29	360 ab	563	
Potassium phosphite	May + Jul	960	417	191 abcd	156	114	59	16	347 abc	535
Urea	Jul	902	351	190 abcd	158	118	56	16	348 abc	538
Control		921	328	187 abcd	162	149	59	25	350 abc	582
P-value		0.5960	0.8015	0.0931	0.2931	0.9092	0.9343	0.7116	0.0214	0.2288

[z] Values in a column followed by different letters are significantly different by Fisher's Protected LSD test at *P = 0.05*.

Table 3
Effect of applying foliar fertilizers at key stages of tree phenology on the quality of fruit of 'Nules' Clementine mandarin trees. Application times refer to the following phenological stages: November, December, and January pre bloom; February-dormancy; April-10% anthesis or 2/3 leaf expansion as indicated; May-post bloom (75% petal fall in the Northeast tree quadrant); and July-exponential increase in fruit growth (Stage II of fruit development, the start of which is identified by maximum peel thickness). (Year 1: 2008-2009; the orchard is located in Fresno, CA)

Treatment	Application time	Rind thickness (inches)	Fruit weight (ounces)	Juice weight (ounces)	Juice volume (pints)	TSS: acid
Urea	Nov	0.106	5.46	10.57	0.61	14.3
Urea + Potassium phosphite	Nov	0.122	5.76	10.59	0.62	14.7
Urea	Dec	0.110	5.62	10.56	0.61	14.2
Urea + Potassium phosphite	Dec	0.118	6.26	10.77	0.63	14.9
Urea	Jan	0.114	5.72	10.80	0.63	14.8
Potassium nitrate	Feb + May + Jul	0.106	5.57	10.55	0.62	14.2
Zinc	Apr 24					
(10% anthesis)	0.114	5.73	11.20	0.65	15.4	
Zinc	Apr 13					
(2/3 leaf expansion)	0.122	6.05	11.60	0.68	14.6	
Boron	Apr 24					
(10% anthesis)	0.122	5.88	10.57	0.62	14.6	
Boron	Apr 13					
(2/3 leaf expansion)	0.114	5.64	10.41	0.61	14.1	
Urea + Potassium phosphite	Apr 13					
(2/3 leaf expansion)	0.118	5.90	10.64	0.62	14.6	
Potassium phosphite	May + Jul	0.102	5.28	10.28	0.60	14.9
Urea	Jul	0.130	5.90	10.61	0.62	13.8
Control		0.118	6.23	10.78	0.63	14.3
P-value		0.5083	0.1462	0.6843	0.6907	0.1919

[z] Values in a column followed by different letters are significantly different by Fisher's Protected LSD test at $P = 0.05$.

the same effect next year or whether yield next year will be proportionally lower due to the effects of alternate bearing (or, conversely, be proportionally greater for treatments causing lower yields this year).

For citrus, it is difficult to increase yield further in the on crop year. The goal for an on crop year is typically to increase fruit size; the winter pre bloom foliar application of low biuret urea (November, December and January), which tended to do both during this first on-crop, is therefore of interest. However, an optimal time of this application or any treatment cannot be determined based on one year of yield data. No conclusions can be made at this time, especially in an alternate bearing orchard.

ACCOMPLISHMENTS

The primary investigator made presentations at the following venues that included information related to this project to educate growers, industry people and other researchers regarding the need to reduce soil-applied fertilizers and the benefits that can be attained using properly timed foliar fertilization:

1. "Phenology and Physiology of Citrus Productivity" at the Tulare County Citrus Growers Meeting, October 7, 2009;
2. "Phenology and Physiology of Citrus Productivity - *The basis for developing and using plant growth regulators and foliar fertilizers in commercial citrus production*" at the Friends of Citrus meeting, February 17, 2010;
3. "Effect of Climate Change on Citrus and Avocado Flowering and Productivity," to researchers at INIFAP, Tepic, Nayarit, Mexico, March 12, 2010; and
4. "Phenology and Physiology of Citrus and Avocado Productivity", University of Arizona, April 28, 2010.
5. "Phenology and Physiology of Citrus Productvity – *The basis for developing and using PGRs and foliar fertilizers in commercial citrus production*" to Australian visitors in citrus research and production at UCR, August 26, 2010.

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Balancing Fertilizer Application Rates with Water Quality Protection in Strawberry Production

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INTRODUCTION

As agricultural non point source regulations increase, all growers must become better informed about the potential impacts of nutrient management on water quality. Santa Maria Valley is home to diverse horticultural crops such as strawberries, lettuce and cole crops, as well as tree and vine crops. Certain segments of the grower community, such as the Spanish speaking growers, have demonstrated a greater need for education, since, in the past, these growers have not had the same access to information due to language, knowledge, financial, and cultural barriers.

The majority of the many Spanish-speaking growers in the Santa Maria Valley fall into three categories with distinct characteristics and educational needs. The first group ("struggling") is comprised of growers who sublease small parcels of land from strawberry cooler and packing houses. These growers are often new to farming and often need very basic fertilizer education. They may not be eligible for cost share assistance because of their short term leases. The second group ("progressing") consists of strawberry and vegetable growers who operate their own small/medium sized farms. They need assistance with specific aspects of fertilizer management such as how to use slow release fertilizers. Finally, there is the group ("advanced") formed by the Spanish speaking farm managers, foremen, and irrigation managers who are employees of large farming operations. They benefit from exposure to more

sophisticated information about nitrate and irrigation management practices. As part of larger operations, they may have access to financial resources necessary to implement more costly management practices.

This project is a collaborative effort by local technical service providers, researchers, and industry to provide education tailored to meet the needs of each group of Spanish speaking growers in the Santa Maria Valley.

OBJECTIVES

1. Determine the education that best meet needs of each Spanish speaking grower group.
2. Assist with applicable University of California (UC) research conducted for nutrient management.
3. Incorporate research findings into education as workshops and factsheets.
4. Conduct individual field visits to demonstrate the nitrate quick test, install soil moisture monitoring equipment, conduct irrigation evaluations, and assist with applying for Natural Resources Conservation Service (NRCS) costshare funding.

DESCRIPTION

A grower survey was conducted. From survey results, the characteristics of three distinct Spanish speaking grower groups were defined and appropriate outreach and education for each group was determined.

Seven research trials were conducted over multiple years. A "Toolbox" of nutrient and irrigation management practices was developed. Twelve workshops were conducted: four for each grower group. Use of Toolbox tools was explained at workshops tailored to each grower group. Guest speakers included UC Davis and UC Riverside specialists. Workshops were held in Spanish or with Spanish translation. Some workshops were held at research demonstration sites.

