

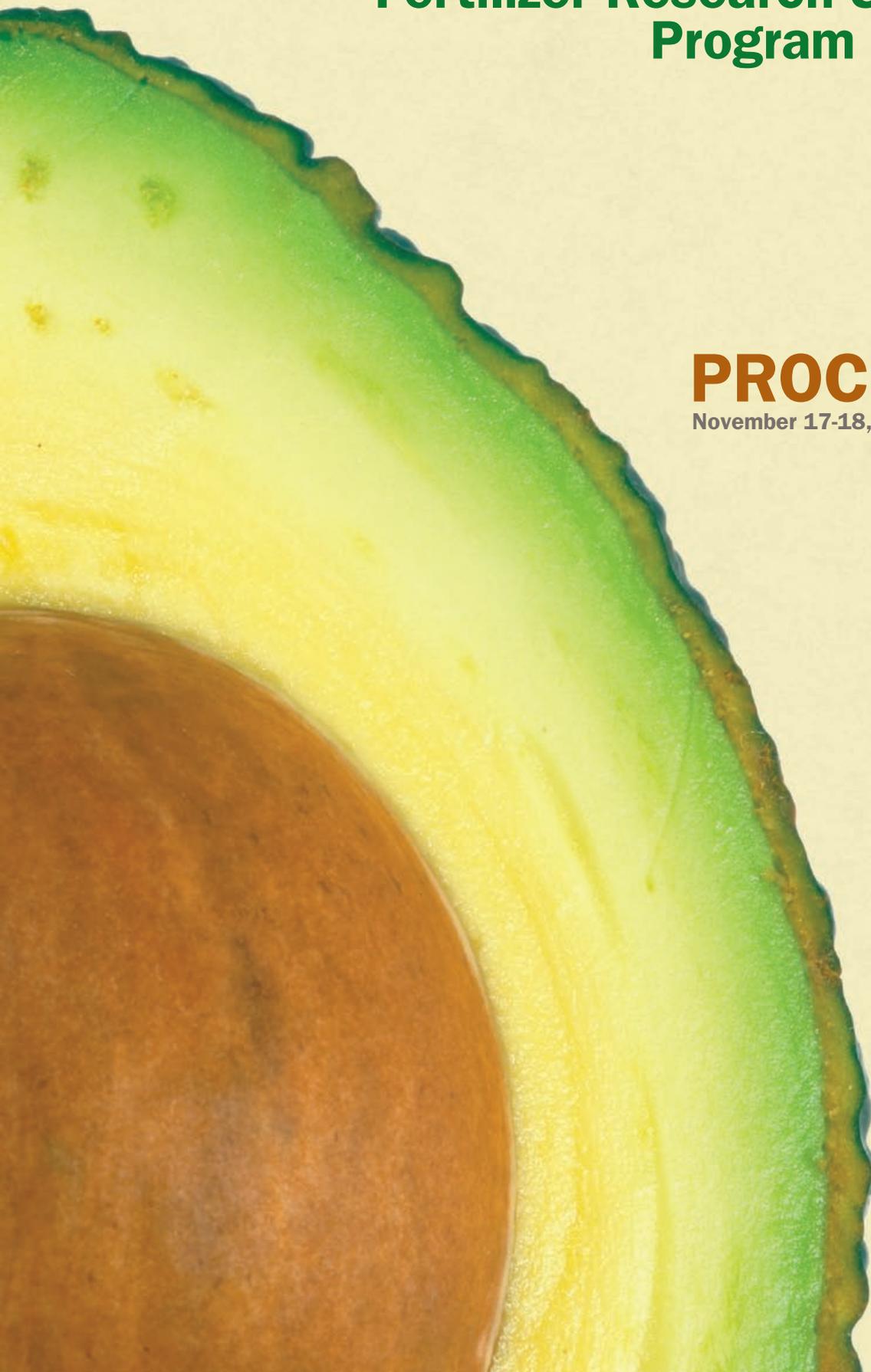
Seventeenth Annual

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
**Fertilizer Research & Education
Program Conference**



PROCEEDINGS

November 17-18, 2009 • Visalia, California



Seventeenth Annual

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
**Fertilizer Research & Education
Program Conference**

PROCEEDINGS

November 17-18, 2008
Visalia, California



Kelsey Olson
Editor



CALIFORNIA DEPARTMENT OF
FOOD & AGRICULTURE

To order additional copies of this publication, contact:

California Department of Food and Agriculture
Fertilizer Research and Education Program
1220 "N" Street
Sacramento, California 95814
(916) 445-0444 · FAX (916) 445-2171
frep@cdfa.ca.gov
www.cdfa.ca.gov/is/flders/frep.html

Publication design:

Ward Associates
Sacramento, California

Note:

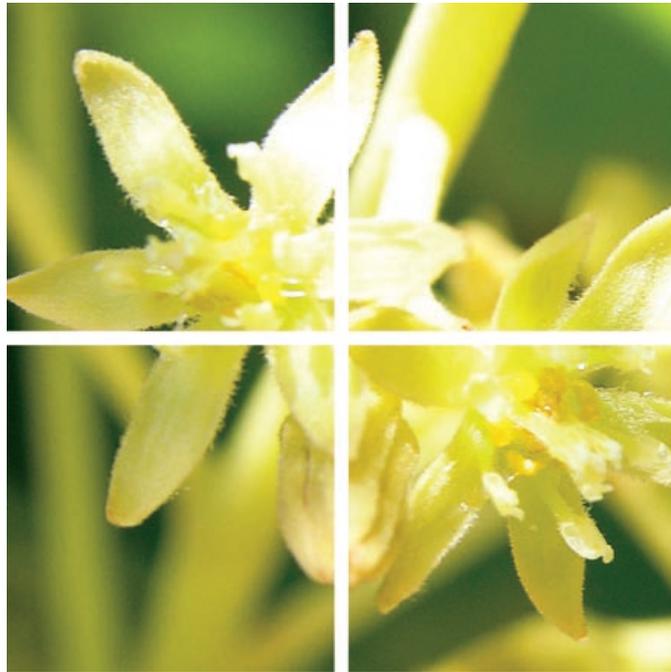
The summaries in this publication that are results of projects in progress have not been subjected to independent scientific review.

The California Department of Food and Agriculture makes no guarantee, expressed or implied, and assumes no legal liability for any of the information contained in this publication.

Table of Contents

INTRODUCTION	5
CONFERENCE PROGRAM	11
SUMMARIES OF PRESENTED FREP RESEARCH PROJECTS	15
17 Developing a Model System for Testing Foliar Fertilizers, Adjuvants and Growth Stimulants Project Leader: Patrick Brown	41 Can a Better Tool for Assessing 'Hass' Avocado Tree Nutrient Status be Developed? Project Leader: Carol Lovatt
25 Matching Fertilizer Applications to Seasonal Growth Patterns in Avocado Project Leader: Richard Rosecrance	51 California Certified Crop Adviser Educational Project Project Leader: Dan Putnam
29 Impact of Low-Residue Winter Cover Crops on Sediment and Nutrient Loss Project Leader: Richard Smith	55 Optimizing Nitrogen Availability in Cherry Growth to Obtain High Yield and Fruit Quality Project Leaders: Kitren Glozer, Joe Grant, and Gregory Lang
35 Precision Delivery of Fertilizer to Satisfy Crop Demand Project Leaders: Michael Delwiche and Robert Coates	
SUMMARIES OF OTHER ONGOING FREP RESEARCH PROJECTS	63
65 Development of Leaf Sampling and Interpretation Methods for Almond Project Leader: Patrick Brown	85 Comparing the Efficiency of Different Foliarly-Applied Zinc Formulations on Peach and Pistachio Trees by Using ⁶⁸ Zn Isotope Project Leader: R. Scott Johnson
69 Development of a Nutrient Budget Approach to Fertilizer Management in Almond Project Leader: Patrick Brown	91 Balancing Fertilizer Application Rates with Water Quality Protection in Strawberry Production Project Leader: Thomas R. Lockhart
75 Evaluation of Humic Substances Used in Commercial Fertilizer Formulations Project Leader: Timothy K. Hartz	95 New Standard for the Effectiveness of Foliar Fertilizers Project Leader: Carol Lovatt
83 Development of a Comprehensive Nutrient Management Web Site for the California Horticultural Industry Project Leader: Timothy K. Hartz	99 Western Fertilizer Handbook, Turf and Ornamental Edition Project Leaders: Renee Pinel and Pam Emery
LIST OF COMPLETED FREP RESEARCH PROJECTS	101

Introduction



INTRODUCTION

Fertilizer Research and Education Program

FOR 16 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 2009 event combines the 17th 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

The Fertilizer Research and Education Program 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.

The 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 2010:

- 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 fertilizer 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 fertilization 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.

**FIGURES 1-3
FREP PROJECT FUNDING**

These figures illustrate the variety of geographical regions, commodities, and disciplines covered by FREP projects during the past 19 years.