Seventy four field visits were conducted with Spanish speaking growers to assist with the soil nitrate quick test (SNQT), soil sampling and interpretation of soil reports. The mobile irrigation lab conducted irrigation evaluations on 11 farms covering 821 acres. Tensiometers were installed in three sugar-snap pea fields and two strawberry fields. Fourteen (14) Spanish speaking growers received Environmental Quality Incentives Program (EQIP) cost share funding from the NRCS.

RESULTS

This is the third and final year of the project. The Toolbox of nutrient and irrigation management practices was detailed in the 2008 FREP proceedings. The 2009 research trial results were summarized in the 2009 FREP proceedings. Comprehensive results of the seven 2010 trials are under development. They will be made available in English and Spanish by the Cachuma Resource Conservation District (CRCD) once they are finalized. Noteworthy preliminary findings of the research trials and survey findings are as follows:

Research Trial – Fertilizer Management for Conventional Strawberries

According to the grower survey, 188 pounds of nitrogen per acre is the average seasonal nitrogen application rate. By reducing both pre plant and in season fertilizer rates, a reduction of 39 pounds of nitrogen per acre was achieved for the common strawberry variety Albion without reducing marketable yield.

Research Trial – Fertilizer Management for Organic Strawberries

Though the marketable crop yield was slightly lower when using the lower fertilizer rates, the net cost savings was greater due to lower fertilizer costs.

Research Trial – Nitrogen in Vegetable Crops

Results from these field trials suggest that nitrogen rates for Napa cabbage can be cut by approximately 44 percent and iceberg lettuce by 54 percent by eliminating pre plant nitrogen application using the SNQT, and 20 ppm as a threshold for nitrogen application. The cooperating grower has cut his fertilizer use by over 50 percent.

CRCD Strawberry Farmers Survey

The CRCD Strawberry Farmers Survey was an excellent means to help understand the challenges and requirements of each Spanish-speaking group of growers to use Toolkit tools. The survey has guided outreach, workshop design, and research for this and other projects.

Preferences were distinguishable among the three groups for preferred topics. Pest control was found to be important to all groups. Notably higher workshop attendance was achieved when timely, pest management information was presented.

Field visits were seen by all groups to be of the most value. The preference among the struggling and progressing groups was to visit and learn from other growers. Printed material was determined useful only by some members of the advanced grower group.

It was revealed that many of the Spanish speaking growers in the Santa Maria Valley are in the struggling group. Growers of this group are often immigrants who are neither literate in Spanish nor fluent in English. Some growers in this group speak Mixtec or other languages of Mexican indigenous people as their primary language. They may not be fluent in Spanish. It is not surprising then that members of the struggling group, with limited access to resources, have a tendency towards lower strawberry yield per acre.

Language barriers create challenges for program outreach and delivery to the struggling group. The survey showed that technical assistance entities such as UC Cooperative Extension, NRCS, and resource conservation districts (RCDs) are not often recognized by this group. Relationships and trust are built from interaction with individuals. The preferred notification method for workshops is a phone call made only a few days prior to the workshop. Printed materials should be understandable by use of

Figure 1
Topics preferred by farmers in each qualitative identified group, from the answers of 29 respondents to an open-question.

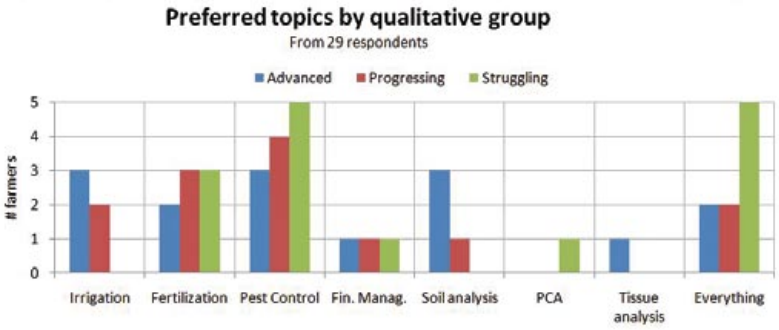


Figure 2
Type of assistance preferred by farmers in each qualitative group, from the answers of 28 respondents to an open-ended question.

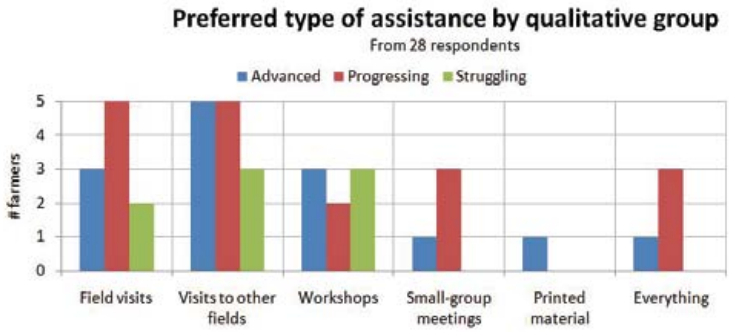
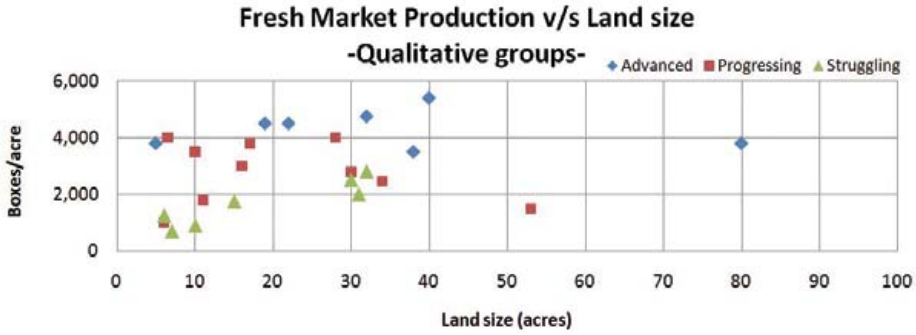


Figure 3
Yield of fresh market product (boxes/acre) versus land size (acres) for the qualitative classified groups advanced, progressing and struggling. A minimum yield to guarantee positive returns would normally be 2,000 boxes/acre.



graphics and simple terms. Nutrient management techniques, such as the SNQT and use of tensiometers, are best taught by demonstration followed by supervised hands-on experience. A substantial amount of time is necessary to educate the struggling group.

Members of all three Spanish speaking groups have reported being able to fine tune their nutrient and irrigation management in response to the education received. Ninety six percent of respondents report using CRCD fertilizer recommendations and 78 percent report using CRCD irrigation recommendations. Eighty three percent of respondents report that they have tried using the SNQT in their fields, while 59 percent report continued use. Some Spanish speaking growers who have received CRCD training report that they have applied about 50 percent of the pre plant fertilizer as applied in previous years.

CONCLUSIONS

Education can be well-received by groups of Spanish-speaking growers when a time investment is made to determine the needs of each sub-group and outreach can be tailored to meet those needs. A Toolbox of tools used to monitor site-specific conditions over a season coupled with local field research can greatly improve nutrient and irrigation management.