Figure 1
FREP Projects by Geographic Region 1991-2009

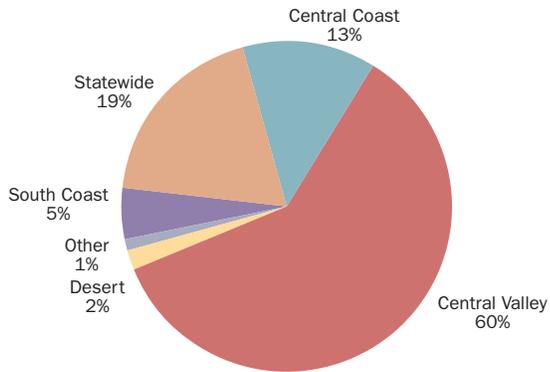


Figure 2
FREP Projects by Discipline 1991-2009

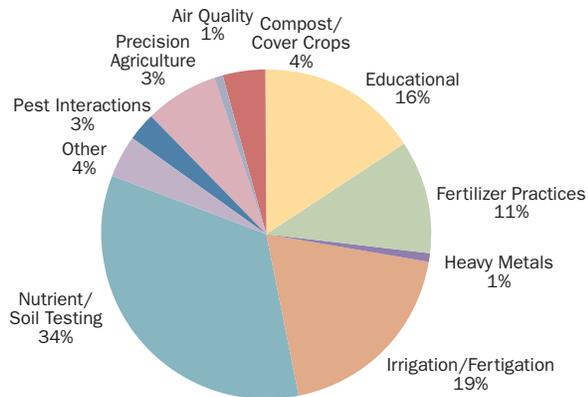
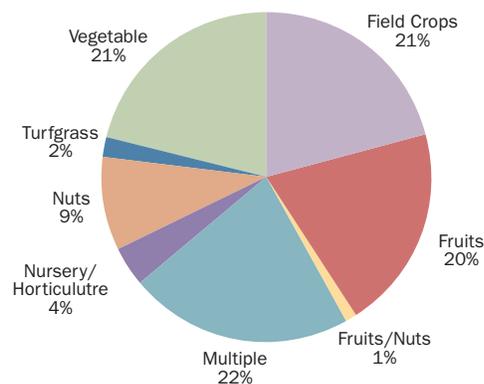


Figure 3
FREP Projects by Commodity 1991-2009



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 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 uncertainty of growers' fertilizer management decisions regarding implementation of environmentally and economically sound use of fertilizing materials.

The study will also evaluate the applicability of research with respect to relative economic importance of the different crops grown in California, of crop-specific fertilizer demand and use by these crops, and with respect to the environmental and agronomic conditions relevant in the crops' respective growing regions. The goal of the effort is to allow FREP perspective of where research efforts have paid off with sufficient range of improved fertilizer management practices and 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 recognize the members of the Fertilizer Inspection Advisory Board's Technical Advisory Subcommittee who review and recommend projects for funding. The professionalism, expertise and experience of Jack Wackerman (chairman), Michael Cahn, Eric Ellison, Rolf Frankenbach, Bob Fry, Tom Gerecke, 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 are the project leaders and cooperators themselves, as well as numerous professionals who peer-review project proposals, significantly enhancing the quality of FREP's work.

Special recognition also goes to the leadership at the California Department of Food and Agriculture, including Nate Dechoretz, Inspection Services Division Director; Asif Maan, Feed, Fertilizer, Livestock Drugs and Egg Regulatory Services (FFLDERS) Branch Chief; and Amadou Ba, Fertilizing Program Branch Chief. Staff Environmental Scientist Amrith Gunasekara is acknowledged for his contributions. FREP Specialist Kelsey Olson is credited for her invaluable role in the publication of this proceedings booklet, and in publicity and coordination of this year's conference. Additional help from Devan Arredondo and the rest of the FFLDERS Branch support staff is also greatly appreciated.

Conference Program



Conference Program

TUESDAY, NOVEMBER 17, 2009

9:00-9:15 Welcome
A.G. Kawamura, Secretary, CDFA (invited)
Renee Pinel, President/CEO, WPHA

Facilitator
Jerome Pier, Crop Production Services

NITROGEN MANAGEMENT

9:15-9:45 *Nitrogen History, Efficiencies, and Where We Are Today!*
Rob Mikkelsen, International Plant Nutrition Institute

9:45-10:15 *Determining Nitrogen Requirements for Drip-irrigated Vegetable Crops*
Timothy K. Hartz, UC Davis

10:15-10:45 *Model System for Testing Foliar Fertilizers*
Patrick Brown, UC Davis

10:45-11:00 Break

11:00-11:30 *Matching Fertilizer Applications to Seasonal Growth Patterns in Avocado*
Richard Rosecrance, CSU Chico

11:30-Noon *Impact of Low-Residue Winter Cover Crops on Sediment and Nutrient Loss*
Richard Smith, UC Davis

Noon-1:00 Lunch

1:00-1:30 *Nitrous Oxide Emissions from Fertilizer Practices*
Dave Goorahoo, CSU Fresno

1:30-2:00 *A Global Look at Nitrogen—Regulations, Pricing and Availability*
Jay Yost, Independent Agribusiness Professionals

WATER MANAGEMENT

2:00-2:30 *Implications of Reduced Irrigation on Plant Physiology and Plant Nutrition*
Don Merhaut, UCCE, Riverside County

2:30-2:45 Break

2:45-3:15 *Role of Plant Nutrition in Water-use Efficiency*
Eric H. Ellison, J.R. Simplot Company

3:15-3:45 *Integrating Irrigation and Nitrogen Fertilizer Management in Vegetables*
Michael Cahn, UCCE, Monterey County

3:45-4:15 *Potential Nitrate Groundwater Regulations in the Central Valley*
Nasser Dean, WPHA

4:15-4:30 Concluding remarks

WEDNESDAY, NOVEMBER 18, 2009

9:00-9:15 Welcome
 Nate Dechoretz, Director, Inspection Services Division, CDFA
 Renee Pinel, President/CEO, WPHA

 Facilitator
 Rob Mikkelsen, International Plant Nutrition Institute

TOOLS IN PLANT NUTRIENT MANAGEMENT

9:15-9:45 *Knowing Your Fertilizer "Rights"*
 Tom Gerecke, Actagro

 9:45-10:15 *Precision Delivery of Fertilizer to Satisfy Crop Demand*
 Michael Delwiche and Robert Coates, UC Davis

 10:15-10:45 *Can a Better Tool for Assessing 'Hass' Avocado Tree Nutrient Status be Developed?*
 Carol Lovatt, UC Riverside

 10:45-11:00 Break

 11:00-11:30 *Enhanced Efficiency Fertilizers—Tools or Toys?*
 Alan D. Blaylock, Agrium Advanced Technologies

 11:30-11:45 *California Certified Crop Advisers—Here to Serve the Customer*
 Allan Romander, CaCCA Program

 11:45-12:15 *Optimizing Nitrogen Availability in Cherry for Yield and Fruit Quality*
 Kitren Glozer, UC Davis

 12:15-1:15 Lunch

 1:15-1:45 *Making the Most of Organic Sources of Nitrogen*
 David Crohn, UC Riverside

AGRICULTURAL LABORATORIES

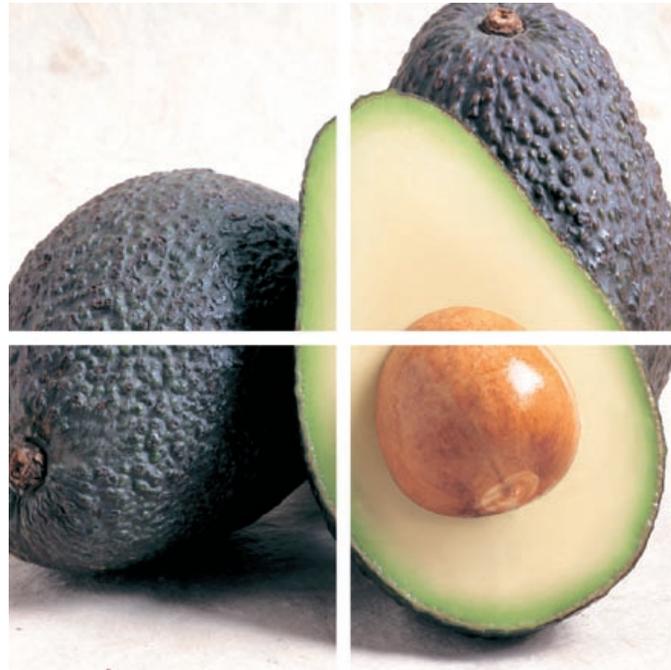
1:45-2:15 *So How Do You Really Get a Good Soil Sample?*
 Michael Larkin, Crop Production Services

 2:15-2:45 *Selecting a Testing Lab*
 Dirk Holstege, ANR Analytical Lab, UC Davis

 2:45-3:15 *Soil, Water and Tissue Testing—A Grower's Perspective*
 Blake Carlson, BNL Farms

 3:15-3:30 Concluding remarks

Summaries of Presented FREP Research Projects



Development of a Model System for Testing Foliar Fertilizers, Adjuvants and Growth Stimulants

PROJECT LEADER

Patrick Brown

Professor

Department of Plant Sciences

University of California

One Shields Avenue

Davis, CA 95616

(530) 752-0929

phbrown@ucdavis.edu

INTRODUCTION

Foliar fertilization and the application of foliar stimulants, adjuvants and other non-pesticide materials (foliar chemicals) have become a central practice of many agricultural producers. Our understanding of these products, is however, remarkably poor and for the majority of foliar fertilizers used in Californian agriculture there is very little information on nutrient uptake, nutrient use efficiency, nutrient transport or the application conditions that optimize efficiency and return on investment.

Foliar chemicals are used for a number of reasons; some of which have a clear physiological and production rationale while others are of doubtful utility. Valid reasons for the use of foliar chemicals include the correction of low nutrient availability in soils (e.g., iron deficiency in high pH soils), overcoming limitations induced by environment (foliar zinc in spring), overcoming excessive nutrient demand during fruit growth (nitrogen, potassium in nuts), targeted fruit quality enhancement and the need to ensure time critical delivery of nutrients to specific tissues (boron to flowers and fruit, calcium to fruit). It is well documented that plant response to foliar-

applied nutrients in the field is an extremely complicated process, which depends on the nutrient status of the plant, species as well as timing of application and environmental factors (Weinbaum, 1988). As a result, contradictory results are often found with the same chemical and the same plant species but with different locations and under various conditions (Buchholz et al., 1998; Weinbaum, 1988). Field trials of foliar fertilizers have frequently been difficult to replicate, hard to interpret and hence poorly adopted by growers.

Studies of foliar fertilizers conducted under controlled laboratory conditions, and frequently with excised tissues, have made significant contributions to our understanding of the principles involved in foliar uptake and can provide valuable insight into predicted field responses. Over the past decade the most significant advances in our understanding of foliar chemicals has been made by the German researchers Schonherr and Buchholz (see references in Fernandez and Ebert, 2005), who have determined that the cuticular membrane is the most important, or the sole pathway, for the foliar nutrients (Marschner, 1995). Recent

evidence, however, suggests that stomatal penetration of aqueous solutions may be an important pathway for nutrient uptake that was overlooked in laboratory-based experimentation in which stomata were absent or not considered (Fernandez and Ebert, 2005). While advances in fundamental understanding have the potential to greatly improve field application, there have been remarkably few attempts to use this information to explain field responses.

Determination of the relative nutritional effectiveness and physiological impact of the wide variety of foliar nutrient formulations available in the market for field and horticultural crops is an experimentally complex, time consuming and inexact science. For many growers, farm advisors, consultants and sales persons making recommendations on the use of the plethora of available foliar materials represents a tremendous challenge. Additionally, for companies that have produced quality, effective products, there is great difficulty in separating their product from those that are less effective.

Current approaches to determining the effectiveness of a particular nutrient formulation are crude and time consuming and do not easily allow for the determination of the biological or environmental factors that determine formulation effectiveness. Studies such as this are typically conducted in the field with the incumbent limitations on environmental control, replicability and reproducibility. Given the very significant degree of uncontrolled variability in field experimentation it is often very difficult to determine the true effectiveness of a product and misleading results can easily be obtained. Field experimentation rarely provides adequately robust information to truly determine the physiological basis underlying a superior material or approach, without this information, results of experiments cannot serve as good predictors of the effectiveness of an approach under different field conditions.

Our goal is to develop a quick and easy system for testing foliar chemicals and to use that system to determine the most effective commercially available products.

OBJECTIVES

- 1 Develop a model system for testing the efficacy of a broad range of foliar chemicals.
- 2 Conduct tests of materials of greatest relevance to growers under standardized conditions. Undertake focused field verification.
- 3 Undertake focused field verification.
- 4 Conduct preliminary research on effect of plant anatomy (stomatal density and distribution, cuticle composition, leaf waxes and hairs, etc.) on foliar efficacy as a prelude to development of new and targeted formulations. (Future goal.)

DESCRIPTION

Task 1: Establish a model growth system to test foliar products

A model system has been developed that allows for rapid replication, careful environmental control, precise foliar nutrient applications and intelligent sampling protocols to determine true nutrient use efficiency. The test-plant system (*Arabidopsis*), which has a short 45- to 60-day life cycle (cultivar dependent) and a very distinct vegetative/floral transition period allows for rapid and reproducible results. Plants were grown in a controlled environment growth chamber in a system that prevents the inadvertent contact of foliar fertilizers with soil. The rapid growth of the test plant allows us to determine both the degree of uptake and the movement of the foliar chemical within the plant. Since this test measures the combined effects of foliar absorption and within plant transport it can be viewed as highly rigorous. Foliar spray materials that do result in either foliar uptake or transport within the plant will be identified. While the method has worked

well for micronutrients it was determined that trials with macronutrients calcium and potassium (Ca and K) would require a new growth media with a greater capacity for precise and rapid manipulation of soil nutrient availability. A variety of growth materials were tested.

Task 2: Test a variety of common foliar products and rates

In addition to the system development and formulation trials, a total of seventeen independent trials of commercial products have now been completed or are underway (Table 1). These trials have evaluated a total of 50 discrete products. In zinc (Zn) trials, products have been contrasted at both fixed application rates of 400 ppm or at approximate field rates for tree crops (Table 2). In potassium, calcium and boron trials, materials have been contrasted at field rates. Additional replications of calcium, boron and potassium trials are underway and integrated results will be presented at a later date.

Task 3: Conduct targeted field validation

Replication of results with select zinc products identified here has been conducted by Scott Johnson and is reported separately. Trials on efficacy of most promising products are tested for an almond orchards and tomato field in 2009.

Task 4: Conduct preliminary research to develop new and targeted formulations

On the basis of early results and theoretical considerations we have conducted tests to determine the relative influence of formulation, additives and surfactants on the uptake and transport of foliar applied zinc. This work has resulted in the development of a new and highly promising zinc formulation (UC Davis Formula #1). We have also tested results of model system trials in a second herbaceous species *Vinca minor* by applying droplets of 29 μ l of 7.5mM ^{68}Zn labeled products to isolated portions of the leaf with or without the addition

of 4000 ppm calcium as calcium nitrate, and/or SAF-T-Side commercial spreader/sticker. The transport of zinc was determined by measuring the appearance ^{68}Zn in leaf regions outside the treated area.

RESULTS AND DISCUSSION

Baseline conditions for plant growth have been established and Perlite has been adopted as the primary growth medium. Briefly growth conditions are: *Arabidopsis* in a controlled environment growth chamber with day length of 16 hours and light intensity of $120 \mu\text{mol.m}^{-2} \cdot \text{sec}^{-1}$, day/night temperature: 22/20°C, relative humidity 70%. Plants were provided water and nutrients by root submersion technique. The soil surface is protected from spray drift by covering the entire surface with a plastic cover. Subsequent to emergence the junction between plant stem and plastic is sealed with lanolin. The system prevents any contamination of rooting media with foliar spray. Results clearly demonstrate the effectiveness of the system at avoiding soil contamination and validates that elemental enrichment found in reproductive tissues of foliar treated plants is solely the result of the foliar uptake and transport of the applied foliar material and not a consequence of soil contamination.

Eight trials of common foliar zinc products have now been completed. Table 2 provides a summary of each of these trials. In all cases results represent relative efficacy in contrast to the unsprayed control and zinc sulfate (Zn sulfate, 400 ppm). In all trials to date the amount of foliar-applied zinc that was subsequently measured in the reproductive tissues represented only from 0 to 15% of the total applied zinc thus illustrating the relatively low overall efficacy of all current foliar zinc materials. When provided at a uniform concentration of 400 ppm materials with a high degree of solubility that provide zinc in the presence of putative complex forming compounds, as well as NZn, exhibited significantly

more relative efficacy than inorganic salts and insoluble zinc products. In general, products that contain amino acids were marginally less effective than products based on carbohydrate complexation. Zn EDTA and NZn were relatively very effective, though marginally less effective than the carbohydrate (CHO) complexes.

When provided at full field rate, several inorganic zinc products that were shown to be marginally effective at 400 ppm showed significant improvement and performed as well as many of the high solubility complexed materials. Zn sulfate provided at 400 ppm was only moderately effective (ranking 5); however, when provided at 1500 ppm, was ranked among the most effective products. Similarly, Neutral Zn, which was shown to be largely ineffective when provided at 400 ppm, was ranked among the most effective products (ranking 8) when provided at 1860 ppm. RNA Microphos improved from mildly effective (3) to moderately effective (7.2) when the application rate was increased from 400 to 5000 ppm.

The application of calcium (Table 3) significantly increased by 200% the amount of ^{68}Zn that absorbed and transported in *Vinca minor* test plants. The use of the spray additive Safe-T-Side had no influence on relative efficacy of zinc sprays. The effectiveness of Ca on Zn transport has been observed in previous studies conducted in walnut and pistachio and will be pursued further in subsequent experiments.

Studies of Ca and K materials are underway. One Ca trial has been completed, but the limited information does not allow us to draw reliable information.

Field trials in both almond and tomato are underway using the most promising of materials observed in model system work.