ACKNOWLEDGEMENTS

This program was supported primarily by FREP funding, with additional funding from a Department of Water Resources Water Use Efficiency grant funding for conducting irrigation evaluations, and a Henry A. Jastro Research Scholarship Award from UC Davis to María Paz Santibáñez towards development of the grower survey. Matching funding was provided from USDA Cooperative State Research, Education and Extension Service for the final season of two field trials and two workshops and a Central Coast Regional Water Quality Control Board, Proposition 50 Grant, for assistance in completion and implementation of nutrient and irrigation management practices.

Improved Methods for Nutrient Tissue Testing in Alfalfa

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INTRODUCTION

Alfalfa is the most critical feed for the state's #1 agricultural enterprise, dairy. It occupies between 930,000 acres and 1.1 million acres, and represents a very important component of California's fertilizer and agricultural footprint, primarily due to a high requirement for phosphorus and potassium. Due to the high acreage, nutrient management of this crop has potentially large impact on the agro ecosystem of the state.

Analytical methods have been developed to assess the nutritional status of alfalfa fields for fertilizer management purposes. Soil tests are somewhat effective to detect some nutrient deficiencies such as P and K, but plant tissue tests are believed to be far more accurate overall. The plant is a better indicator of the nutrient supplying capabilities of a soil due to variations in rooting depth and nutrient supplying characteristics of specific soils. Unfortunately, most alfalfa growers do not tissue test and many growers fertilize (or do not fertilize) based upon past practice with little idea of the actual nutrient status of the field. Additionally, tissue testing techniques vary significantly from state to state. Simplified methods of analysis could promote wider adoption of nutrient monitoring practices and perhaps encourage the adoption of standardized methods between regions or states.

Many alfalfa crops in California are routinely tested for forage quality (e.g. fiber, protein and calculated digestibility values) to determine their nutritional value for feeding purposes. If those same cored samples used for forage quality analysis could also be used for nutrient management purposes, it would greatly simplify the process of tissue testing and encourage more careful nutrient management. Using this method, growers may be able to 'pick up' nutrient deficiencies that would otherwise go undetected.

OBJECTIVES

The objectives of this project are to:

1. Evaluate the feasibility of using a whole-plant sample (simulated cored-bale hay sample) to determine the nutrient status of alfalfa fields and to guide fertilization practices
2. Compare three different plant tissue sampling methods for nutrient monitoring (top 6 inches, fractionated plant, and whole plant sample) as to their ability to reflect the nutritional status of fields
3. Quantify the phosphorus, potassium and sulfur tissue concentration in alfalfa plant tissue over time as the crop matures from early bud growth stage to 10% bloom and correlate these values with stage of growth and crop height
4. Determine alfalfa yield response from phosphorus, potassium and sulfur fertilization
5. Develop critical plant tissue concentration values for whole plant alfalfa samples (simulated baled hay sample)
6. Evaluate the accuracy of Near Infrared Reflectance Spectroscopy (NIRS) analysis to determine nitrogen, phosphorus, potassium, sulfur, boron and molybdenum concentrations

DESCRIPTION

Sampling Commercial Alfalfa Fields to Compare Tissue Testing Protocols with Wet Chemistry and NIRS Analytical Methods

Twelve commercial alfalfa fields were sampled over the season in three different alfalfa production regions (five fields in the Intermountain area, four in the Sacramento Valley, three in the high desert). Each field was sampled three times over the season—each of the three cuts in the Intermountain area, and cuts two, three, and the second to the last cutting (fifth or sixth) in the Sacramento Valley and High Desert. Fields were selected to represent a range of nutrient levels. Plant samples were collected at the early bud, late bud, and 10 percent bloom growth stages at each of the three cuttings. Plant samples were collected and processed using the following sampling protocol: 1) Fractionated plant sample according to the standard UC protocol. Plant samples were divided into thirds. The stems from the mid third portion will be analyzed for PO4-P and K. The leaf portion of the middle third will be analyzed for SO4-S, and the top third portion for boron and molybdenum. 2) The top 6 inches of the alfalfa plant (method used in other alfalfa-producing states) will be analyzed for total P, K, total S, boron and molybdenum. 3) Whole plant samples (used in some states and comparable to cored bale samples) will be analyzed for the same nutrients as the top 6-inch samples as well as N. Soil samples will also be collected from each field. Soil samples will be analyzed for pH, Olsen P, and exchangeable K, and nitrogen. This task will allow us to determine the relationship between the different sampling methods and compare the results with soil analyses.

In addition to the wet chemistry methods mentioned above, all the whole plant samples will also be analyzed using NIRS by UC Forage Specialist Dan Putnam's laboratory at UC Davis and at a commercial laboratory experienced with NIRS (JL Analytical Services, Inc).

NIRS Analysis of Existing Samples

Previous research was conducted in the Intermountain area using similar protocol to that mentioned in the preceding section, except fields were not sampled over time to assess the effect of plant maturity. A total of 117 samples were collected over 2 years from 39 fields ranging in nutrient status from extremely deficient to very high. The samples were analyzed using wet

Figure 1
Collecting plant tissue samples from a commercial alfalfa field in the Intermountain area.

chemistry techniques by the UC Division of Agriculture and Natural Resources (UC-DANR) Analytical Lab. Those samples were retained and provide us with a robust data set to assess the value of NIRS for estimating the mineral content of forages and to help establish a calibration that can be used to analyze other samples.

Laboratory Samples for NIRS and Wet Chemistry Validation and Calibration

We will request 100 samples from different alfalfa production regions in California from JL Analytical. The samples selected will represent fields with a wide range of nutritional status. The samples will be analyzed for total P, K, total S, boron and molybdenum. This will allow us to validate the relationship between NIRS and wet chemistry that we develop from the aforementioned tasks and to further refine the calibration.

Fertilizer Rate Studies

Fertilizer response trials were conducted in the Sacramento Valley for phosphorus and in the Intermountain area for potassium (phosphorus rate studies have been conducted previously). The purpose was to correlate alfalfa yield with plant tissue nutrient concentration. Each trial had five different rates (unfertilized and four increasing fertilizer rates) with four replications. A phosphorus rate study was also attempted in the High Desert but failed; this will be repeated in 2011. The trials were harvested for three cuttings spaced throughout the season in the Sacramento Valley and all three cuttings in the Intermountain area. Plant tissue samples were collected. Yield data will be collected to determine the yield response to applied P, K, and S and to correlate those yield levels with plant nutrient concentration. This research will provide information needed to develop critical tissue levels for whole plant analysis, which can be used to interpret results from cored bale samples.