On the basis of the integrated results we designed a new foliar zinc formulation (UC Davis Formula #1) that was shown to be highly effective (Table 2). Field trials of this material and other promising products were conducted in 2009 (results pending).

CONCLUSION

The approach used here has been shown an effective method to determine the relative efficacy of a variety of foliar test materials. Complexed and chelated materials are generally more efficient than inorganic sources; however, the effect of application rate on efficacy of inorganic zinc products is significant and illustrates the important difference between results expressed as efficacy as opposed to efficiency. Trials to validate these results in almond and pistachio are underway in collaboration with Dr. Scott Johnson and will be supplemented with trials conducted at University of California, Davis, in 2009. To avoid premature interpretations, results of the first trial results for Ca and B products and for zinc in almond and tomato will not be provided until subsequent validation is completed.

Table 1.

Record of experimental trials conducted to date. Results of select trials listed below have been reported previously (CDFA report 06-0624, 2008) or will be reported subsequent to additional replications.

Experiment number and title	Products tested*
1: Zinc Foliar Trial <i>All applied at 400 ppm Zn in solution.</i>	Zn EDTA (10%), NZn (5%), Neutral Zn (52%), Zn fulvic (7%), Zn lignosulfonate (7%), Zn Metalosate (7%), Zn sulfate (36%).
2: Zinc Foliar Trial <i>All applied at 400 ppm Zn in solution.</i>	Zn EDTA (10%), NZn (5%), Neutral Zn (52%), Zn fulvic (7%), Zn lignosulfonate (7%), Zn Metalosate (7%), Zn sulfate (36%).
3: Rubidium Leakage Trial	Rubidium Chloride 5000 ppm.
4: Zinc Foliar Trial <i>All applied at 400 ppm Zn in solution.</i>	NZn (5%), Zn oxide (40%), Zn Metalosate (7%), Krystal Klear Zn (9%), Bionutrient Zn (8%), ProNatural Zn (5.8%), RNA Microphos (52%), BioLink Zn (8%), BioMin Zn (7%), Zn sulfate (36%), RNA Zn Nitrate (10%).
5: Zinc Foliar Trial <i>All applied at 400 ppm Zn in solution.</i>	NZn (5%), Zn Oxide (40%), Zn Metalosate (7%), Krystal Klear Zn (9%), Bionutrient Zn (8%), ProNatural Zn (5.8%), BioLink Zn (8%), BioMin Zn (7%), Zn sulfate (36%), RNA Zn Nitrate (10%).
6: Potassium Foliar Trial 1 and 2	K-acetate, KNO ₃ , K ₂ SO ₄ , Metalosate K, Tracite, pHiger K, Manni-plex K, Manni-plex K acetate, 30 K plus control.
7: Zinc Foliar Trial (Vinca)	Influence of surfactants and Ca on Zn foliar uptake and transport.
8: Zinc Foliar Trial (almond)	Influence of surfactants, formulation and Ca on Zn foliar uptake and transport in filed grown almonds.
9: Zinc Foliar Trial <i>All applied at 400 ppm Zn in solution.</i>	NZn (5%), Zn fulvic (7%), Zn Metalosate (7%), Krystal Klear Zn (9%), Bionutrient Zn (8%), ProNatural Zn (5.8%), BioLink Zn (8%), BioMin Zn (7%), Zn sulfate (36%), Zn lignosulfonate (7%), Zn EDTA (10%), RNA Zn Nitrate (10%).
10: Zinc Foliar Trial <i>All applied at field rates.</i>	Zn Oxide (40%), Zn fulvic (7%), Zn Metalosate (7%), Bionutrient Zn (8%), ProNatural Zn (5.8%), RNA Microphos (52%), Zn sulfate (36%), RNA Zn Nitrate (10%), Zn oxide (40%), Neutral Zn (52%).
11: Calcium-Boron Trial 1 <i>All applied at field rates.</i>	CellMate (FBS), Boron Boost (FBS), FoliCal (Wilbur Ellis), Ca nitrate, Ca chloride.
12: Calcium-Boron Trial 2 <i>All applied at field rates.</i>	CaCl ₂ , 34%; Ca(NO ₃) ₂ , 11%; Wuxal Calcium, 15%; Ca phosphite (Vigor Cal, 4%); Ca citrate complex (FoliGro Calcium, 6%); ProNatural Calcium, 5%; NDemand Calcium, 5.5%; Foli-cal (Brandt), 10%; Actagro Ca, 7%; Cell-Mate-F +/- X-100, 8%.
13: Zinc Foliar Trial <i>All applied at 400 ppm in solution except UC Davis Formula #1.</i>	Actagro Zinc (6.5%), Actagro Zinc (6.5%) plus Monarch, Florentine Zinc (6%), Manni-plex Zn (7%), Zn EDTA (9%), Albion Zn Metalosate (6.8%).
14: Zinc Foliar Trial <i>All applied at field rate.</i>	Experimental Zn (7%), Zn sulfate, UC Davis Formula #1a, UC Davis Formula #1b, UC Davis Formula #1c, Actagro Zinc (6.5%).
15: Calcium-Manganese Foliar Trial <i>All Ca applied at 500 ppm and all Mn applied at 400 ppm.</i>	Biomin Ca (5%), Ca glycinate (5%), Exp Ca (10%), Folia-cal (%), CaCl ₂ (34%) Ca(NO ₃) ₂ ·4H ₂ O (16.9%), Exp Mn (5%), Manni-plex Mn (5%), Mn sulfate (32.5%) (RESULTS PENDING).
16: Zinc Foliar Field Trial (tomato) <i>All applied at field rate.</i>	UC Davis Formula #1a, UC Davis Formula #1b, UC Davis Formula #1c, Zn sulfate monohydrate (35.5%), Zn Manni-plex (7%), Zn EDTA (9%), Actagro Zinc 6.5%, Foli-gro NZn (5%), Neutral Zn (52%). (RESULTS PENDING).
17: Zinc Foliar Field Trial (almond) <i>All applied at field rate.</i>	UC Davis Formula #1a, UC Davis Formula #1b, UC Davis Formula #1c, Zn Metalosate (6.8%), Manni-plex Zn (7%) (RESULTS PENDING).

*Mention of a product trade name or commercial enterprise does not imply endorsement of this product or commercial enterprise by the author or the University of California, Davis.

Table 2.

Integrated results of six independent trials of zinc foliar materials. Five trials were conducted at standardized zinc concentrations in final solution (400 ppm), an additional trial was conducted at field concentrations determined as the approximate median of label rates. Where a single concentration is listed it implies that field rate does not vary significantly from 400 ppm. Overall rankings represent an integration of relative efficacy of product in comparison with control and with 400 ppm zinc sulfate which was utilized in all experiments.

Material name*	Concentration (ppm)	Overall ranking 1 = no significant difference from control; 2-4 = small increase in tissue Zn; 5-7 = consistent and significant increase in tissue Zn; 8-10 = consistent very significant increase in tissue Zn.	Comments
Zinc FL 1-0-0	400 ppm	1	40% Zn as Zn oxide. Miscible in water, solubility limited.
Neutral zinc	400 ppm	1	52% Zn oxide and sulfate.
Zn phosphate/oxide	400 ppm	3	52% Zn as phosphate/oxide mixture. Miscible in water, solubility limited.
Zinc fulvic acid	400ppm	4	7% Zinc fulvic acid complex.
Zinc sulfate	400 ppm	5	36% Zinc sulfate. Variability in response between experiments.
Chelate Zn 1	400 ppm	6	9% synthetic chelated Zn.
Zn lignosulfonate	400 ppm	6.5	7-10% Zinc sulfate lignosulfonate.
Chelate Zn 2	400 ppm	6.6	8% Zn, hydroxy-carboxylic, amino acid complex.
Zn nitrate	400 ppm	7.0	10% Zn as zinc nitrate. Variability in response between experiments.
Zn ohosphate/oxide	5000 ppm	7.2	52% Zn as phosphate/oxide mixture. Miscible in water, solubility limited.
Amino Zn 1	400ppm	7.2	5.8% Zn amino acid.
Complex Zn 1 acid, glycine	400 ppm	7.3	7% Zn sulfate, citric
Amino Zn 2	400 ppm	7.3	7% Amino complexed Zn.
Complex Zn 2	400 ppm	7.3	8% Zn.
Zn EDTA	400 ppm	8	10% EDTA complexed Zn.
Neutral zinc	1860 ppm	8	52% Zn oxide and sulfate.
Zinc sulfate	1500 ppm	8	36% Zinc sulfate.
NZn	400 ppm	8.4	5% Zn as Zn nitrate with urea and urea ammonia nitrate.
Zn CHO complex 1	400 ppm	8.6	6% Zn carbon complex.
Zn CHO Complex 2	400 ppm	9	7% Zn carbon complex.
UC Davis Formula #1	1000 ppm	10	25% Zn. Non-commercial product. Zn sulfate and Zn nitrate with organic complex and adjuvants.

* Mention of a product trade name or commercial enterprise does not imply endorsement of this product or commercial enterprise by the author or the University of California, Davis.