RESULTS AND DISCUSSION

The experiments are mid way through the first year of the two year study funded by FREP. Thus, the results to date should be considered very preliminary. A phosphorus rate study was established in the Sacramento Valley and a potassium rate study in the Intermountain region. Yields were measured and plant samples

Figure 2
The effect of applied phosphorus on the yield of alfalfa for four cuttings in the Sacramento Valley, 2010.

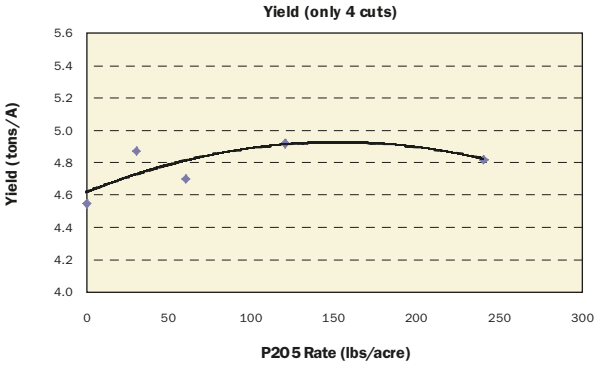
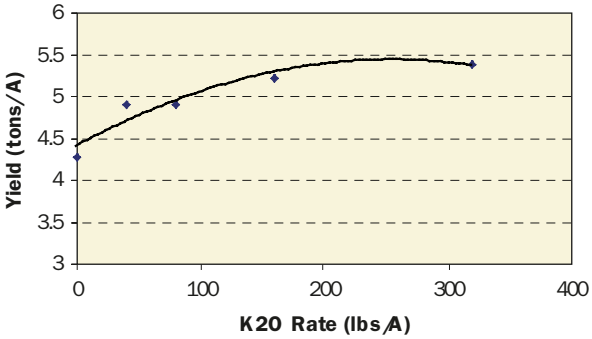


Figure 3
The effect of applied phosphorus on the total seasonal yield of alfalfa in the Intermountain area, 2010.



collected. Soil tests indicated that the Sacramento site was extremely deficient in P at the outset of the trial. However, in spite of very low soil P levels (Olsen P values 2.5 or less) we saw little yield response to P applications (Figure 2). The reasons for this are not clear at this writing, but may be due to overwhelming additional soil factors such as drainage and aeration on the heavy clay soils in Western Yolo County, or other limitations. Weather patterns in 2010 may have also played a role. It is possible that this research may lead to additional fertilizer recommendations based upon confounding factors, such as soil condition.

Alfalfa yield responded dramatically to K rates at the Intermountain site. The total yield increase for the season was over a ton per acre from the lowest to the highest application rate (Figure 3). A yield increase occurred with each incremental increase in K application rate but the rate of increase was less between the highest application rates. This is a typical yield response curve for applied fertilizer. These data together with plant tissue values and subsequent field trails will be used to establish critical values for whole plant tissue levels.

Additional field samples were taken from growers' fields to develop correlations between tissue sampling methods (whole plant, fractionated plant, and top 6 inches). Samples have been accumulated to do batch-plant sample runs in the fall-winter periods (such data is not available at this writing). Data from previous year's study (not funded by FREP) has shown promise of highly-correlated bale sampling (whole plant) methods with partial sampling methods, correlated with soil P status.

CONCLUSIONS

While it is too early to generate conclusions mid way through this two year study, the results to date appear promising. The goal of this project is to develop an alfalfa tissue testing protocol that is simple to use and sufficiently accurate so that nutrient analysis can become a routine component of forage quality testing. The samples generated from these on-farm locations and the fields in the controlled fertilizer studies should assist in generating improved testing protocols. Those who would benefit include alfalfa growers, consultants (PCAs, CCAs and Farm Advisors), fertilizer companies, and testing laboratories that could expand their services to meet increased demand for nutrient analyses.

Western Fertilizer Handbook, Turf & Ornamental Edition- Book Development

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INTRODUCTION

The safe utilization of fertilizers is an important goal of the agriculture industry as well as the California Department of Food and Agriculture (CDFA) and the Western Plant Health Association (WPHA). Use of fertilizers in urban settings by both professionals in the "turf and ornamental" industry and "home and garden" users is of growing concern and importance. The fertilizer industry is seeing a growing concern by government in how and whether commercial fertilizer products should be available for use. In the Midwest and eastern United States, bans or limitations are being implemented on certain fertilizer products in urban sectors to control their overuse. Much of the problem is linked to a lack of knowledge by homeowners and urban professional fertilizer applicators on how, what and when to use plant nutrient products.

One useful reference for fertilizer use in urban areas is the horticulture version of the *Western Fertilizer Book*. This reference has not been updated in 11 years and there are newer technologies and practices that should be incorporated into a reference book of this type. CDFA has provided WPHA with funding to support the employment of an intern to assist in the production of the book. This includes creating tables and figures, verifying references and creating a useful glossary that will make this tool a handy reference for today's agribusiness professionals, growers, landscapers and Certified Crop Advisors and horticulturalists.

OBJECTIVES

1. Provide users of fertilizers with current best management practices on the safe use of fertilizers in urban settings.
2. Provide professional and home users of fertilizers with current science on the safe use of fertilizers in urban settings.
3. Develop an up to date resource book that provides the information listed above in one comprehensive package, a book that will be published and made available for purchase throughout the United States.
4. Provide an opportunity for an intern to utilize publishing skills as well as learn more about the plant health industry.

DESCRIPTION

The project's goal is to provide current information on when, where and how to use fertilizers in urban settings via this valuable reference tool that incorporates current research and data. Specifically, the committee has added information on slow release, control release and organic fertilizers and is placing more emphasis

on solution culture, media mixes and turf. The text has not only been updated, but the tables and figures have been modified to have a more professional and user friendly format. WPHA's intern worked alongside the writing team and publisher to see the development of the book.

The industry professionals involved in writing the text and providing data are dedicating as much time as they have to the project. The student intern, whose sole responsibility for WPHA is the publication of the book, helped to organize the text, created tables and graphs needed for the document, developed a style-book for the text and requested permission to reprint specific tables pulled from other sources.

ACCOMPLISHMENTS

Throughout the past several years, the WPHA's Western Fertilizer Handbook Committee, a sub-committee of the WPHA Soil Improvement Committee, has been working to develop accurate text for the third edition of the turf and ornamental edition of the *Western Fertilizer Handbook*.

To date, the Western Fertilizer Handbook Committee has revised drafts of each chapter, obtained peer reviews and has proof edited by the editorial team. The first five chapters and the appendices are at the publisher for layout and the Soil Improvement Committee is working on the development of the glossary and index. In early 2011, the manuscript will go into the final stages of layout and head for printing. This winter WPHA will hire another student intern to help proofread the semi final document, compile the final list of credits and acknowledgments and be sure that all scientific terms are notated correctly on the final manuscript. The book should be available for purchase in the spring of 2011.

California Certified Crop Adviser Educational Project

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INTRODUCTION

There are hundreds of crop advisers in California who make recommendations on a regular basis on fertilizers and crop management. These professional advisers are critical to the hundreds of decisions farmers make each year, decisions that can have large environmental and economic impacts. The ability to provide advice to make rapid, intelligent and scientifically sound management decisions prevents California farmers from over applying fertilizers or manures. Good management decisions provide economic opportunities contained in good fertility management, and prevent water quality or air quality contamination from sub-optimum agricultural practices.

The California Certified Crop Adviser (CCA) program is the heart of competency certification for this group of professionals in California. It has established its position as an asset in public education related to fertilizers, soil resource management, and crop production.

The CCA program tests potential advisers using standardized, scientifically based exams, sets professional requirements, and provides certification for continuing education. The program continues training and cosponsoring seminars and other learning opportunities.

However, since CCA certification is mostly not required by state regulations or other entities, outreach efforts are required to maintain the strength, professionalism, and integrity of the program. As a result, the Fertilizer Research and Education Program (FREP) funding has provided valuable outreach components to increase membership and maintain the high standards of the program. The CaCCA program has developed incentives for growers to utilize the skills and knowledge of CCAs in their production operations as the state becomes more and more active with regards to environment regulations. Specifically, CaCCA has been very active with certification for development of nutrient management plans (NMPs), which have been driven largely by permitting and public agencies.

The CaCCA Program is a voluntary, non-profit organization that represents the CCAs who provide nutrient recommendations to private applicators, agricultural producers such as the dairy industry, and governmental agencies tasked with the stewardship of the state's natural resources.

Funding received during the current year for the CaCCA educational project from CDFA FREP enabled the all volunteer CCA board to achieve work objectives to improve the educational opportunities of California agriculture related to fertilizers, farm management and agricultural sustainability.

OBJECTIVES

The objectives of this project are to:

1. Broaden California CCA's identification and role in the California regulatory environment.
2. Increase and strengthen California CCA membership.
3. Outline multi-tiered, long term plan towards self-sustainability as an organization.
4. Efficiently administer and track the continuing education units (CEUs) of the California CCA and keep the flow of information to CACCA members.

DESCRIPTION AND ACCOMPLISHMENTS

The FREP funded program for the CaCCA has taken a proactive outreach approach to fulfill its outreach and educational objectives. These include:

- Current number of CCAs in California is 481, increased from previous years.
- Approved 242 Continuing Education Classes for CCAs.
- The ICCA/CaCCA/Manure Management Exam were held on February 5, 2010, in Sacramento, Riverside, Salinas, and Tulare. 54 individuals took one or both exams and 36 individuals participated in the Manure Management Exam and on August 6, 2010, in Modesto. 37 individuals took one or both exams and 9 individuals participated in the Manure Management Exam.
- Training sessions for the exams were offered to individuals prior to each exam testing date. Sessions were held in Fresno and Sacramento.
- Created California Certified Crop Adviser Fan Page on Facebook. The page is updated regularly with information that is relevant to CCAs. This page allows communication with current and potential CCAs; it also allows communication with other state CCA programs as many representatives of those programs are fans. The page is at http://www.facebook.com/#!/pages/California-Certified-Crop-Advisers/272373776767?ref=ts.
- CaCCA Annual Meeting was held on February 2, 2010, in Tulare in conjunction with California Plant and Soil Conference. Speakers included: CaCCA Chairman Rob Mikkelsen, CaCCA Marketing Chairman Allan Romander, WPHA President Renee Pinel, and California Specialty Crop Council Executive Director Lori Berger. Over 50 CCAs attended the meeting. Annual Meeting sponsors were: Simplot Grower Solutions, Yara North America, and The Tremont Group.
- Articles were published in *Western Farm Press* as a result of outreach efforts being made. The articles were CCA Role Grows in Water, Nutrients http://westernfarmpress.com/environment/cca-role-water-nutrients-0224/ and Recruiting the Future of Agriculture http://westernfarmpress.com/news_archive/recruiting-future-agriculture-0322/.
- Organic Production Seminar was held in partnership with the Organic Fertilizer Association of California (OFAC) on August 18, 2010, in Tulare. Over 190 people attended with 161 paid registrants. 49 CCA signed

in for CEUs. These seminars will provide funding to the CaCCA program with profits from their share of the program. It was also an educational opportunity for CCAs and PCAs. A future Organic Production Seminar, in partnership with OFAC, is planned for January 12, 2011, in Winterhaven, CA.

- The CCA Candidate program is being promoted to agricultural students that qualify for the program, but do not have the necessary experience.
- Representatives of the CaCCA program participated in the California Association of Pest Control Advisers (CAPCA)/Western Plant Health Association (WPHA) Student Dinners at UC Davis, CSU Chico, CSU Fresno, UC Riverside, Cal Poly Pomona and Cal Poly San Luis Obispo. The updated the students on the CCA program.
- Articles on CaCCA program and activities were published in the *CAPCA Adviser*.
- Hosted members of the staff of the UC Davis Agricultural Sustainability Institute that are conducting the California Nitrogen Assessment on a fertilizer facility tour.
- The CaCCA program will be exhibiting this fall at the following events: California Association of Pest Control Advisers Conference, NRCS Employees Meeting, Central Valley Grape Expo, Central Coast Grape Expo, Pacific Nut Expo, and California Alfalfa and Forage Conference.
- Presentations will be made this fall on the program at various CAPCA chapter meetings and the WPHA Nutrient Management Series.
- Continuous discussions with representatives of California fertilizer and ag retail industry on benefits of program.
- News releases were prepared and distributed on the CaCCA program and upcoming exam opportunities.
- Maintained and updated CaCCA website www.cacca.org on a regular basis.
- Met with various regulators regarding the CaCCA program including the Central Valley and Central Coast Regional Water Quality Boards.
- Continued steps to develop other sources of financing, including raising of dues and exam fees, developing sponsorship opportunities and options for seminars.
- Coordinated activities with ICCA program, including participating in the ICCA Board Meetings.
- Electronic newsletters are distributed to CaCCA members. Subjects include program status, upcoming meeting and other relevant information.
- CAPCA as cooperator on this grant provides daily administration for the CEU approval and member communications. They distribute newsletters and keep web site current.
- CAPCA coordinated with ICCA on all announcements and coordinates the exams.
- Representatives of the CaCCA program participated in the ICCA Board of Directors meeting in Spokane in August.
- CAPCA compiles the quarterly reports for the project leader for the CDFA/FREP grant.
- Involvement with the Stanley W. Strew Foundation "Pathway to PCA" program that will reach students interested in plant science and agronomy. The program will result in more Pest Control Advisers and CCAs in the future.