Table 3.

Influence of calcium and surfactant addition on efficacy zinc transport in *Vinca minor*.

Treatment	⁶⁸ Zn/ ⁶⁷ Zn ratio
Ck	4.72 ± 0.12
68Zn	6.45 ± 1.31
68Zn + Ca	13.4 ± 2.59
68Zn + SAT-T-SIDE	5.27 ± 0.16
68Zn + Ca + SAT-T-SIDE	14.3 ± 3.55

REFERENCES

- Buchholz, A., P. Baur and J. Schonherr. 1998. Differences among plant species in cuticular permeabilities and solute mobilities are not caused by differential size selectivities. *Planta* 206: 322-328.
- Fernandez , V., and G. Ebert. 2005. Foliar iron fertilization: a critical review. *Journal of Plant Nutrition*. 28: 2113-2124.
- Schonherr, J., V. Fernandez and L. Schreiber. 2005. Rates of cuticular penetration of chelated Fe-III: role of humidity, concentration, adjuvants, temperature, and type of chelate. *Journal of Agricultural Food Chemistry* 53: 4484-4492.
- Weinbaum, S.A. 1988. Foliar nutrition of fruit trees. In: Neumann. P.M. (ed.) *Plant growth and leaf applied chemicals*. CRC Press Boca Raton, Florida. Pages 81-100.
- Wittwer , S.H. and F.G. Teubner. 1959. Foliar absorption of mineral nutrients. *Annual Review of Plant Physiology* 10: 13-32

Matching Fertilizer Applications to Seasonal Growth Patterns in Avocado

PROJECT LEADER

Richard Rosecrance
Associate Professor
Plant Sciences, College of
Agriculture
California State University
Chico, CA 95926
(530) 898-5699
rosecrance@csuchico.edu

PROJECT LEADER

Carol J. Lovatt
Professor
Department of Botany and
Plant Sciences
University of California
4130 Batchelor Hall
Riverside, CA 92521-0124
(951) 827-4663
carol.lovatt@ucr.edu

COOPERATOR

Ben Faber
Farm Advisor
UC Cooperative Extension, Ventura
County
669 County Square Drive, #100
Ventura CA, 93003-5401
(805) 645-1451
bafaber@ucdavis.edu

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-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. 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 Trouble-shoot, 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 primary 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 (<1/2 inches), small branches (1/2-2 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 Web site

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

Fruit dry matter accumulation followed a double sigmoid curve (Figure 1). About half of the total fruit dry weight occurred between mid-May and mid-November and the remainder accumulated between mid-February until harvest in mid-July. During winter (November through February) little dry matter accumulation occurred. At fruit maturity, the flesh, seed, and peel comprised 67, 20, and 13% of the total fruit dry weight, respectively.

Similarly, nitrogen, phosphorus, and potassium (N, P, K) accumulation in fruit followed a double sigmoid pattern (Figure 2). Fruit nutrient accumulation occurred between mid-May and November and between April and July. Little N, P, and K accumulated during the winter and early spring, however the accumulation patterns differed among the nutrients. The N and P accumulation patterns were similar to dry matter accumulation with about 50% of the total fruit N and P contents occurring mid-May and November and 50% occurring from April to July. In contrast, only about 30% of the total fruit potassium content occurred between mid-May and November, while 70% of the fruit K accumulated between April and July.

Fruit dry weights and nutrient contents were closely correlated (Figure 3). Best-fit trend lines indicated that fruit dry weight was linearly related to fruit N and P content and exponentially related to fruit K. These data indicate that fruit dry weight can be used to estimate N, P, and K fruit content in well fertilized orchards. The differences in the nutrient accumulation patterns may reflect the various roles these nutrients play in the fruit. Unlike most fruits, cell division in

avocado mesocarp tissue is not restricted to the first 30 days after anthesis, but continues during fruit development and even occurs in the mature fruit attached to the tree. Indeed, cell division is the major factor that increases fruit size in the latter phase of fruit development. Both N and P play important roles in cell division and thus are required in order for the fruits to grow. Potassium is required for the production and transport of plant sugars that increase the weight of fruit. Thus, the large influx of K into fruit may reflect the role it plays in sugar transport as fruit reach maturity.

Fruit accumulated the majority of their nutrients between full bloom and autumn and during the following spring. These periods of high fruit nutrient demand should coincide with fertilizer applications. Spring (April) fertilization with nitrogen over a four-year period, for example, increased yield by 50% over the control where nitrogen was metered out in six N applications over the year (Lovatt, 2001). These increases occurred despite the lack of evidence of N deficiency in leaves. April nitrogen fertilization appears to be critical to support fruit development of the current crop, fruit set for the next crop, and growth of the vegetative flushes.

In the coming years this project will incorporate fruit and whole tree nutrient data into a nutrient fertility model for avocado trees. We are currently evaluating tree fertilization models and seeking input from growers and researchers to improve the models to meet the needs of California avocado growers.

LITERATURE CITED

- Arpaia, M.L., J.L. Meyer, G.W. Witney, G. S. Bender, D.S. Stottlemeyer, and P.R. Robinson. 1996. The Cashin Creek nitrogen fertilizer trial—what did we learn? California Avocado Society 1996 Yearbook, 80: 85-98.
- Lovatt, C. J. 2001. Properly timed soil-applied nitrogen fertilizer increases yield and fruit size of 'Hass' avocado. *Journal of the American Society for Horticultural Science*, 126(5): 555-559.

ACKNOWLEDGEMENTS

This research was supported by the California Department of Food and Agriculture's Fertilizer Research and Education Program and California Agriculture Research Initiative.

Figure 1.
Dry matter accumulation in avocado fruits over the season.

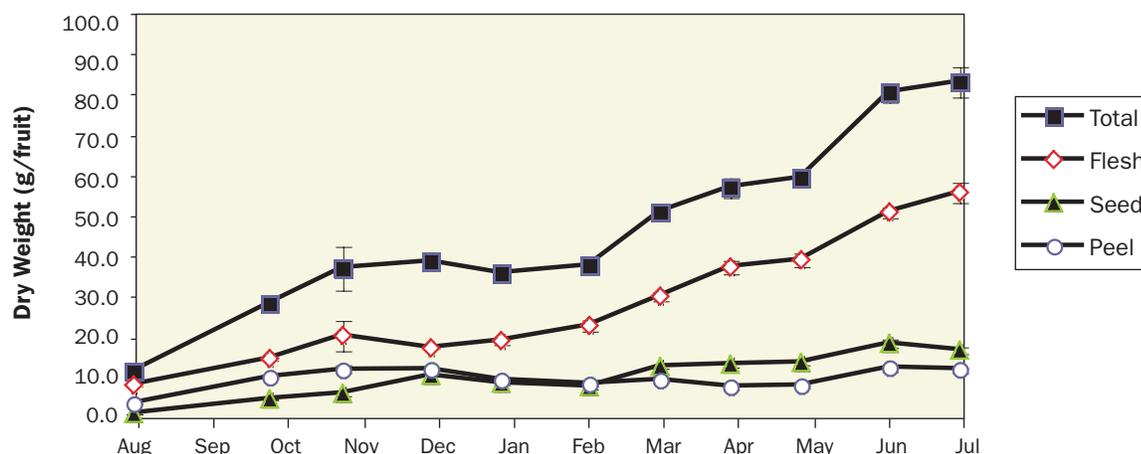


Figure 2.
 Nitrogen, phosphorus, and potassium
 accumulation in avocado fruits over the season.