The next ICCA/CaCCA/Manure Management Exam will be held February 4, 2011 in Salinas, Sacramento, Tulare, and San Diego. Registration signup period is October 1 through December 10, 2010. Registration information is available at https://www.certifiedcropadviser.org/exams.

SUMMARY

The California CCA program, thanks to the support from CDFA FREP, has been very successful and continuing its growth. This program is heavily invested in the educational component of the FREP objectives, and developing long-term basic expertise and competency embodied in the more than 480 Certified Crop Advisers in California. It has provided training on new issues faced by the state's crop advisors, including organic production, water contamination, and manure management. The CCA program has conducted vigorous outreach efforts to assure the growth and sustainability of the program. It has expanded its certification program to include nutrient management training for those developing nutrient management plans. The continued success of the California CCA program serves the agricultural industry and the general public by assuring that agricultural practices are environmentally sound and economically feasible.

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Management Tools for Fertilization of the 'Hass' Avocado

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INTRODUCTION

This project focuses on developing best management fertilizer practices to improve nutrient use efficiency (yield per unit input of fertilizer) and reduce environmental pollution related to excessive fertilizer applications. For the 'Hass' avocado (Persea americana L.) industry of California, fertilization rates and optimal leaf nutrient ranges have been borrowed from citrus for all nutrients except nitrogen (N), zinc (Zn) and iron (Fe). Competition from Mexico, Dominican Republic, Chile, Australia, Peru, and South Africa requires the California avocado industry to increase production per acre to remain profitable. Optimizing fertilization is essential to achieve this goal.

The development of best management fertilizer practices is particularly important for alternate bearing avocado trees, for which most growers use the results of their August through September leaf analyses to replace nutrients used by the current crop. If not managed correctly, trees that are setting fruit in an off year receive more fertilizer than is needed (Lovatt, 2001). Over fertilization with nitrogen can significantly decrease avocado fruit size (Arpaia et al., 1996). Properly timing soil applied nitrogen can increase yield and fruit size and reduce alternate bearing of the 'Hass' avocado.

We believe that the deliverables of this project will increase yield, fruit size and profitability for California's 6,000 avocado growers, while protecting the groundwater. Information on best management fertilizer practices will be supplied in two formats: 1) graphically, plots will be developed documenting the stage to stage (month to month) changes in the concentrations of each essential mineral nutrient in vegetative and reproductive organs for both on and off crop trees; and 2) dynamically, a computer-based fertilizer model will be developed. Computer based fertilizer recommendations have been successfully adopted by growers for other crops (almond, pistachio, walnut, macadamia, etc.) and should be developed for avocado.

OBJECTIVES

1. Develop user friendly phenological timelines reporting biomass accumulation and total nutrient uptake for specific reproductive structures and vegetative components.
2. Develop a computer program that growers can easily use to calculate their own fertilizer recommendations (nutrient, application time and rate) based on tree phenology, crop load, and vegetative growth calculations.
3. Troubleshoot, and finalize the computer program and make it available on the web. Our computer-based approach involves mathematical data mining, graphic representation of results for ease of use, and development of the computer program.

DESCRIPTION

The principal investigators (PIs) recently completed the difficult task of quantifying nutrient partitioning during all stages of tree phenology by excavating on and off crop avocado trees every two months over two years at Somis Pacific in Moorpark, California. At excavation, trees were dissected into inflorescences, fruit, leaves, green shoots (<½ inches), small branches (½-2 inches), mid-size branches (2-4 inches), scaffolding branches (4-6 inches), wood (> 6 inches), scion trunk, rootstock trunk, scaffolding roots, small roots and new roots. Total weight of each component was recorded. Sub samples were washed, dried, ground, weighed and analyzed for nutrient content of 12 essential elements.

A phenology and yield based nutrient model will be developed for avocado from these tree excavation data. Uptake and partitioning of nitrogen and other nutrients into tree components in both on and off crop trees will be determined by the model. A basic fertilization model will be developed first, based on the nitrogen almond model (see website for model: http://ucce.ucdavis.edu/rics/fnric2/almondNKmodel/almond_n_model.htm).

After discussions with growers and researchers, we will modify the program based on their recommendations.

RESULTS AND DISCUSSION

Development of avocado nutrient fertilization model

Calculating the appropriate rate of fertilizer to apply is a complex process that involves interpretation of leaf and soil analyses, and a range of orchard and site condition factors.

In a typical well managed orchard with reasonably fertile soil, nitrogen, potassium and zinc are likely to be the only nutrients that need to be applied regularly. Therefore, the fertility model developed for this project will include these nutrients. The following are factors to consider when developing a nutrient fertilization model include:

- crop load or yield
- canopy size
- leaf nitrogen, potassium and zinc levels
- soil texture
- root rot status (lower rates for affected trees)

The relationship between avocado yield and nutrient removal in the crop must be determined in order to develop a fertilizer recommendation model. In this case, we used the nutrient removal calculator based on data from Dr. Arpaia, found at the website: http://www.avocadosource.com/tools/NutRemCalc.htm.

The relationship between tree canopy diameter and tree canopy nitrogen demand was determined from 15N applications and tree excavation data (Table 1). The relationship was found to be a power function ($y = 7.39x1.9615$), where y = canopy N (grams) and x = canopy diameter (meters). The demand for this nitrogen is distributed over four months: 1) 31% in early

Table 1
Relationship between tree canopy diameter and tree nitrogen demand for avocado trees (g N per tree).