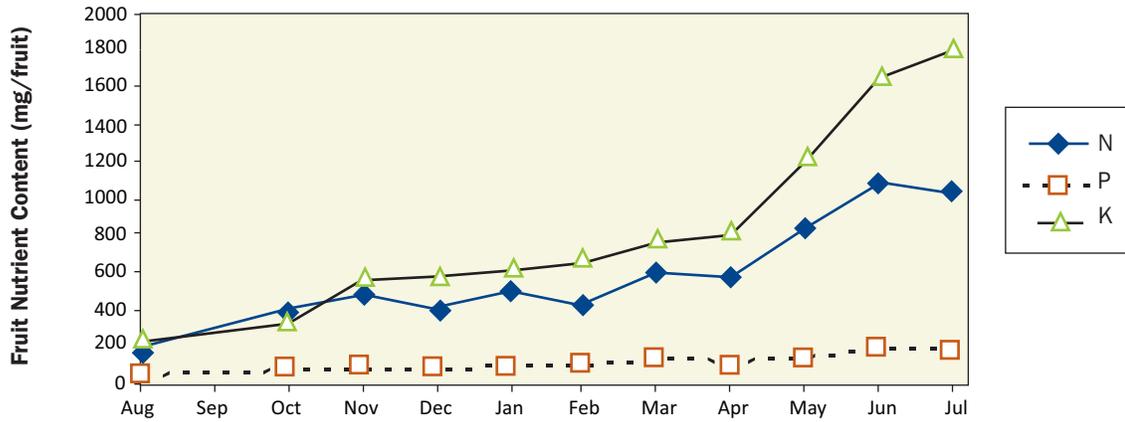
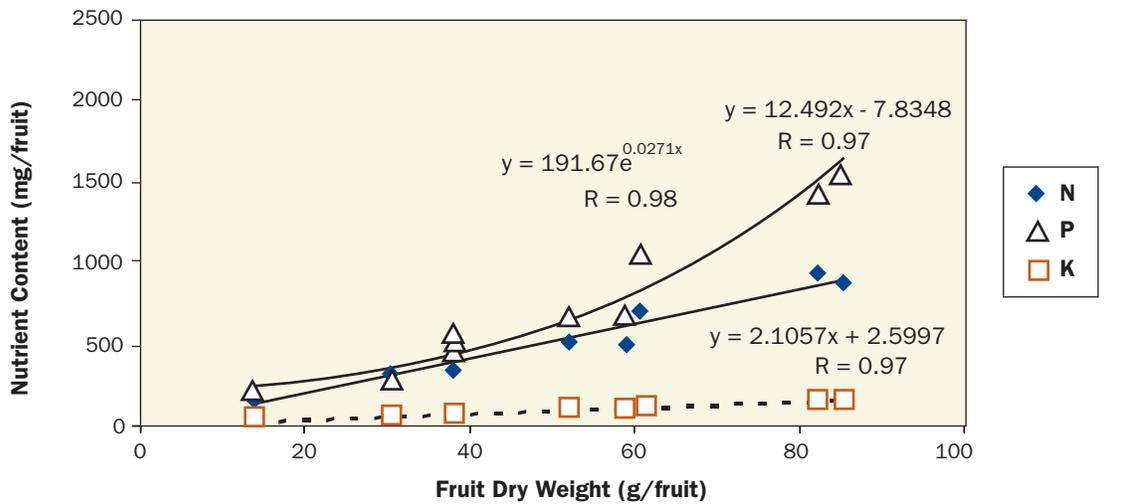


Figure 3.
 Relationship between dry matter content and
 nitrogen, phosphorus, and potassium accumulation
 in avocado fruits over the season.



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

PROJECT LEADER

Richard Smith
Farm Advisor
UC Cooperative Extension,
Monterey County
1432 Abbott Street
Salinas, CA 93901
(831) 759-7357
rifsmith@ucdavis.edu

PROJECT LEADER

Michael Cahn
Farm Advisor
UC Cooperative Extension,
Monterey County
1432 Abbott Street
Salinas, CA 93901
(831) 759-7377
mdcahn@ucdavis.edu

INTRODUCTION

Complying with these water quality 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 cost represents a small portion of the production budget (i.e., <5%, Tourte and Smith, 2001). 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:

- Slow adoption of the pre-side-dress nitrate quick test to account for residual nitrate pools that are available in the soil.
- High levels of nitrogen returned to the soil from previous crops.
- 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:

- High land rents discourage tying up ground with a non-cash crop.
- 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 'Trios 102.'

PROJECT DESCRIPTION

The trial was conducted with a cooperating grower west of Salinas. The site had slopes that ranged from 1-3%. There were three replications of each treatment and each plot was eight 40-inch beds wide by 1280 feet long. Cereal rye 'AG104' and winter dormant triticale 'Trios 102' were seeded on November 18, lillistoned into the soil on November 19 and germinated by rain on November 26, 2008. The cover crop was managed to maintain biomass levels that would not disrupt soil preparation and seeding operations of the subsequent broccoli (scheduled for planting mid-March 2009). 'AG 104' grew more rapidly than 'Trios 102' and was sprayed with 2% glyphosate on January 20, 2009 (55 days after germination) and 'Trios 102' was sprayed with 2% glyphosate and one pint/acre of Goal 2XL on February 4, 2009 (70 days after germination). The untreated control was sprayed with one pint/acre of paraquat on January 20 to control weeds. Cover crop growth was measured by biomass sampling on six dates; cover crop ground cover was measured by taking photos and estimating percent ground cover using an 80-point grid.

Runoff from the plots was measured during rain events during the course of the trial. Run-off 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 the 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 pounds nitrogen (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.

Run-off events occurred during February and the beginning of March 2009, when a majority of the rainfall occurred (Figure 4). Run-off was measured most frequently in the fallow plots. Only one run-off event occurred in the 'AG104' treatment, and no run-off occurred in 'Trios 102' (Table 1). Average storm run-off volumes were highest in the bare fallow treatment. Average suspended sediment, total nitrogen, orthophosphate, and total phosphate concentrations in run-off collected from the fallow treatment between March 3 and 4 exceeded regional water quality standards for agricultural run-off (Table 2). Nitrate-N levels in leachate collected from the 'AG 104' and fallow treatments ranged from 130 to 234 milligrams/liter between February 12 and March 5, 2009. Estimated leaching losses of nitrate-nitrogen were 132 and 155 pounds 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 two-three 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.

LITERATURE CITED

- Johnstone, P.R., T.K. Hartz, M.D. Cahn and M.R. Johnstone. 2005. Lettuce response to phosphorus fertilization in high phosphorus soils. *HortScience* 40(5):1499-1503.
- Smith, R.F. K. Schulbach and L. Jackson. 1997. Development and promotion of nitrogen quick tests for determining nitrogen fertilizer needs of vegetables. *Proceedings of the Fertilizer Research and Education Program Conference*. Pages 51-52.
- Smith, R.F. and M. Cahn. 2007. Winter cover crops: strategies for including them in Salinas Valley vegetable rotations. *Monterey County Crop Notes*. September-October.
- Tourte, L. and R.F. Smith. 2001. Production costs for head (wrapped iceberg) and leaf (romaine) lettuce in Monterey and Santa Cruz Counties. <http://coststudies.ucdavis.edu/files/lethead2001.pdf>.

ACKNOWLEDGEMENTS

This research was supported by CDFA-FREP. We appreciate the collaboration with Chris Drew of Sea Mist Farms and Jose Aguiar of Kleen Globe.

Figure 1.

Biomass production (ton dry matter/acre) by cover crops on various dates following germination. Error bars represent standard error. Asterisks indicate statistical differences between means (LSD; $P < 0.05$).

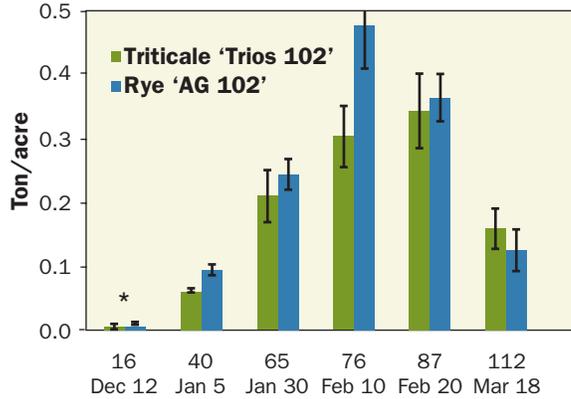


Figure 3.

Percent ground cover of cover crops on various dates following germination. Error bars represent standard error. Asterisks indicate statistical differences between means (LSD; $P < 0.05$).

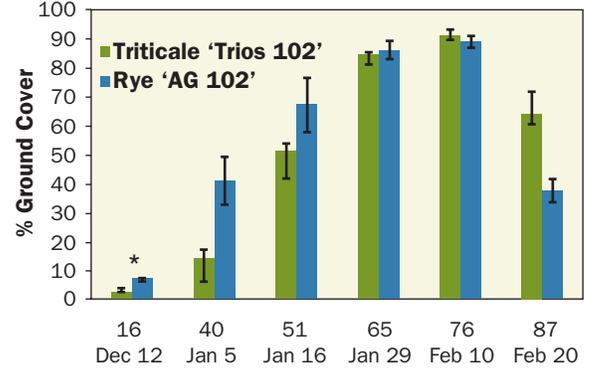


Figure 2.

Nitrogen (pounds N/acre) in cover crop biomass on various dates following germination. Error bars represent standard error. Asterisks indicate statistical differences between means (LSD; $P < 0.05$).

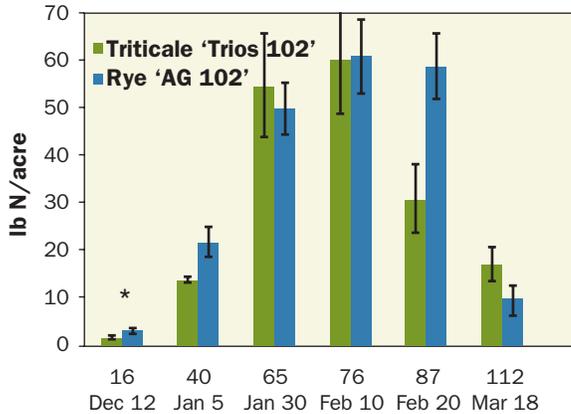


Figure 4.

Cumulative and daily rainfall at trial site.

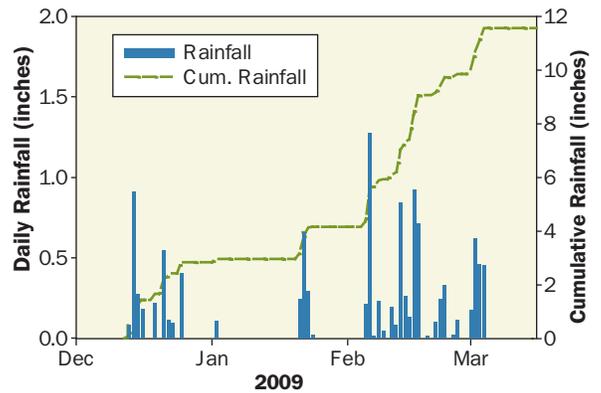


Table 1.

Average storm run-off volumes for cover crop treatments

Average run-off volumes during storm events						
Cover crop treatment	2/16/2009	2/17/2009	2/27/2009	3/3/2009	3/4/2009	Total
	Gallons per plot					
Rye	0	0	0	0	1082	1082
Trios	0	0	0	0	0	0
Bare fallow	234	335	263	767	1480	3079

Table 2.

Average nutrient and sediment concentrations in storm run-off sampled from fallow plots on March 3-4, 2009.

Constituent	Value	Unit
Total nitrogen	15.5	mg/L
Ammonium-N	0.1	mg/L
Nitrate-N	0.3	mg/L
Orthophosphate	0.7	mg/L
Total phosphate	4.7	mg/L
Potassium	1.5	mg/L
Sulfate-S	0.5	mg/L
TDS	160	mg/L
Total suspended		
Solids	7023	mg/L
Turbidity	3767	NTU
pH	7.8	
EC	0.1	ds/m

Table 3.

Estimated leaching losses of nitrate-nitrogen in individual bare-fallow and rye cover cropped plots between February 12-March 5, 2009. Note that the rye cover crop was killed with glyphosate, sprayed on January 20, 2009.

Cover crop treatment	Evapo-transpiration	Rainfall	Soil moisture storage	Percolation	Avg. nitrate-N concentration of leachate	Nitrogen loss
	Inches				mg/L	lb N/acre
Fallow	1.6	5.45	0.2	3.7	188	155
Rye	1.6	5.45	0.1	3.8	155	132

Precision Delivery of Fertilizer to Satisfy Crop Demand

PROJECT LEADER

Michael J. Delwiche

Professor and Chair
Biological and Agricultural
Engineering
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-7023
mjdelwiche@ucdavis.edu

COOPERATOR

Robert W. Coates

Associate Development Engineer
Biological and Agricultural
Engineering
University of California, Davis
One Shields Avenue
Davis, CA 95616
(530) 752-6731
rwcoates@ucdavis.edu

COOPERATOR

Patrick H. Brown

Professor
Plant Sciences
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-0929
phbrown@ucdavis.edu

COOPERATOR

Blaine R. Hanson

Cooperative Extension Specialist
Land, Air, and Water Resources
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-4639
brhanson@ucdavis.edu

COOPERATOR

Richard Y. Evans

Cooperative Extension Specialist
Plant Sciences
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-6617
ryevans@ucdavis.edu

COOPERATOR

Lawrence R. Oki

Cooperative Extension Specialist
Plant Sciences
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-4135
lroki@ucdavis.edu

INTRODUCTION

Site-specific irrigation and fertigation control has been shown to improve crop uniformity and reduce water, fertilizer, and chemical waste from over-application. Site-specific management means that hydrozones are smaller and contain plants with more uniform needs. Site-specific irrigation has been most thoroughly tested in center pivot and linear move systems for field crops. Much less development has occurred for fixed irrigation systems, which are used in high-value permanent crops and commercial horticulture. Site-specific technology for fixed irrigation and fertigation would be applicable in orchards, vineyards, landscapes, nurseries, and greenhouses, each of which has unique management challenges. The water and nutrient demand of trees, plants, and vines are impacted by variations in soil condition,

elevation, or microclimate. To complicate matters, fertigation accuracy and uniformity may be adversely affected by factors such as flow time through the pipes, fertilizer mixing in the pipes, and emitter clogging.

Converting conventional fixed irrigation systems (sprinkler and microirrigation) to allow site-specific delivery of water and nutrients would create many small hydrozones, each with a valve that must be independently controlled. Additionally, each should have the capability to read in-field sensors such as temperature and soil moisture, which are commonly used to optimize irrigation control. Implementation of such systems has been limited because of the expense and complexity of installing wired irrigation valves and sensors for many zones. We addressed this problem by developing a wireless valve

controller network. In orchards, a large area of trees in which water and nutrient needs vary could be made into multiple small blocks. In container nurseries, multiple beds of different plants that were previously irrigated together could be treated individually. In landscapes, valves could be placed at any location without worrying about a web of wires. Individual valve schedules would be different in order to match differing water and fertilizer requirements. Data from electrical conductivity, water pressure, soil moisture, and flow sensors would allow intelligent water and fertilizer control, and automatic detection of line breaks and emitter clogging.

OBJECTIVES

Variations in plant nutrient demand and environmental regulations provide significant incentive for development of fertigation systems that allow control of water and chemicals at a resolution smaller than the entire field or nursery block. Ease of installation and simplicity of operation suggest elimination of wires from the system. Our objectives in this research project are:

- 1 Design a wireless valve controller network to simplify the implementation of precision irrigation and fertigation.
- 2 Develop general operating strategies for site-specific fertigation to allow application of prescribed amounts of fertilizer at specific locations.

DESCRIPTION

The design and testing of our wireless valve controller network was described by Coates and Delwiche (2009) and Delwiche, et al. (2008). A network of nine nodes has been operating in a nursery on the University of California, Davis, campus since late 2008. In brief, the system uses mesh networking in which messages pass from one node to any other node in the network by routing them through intermediate nodes.

Figure 1. Wireless valve controller with one-inch latching valve.



This allows increased network range without using high-power radios, and communication redundancy; a failed node does not disable the network since multiple routing paths exist. The nodes are battery operated and recharge with miniature solar panels. An operator enters node addresses and irrigation schedules on the central field controller and they are distributed to individual nodes in the network.

Each node operates a latching solenoid valve to control the flow of water and dissolved fertilizer to a hydrozone (Figure 1). Various sensors can be used to record information about irrigation or crop performance. In this project, electrical conductivity (EC) sensors in the fertigation lines allowed detection of the fertilizer head and tail by the change in conductivity as the fertilizer passed through. Using fertilizer-specific calibrations, the actual concentration of fertilizer was also determined and can be used to adjust fertigation timing at each control valve.

A simple two-pin EC probe (CDH-712, Omega Engineering, Stamford, Connecticut) with threaded body was selected for ease of installation into an irrigation system using a threaded tee (Figure 2). The meter has a range of 0 to 2,000 $\mu\text{S}/\text{cm}$. This will be suitable for many situations that require frequent fertigation using general

fertilizer injected at about 100 to 450 ppm nitrogen. A sensor with greater range could be used for orchard and vineyard fertigations which sometimes use higher concentrations of nutrient and operate less frequently. The conductivities of solutions containing urea-ammonium-nitrate-32% (UAN-32) or a general NPK fertilizer (20-20-20) were measured at known concentrations of nitrogen. The measured conductivities were a linear function of nitrogen concentration. The NPK fertilizer was used for fertigation control tests with the wireless EC sensors.

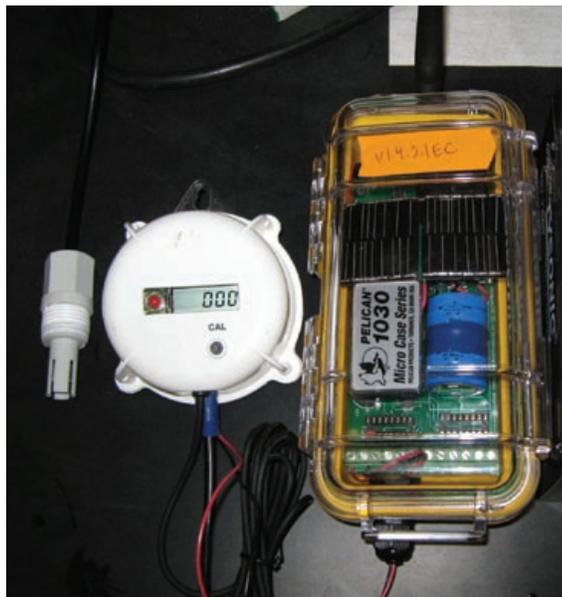
Long Fertigation Lines

We first conducted tests to determine the behavior of injected fertilizer in relatively long irrigation lines. One EC sensor was installed in 5/8" drip tubing about six feet from a positive displacement fertilizer injector (DI16, Dosatron, Clearwater, Florida). A second EC sensor was installed after another 500 feet of drip tubing. At the end of the drip line were three microsprinklers with flow rates of 15 gallons per hour. The fertilizer injector was set to inject at a 1:100 ratio for a final nitrogen concentration of 200 ppm (20-20-20 fertilizer). The EC at each sensor was recorded every 4 seconds and analyzed to show how we can detect the head and tail of the fertilizer and quantify applied fertilizer over time.