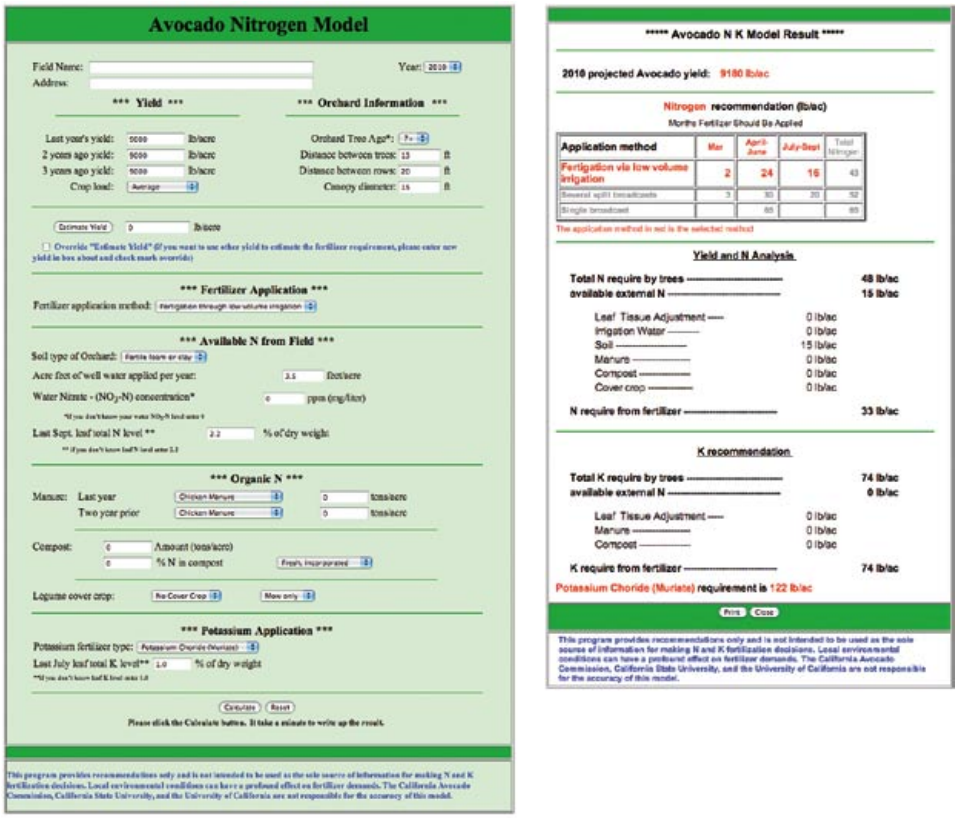
Tree Canopy Diameter (m)	End of fruit drop period (early July)	6 weeks later (mid August)	4 weeks later (mid September)	4 weeks later (mid October)	Total
	(grams Nitrogen per Tree)				
2	9	9	7	3	29
4	36	36	27	13	111
6	79	79	59	30	246
8	141	141	106	53	440
10	217	217	163	81	679

July, 2) 31% in mid August, 3) 26% in mid September, and 4) 13% in mid October.

Leaf nitrogen levels also affect the amount and timing of N fertilization recommendations. If leaf tissue nitrogen is excessive, nitrogen recommendations are reduced. For example, 6 lbs N/acre are subtracted from the budget for every tenth of a percentage above 2.6 %N. In terms of timing, if leaf nitrogen is low, the program recommends applying more N at the start of inflorescence bud break.

These factors above are used as inputs into the model (Figure 1). Currently we are trouble-shooting the model. In the future we will

Figure 1
Nitrogen and potassium fertilizer model for the 'Hass' avocado in California, input (left) and output (right)



be adding zinc fertilization to the model.
An important factor to take into account to determine zinc recommendations is root health of the orchard. The key questions is the problem lack of zinc or lack of roots? Avocados have a relatively shallow root system, which is highly susceptible to Phytophthora root rot. This disease will degrade the root system of avocado trees and will strongly decrease zinc uptake. Thus, a query will be included in the model to evaluate if roots are present in the leaf litter or mulch.

RECOMMENDATIONS

Three grower presentations showcasing the model were given in San Luis Obispo, Ventura, and Temecula this past summer. We received very good feedback concerning the model from three meetings that occurred in June 2010. For example, the recommended timing of fertilizer application in the model is currently based on calendar date. Growers mentioned that fertilizer applications should be based on tree phenology rather than calendar date because of the very different climates where avocados are grown in California.

LITERATURE CITED

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Impact of Low-Residue Winter Cover Crops on Sediment and Nutrient Loss

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INTRODUCTION

Complying with the Central Coast Regional Water Quality Control Board Agricultural Waiver regulations is an especially difficult challenge for the Salinas Valley, because of the intensive rotations and the nearly, year-round production. Cool season vegetables are high value and fertilizer costs represent a small portion (approximately 3%) of the total production budget (Tourte and Smith, in press).

As a result, given economics of these crops, there is little incentive to reduce fertilizer rates and there is a tendency for fertilizer rates to exceed the nutrient needs of the crop. In addition, there are other factors that lead to a buildup of nitrate in the soil of production fields: 1) slow adoption of the presidedress nitrate quick test to account for residual nitrate pools that are available in the soil; 2) high levels of nitrogen returned to the soil from previous crops; 3) high mineralization rates of the soil organic matter and previous crop residue. As a result of these factors, soil nitrate levels tend to peak in the fall, just before the beginning of the rainy season (Smith, Schulbach, and Jackson 1997). In addition, soil phosphorus levels are also high in Salinas Valley soils (i.e. mean values of 70 ppm); this is primarily due to little use of soil tests to guide phosphorus fertilization (Johnstone et al, 2005). Winter cover crops absorb excess soil nitrate and maintain it in the plant biomass, thereby reducing the potential for nitrate leaching. Winter cover crops are also an excellent practice for protecting the soil and reducing sediment and nutrient losses during storm events (Smith and Cahn, 2007). However, the use of winter cover crops is severely limited in the Salinas Valley for the following reasons: 1) high land rents discourage tying up ground with a non-cash crop; and 2) winter cover crops increase the risk of getting rained out of the fields in the spring and thereby potentially missing planting dates.

Given the benefits that cover crops can provide in reducing nutrient loss from vegetable production fields and the impediments to their use, we are researching an alternative cover crop strategy which uses low residue cover crops. These cover crops cover during the period of high intensity rainfall but are killed before they fully mature and impede subsequent early-spring soil preparation and planting operations.

PROJECT OBJECTIVES

1. Evaluate the impact of low-residue cover crops on sediment and nutrient loss as well as nitrate leaching during winter storms.
2. Compare the efficacy of faster growing cereal rye 'AG102' and slower growing triticale '888'.

PROJECT DESCRIPTION

The trial was conducted with a cooperating grower east of Salinas. The site had slopes of approximately 1%. There were three replications of each treatment and each plot was eight 40 inch beds wide by 1,100 feet long. Cereal rye 'AG104' and winter dormant triticale '888' were seeded on November 13, 2009, lillistoned into the soil the next day and germinated by sprinkler irrigation on November 24, 2009. Cover crop were treated with 2% glyphosate on January 15, 2010 (52 days after germination), to assure manageable levels of residue. The untreated control was also treated for weeds at this time. Cover crop growth was measured by biomass sampling on seven dates.

Runoff from the plots was measured during rain events during the course of the trial. Runoff from each plot was channeled through flumes at the base of the slope. The flumes were instrumented to measure the flow rate and total volume of runoff. An automatic sampler collected composite samples of runoff during storm events. Water samples were sent to the Division of Agriculture and Natural Resources (DANR) Analytical laboratory at University of California, Davis for nutrient and sediment analyses. To measure nitrate leaching, four suction lysimeters, two feet deep, were installed in one replication of the rye and control treatments to measure deep percolation of nitrate. Leachate samples were drawn from the lysimeters by applying 40 cbars of suction prior to rainfall events and collecting the leachate following the rainfall event. Nitrate leaching was estimated from the concentration of nitrate in leachate samples and by estimating the amount of percolation during storm events from rainfall, soil moisture storage, and evapotranspiration data.

RESULTS AND DISCUSSION

Rye 'AG104' initially grew faster than triticale 'Trios 102' and had significantly greater biomass at 16 and 40 days after germination (Figure 1). 'AG 104' was sprayed with glyphosate at 55 days after germination, but biomass continued to accumulate for 21 more days and peaked at 0.48 tons/acre at 76 days after germination. 'Trios 102' was sprayed with glyphosate at 70 days after germination and its biomass peaked at 0.34 tons/acre at 87 days after germination. After reaching their peak of biomass, the biomass levels of both varieties declined. Nitrogen accumulation roughly followed the same pattern as the biomass accumulation. Both cover crop varieties contained 30 lbs N/acre in the tops at 76 days after germination (Figure 2). 'AG 104' maintained higher levels of nitrogen in its biomass than 'Trios 102' at 87 days after germination, but nitrogen levels in both cover crops declined at 112 days after germination. Percent ground cover followed the same pattern as biomass accumulation. Both cover crops had about 90% ground cover at 76 days after germination. Percent ground cover of both cover crops declined at 87 days after germination

Runoff events occurred during February and the beginning of March 2009, when a majority of the rainfall occurred (Figure 4). Runoff was measured most frequently in the fallow plots. Only one runoff event occurred in the'AG104' treatment, and no runoff occurred in 'Trios 102' (Table 1). Average storm runoff volumes were highest in the bare fallow treatment. Average suspended sediment, total nitrogen, orthophosphate, and total phosphate concentrations in runoff collected from the fallow treatment between March 3 and 4, exceeded regional water quality standards for agricultural runoff (Table 2). Nitrate-N levels in leachate collected from the

'AG 104' and fallow treatments ranged from 130 to 234 mg/L between February 12 and March 5, 2009. Estimated leaching losses of nitrate-nitrogen were 132 and 155 lb of N/acre for the 'AG 104' and fallow plots, respectively.

CONCLUSIONS

Low residue cover crops can provide rapid ground cover. Cover crop residues increased for 2-3 weeks following being sprayed by glyphosate but declined thereafter. Decomposition of cover crop residues assured that the residue will not impede land preparation and planting for the subsequent vegetable crop. Low residue cover crops accumulate modest amounts of nitrogen in their biomass but it is not retained after the cover crop is killed by herbicides. Storm run-off was significantly reduced using the low residue cover crops.

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ACKNOWLEDGEMENTS

This research was supported by CDFA-FREP. We appreciate the collaboration with Ed Mora of D'Arrigo Brothers.

Completed Projects List

The following is a list of final reports for FREP-funded research. In parentheses following the title is the name of the primary investigator and the project reference number. We invite you to view the full final reports by visiting the California Department of Food and Agriculture's Fertilizer Research and Education Program website at www.cdfa.ca.gov/is/fflders/frep.html ; or, you may contact the program at frep@cdfa.ca.gov , (916) 445-0444 to obtain printed copies.

FRUIT, NUT AND VINE CROPS

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

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

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

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

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

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

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

Development of Nitrogen Fertilizer Recommendation Model for California Almond Orchards
(Patrick Brown and Steven A. Weinbaum, 93-0613)

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

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

Using High Rates of Foliar Urea to Replace Soil-Applied Fertilizers in Early Maturing Peaches
(R. Scott Johnson and Richard Rosecrance, c. 1995)

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

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

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

Development of Nitrogen Fertilizer Recommendation Model for California Almond Orchard
(Steve Weinbaum, 93-0613)

Nitrogen Efficiency in Drip-Irrigated Almonds
(Robert J. Zasoski, 93-0551)

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

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

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

Potential Nitrate Movement below the Root Zone in Drip-Irrigated Almonds
(Roland D. Meyer, 92-0631)

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

Nitrogen Fertilizer Management to Reduce Groundwater Degradation
(Steve Weinbaum)

VEGETABLE CROPS

Development of practical fertility monitoring tools for drip-irrigated vegetable production
(Timothy K. Hartz, 06-0626)

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

Detecting and Correcting Calcium Limitations
(Timothy K. Hartz, 04-0701)

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

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

Efficient Phosphorus Management in Coastal Vegetable Production
(Timothy K. Hartz, 01-0509)

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

Reducing Fertilizer Needs of Potato With New Varieties and New Clonal Strains of Existing Varieties
(Ronald Voss, 00-0514)

Effect of Different Rates of N And K on Drip-Irrigated Beauregard Sweet Potatoes
(Bill Weir, 00-0507)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Nitrogen Management through Intensive on-Farm Monitoring
(Timothy K. Hartz, 94-0362)

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

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

Optimizing Drip Irrigation Management for Improved Water and Nitrogen Use Efficiency
(Timothy K. Hartz, c. 1992)

FIELD CROPS

Fertilization Technologies for Conservation Tillage Production Systems in California
(Jeffrey Mitchell, 01-0123)

Site-Specific Fertilizer Application in Cotton
(Richard Plant, 01-0507)

Fertility Management in Rice
(Chris Van Kessel, 04-0704)

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

Leaf Color Chart for California Rice
(Randal Mutters, 01-0510)

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

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

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

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

Development of Irrigation and Nitrogen-Fertilization Programs for Turfgrass
(Robert Green, 97-0365 M97-07)

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

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

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

Long Term Rice Straw Incorporation: Does It Impact Maximum Yield?
(Chris Van Kessel and William Horwath, 00-0651)

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

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

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

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

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

Establishing Updated Guidelines for Cotton Nutrition
(Bill Weir and Robert Travis, 94-0193)

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

HORTICULTURE CROPS

Nitrogen Run-off in Woody Ornamentals
(Donald J. Merhaut, 00-0509)

Precision Horticulture: Technology Development and Research and Management Applications
(Patrick Brown, 00-0497)

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

IRRIGATION AND FERTIGATION

Ammonia Emission from Nitrogen Fertilizer Application
(Charles Krauter, 00-0515)

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

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

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

Uniformity of Chemigation in Micro-irrigated Permanent Crops
(Larry Schwankl, Terry Prichard, 97-0365 M97-08B)

Agricultural Baseline Monitoring and BMP Implementation: Steps Towards Meeting TMDL Compliance Deadlines within the Newport Bay/ San Diego Creek Watershed
(Laosheg Wu and John Kabshima 97-0365 M99-01)

Site-specific Fertilizer Application in Orchards, Nurseries and Landscapes
(Michael Delwiche 06-0600)

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

EDUCATIONAL AND MISCELLANEOUS

Development and implementation of Online, Accredited Continuing Education Classes on Proper Sampling and Application of Nitrogen/ Crop Nutrients
(Renee Pinel, 07-0223)

California Certified Crop Adviser FREP Educational Project
(Dan Putnam, 07-0352)

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

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