Site-specific Delivery

We also conducted tests to explore site-specific fertigation. Similar to the first test, we installed an EC sensor about six feet from the injector. Immediately following the sensor, we installed a tee to a wireless valve-control node. A single microsprinkler was installed and this was called Fertigation Zone 1. After another 12 feet of drip line, we installed the second EC sensor and a wireless valve-control node with one microsprinkler for Fertigation Zone 2. Fertilizer was injected with a target rate of 200 ppm nitrogen. The goal of the tests was to apply the same quantity of water to each zone, but vary the

Figure 2. Electrical conductivity probe, display and wireless node used for measurement of dissolved fertilizer in fertigation water.



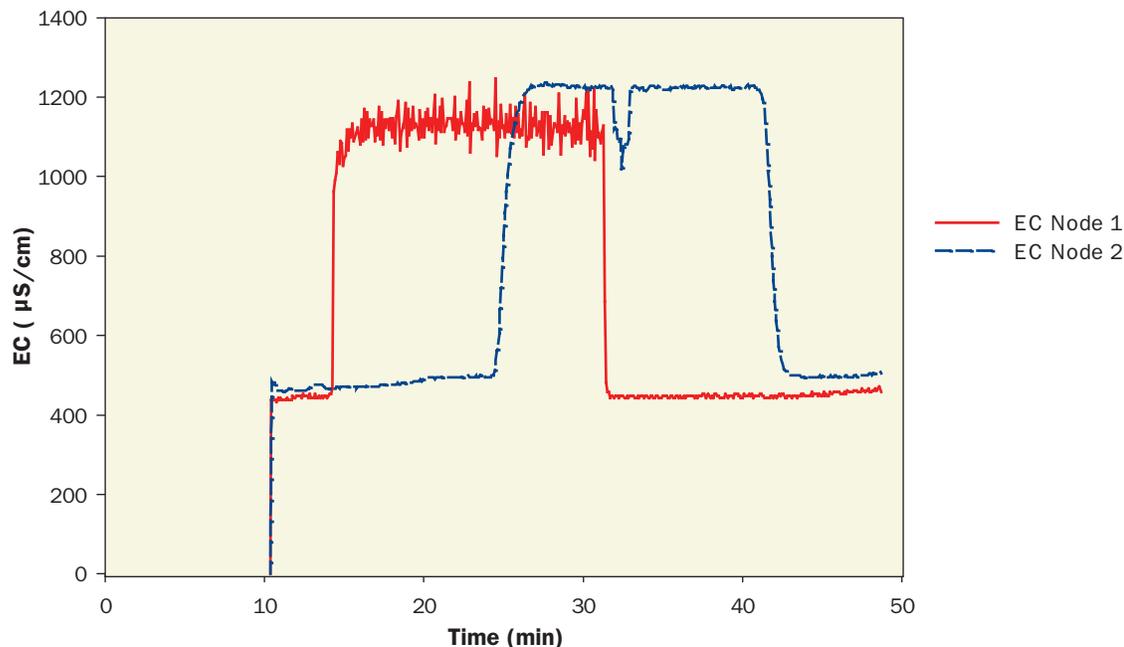
amount of fertilizer. In the test results presented here, Zone 2 was prescribed twice the amount of fertilizer as Zone 1. EC was recorded over time to show how real-time control will be implemented with the wireless nodes.

RESULTS AND DISCUSSION

Long Fertigation Lines

Figure 3 shows the EC measurements taken near the injector and at the end of a 500 ft drip line. Irrigation was begun just after the 10-minute mark. Prior to this, water had partially drained from the line and gave an EC measurement of zero. For the first four minutes, only water flowed through the lines. This provided a baseline EC measurement of the irrigation water. The baseline was subtracted from subsequent EC measurements in order to calculate nitrogen concentration using our calibration equations. Fertilizer injection occurred between the 14- and 31-minute marks. The lines were then flushed with water for 16 minutes.

Figure 3.
EC measurements near the fertilizer injector (Node 1) and at the end of a 500-foot drip line (Node 2).



We made several observations about this simple test. EC measurements at Node 1 varied over time due to the cyclical injection of fertilizer stock solution by the injector. EC measurements at Node 2 were more stable, indicating the fertilizer was well mixed after traveling 500 feet. The fertilizer head and tail were well defined at both measurement nodes. In tests with a slower flow rate, the EC changed more gradually, indicating that the fertilizer head and tail had spread out. A dip in EC at Node 2 occurred at 32 minutes and was due to air bubbles that became entrapped in the tip of the EC probe. The probe was inverted to release the bubbles and prevent future entrapment of air. EC at Node 2 was also slightly higher than the EC at Node 1 even though we would expect them to be the same. Integration of the EC (minus the base EC) over time at Node 2 was 4% greater than for Node 1. This would predict that more fertilizer has passed Node 2, though this was not the case. Later comparison of the EC probes in the same

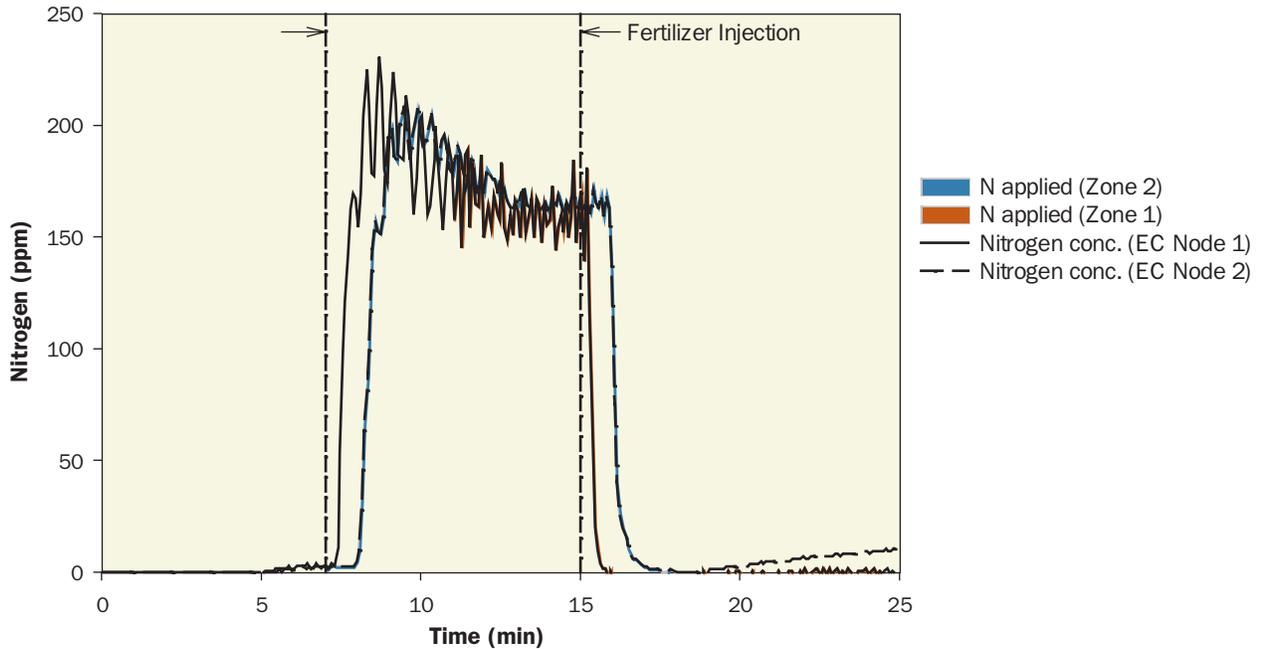
solutions showed that the EC at Node 2 was generally 40 µS/cm higher than the EC at Node 1, which accounts for most of the difference seen in our measurements. Since the meters had been calibrated prior to these tests, this unexplained difference requires additional scrutiny to ensure accurate measurement of fertilizer concentration.

Site-specific Delivery

Application of different levels of water and fertilizer could be done through one of several methods. The simplest method would be to run each zone independently. However, in many systems, the flow rate of a single site-specific zone may result in too low a flow rate for the injector or pumps being used. Also, there might not be enough time in the day to fertigate each zone separately. This means that zones with different fertigation rates may have overlapping operating times. Figure 4 shows data for a test in which twice as much fertilizer was prescribed for Zone 2 as for Zone 1 by following these time points:

Figure 4.

Nitrogen concentration (ppm) in fertigation water at inlet to two zones with area under each curve representing the applied fertilizer.



- 1-minute: Irrigation in both zones began and continued for six minutes.
- 7-minute: Valve to Zone 1 turned off and fertilizer injection began. Zone 2 fertigated for four minutes.
- 11-minute: Valve to Zone 1 reopened, fertigation of both zones for four minutes.
- 15-minute: Injector bypassed and both zones flushed for three minutes.
- 18-minute: Zone 2 valve closed and Zone 1 flushed for another four minutes.

This resulted in each zone receiving water for 17 minutes, Zone 1 receiving fertilizer for four minutes, and Zone 2 receiving fertilizer for eight minutes. Since the flow rate to each zone was equal, the amount of fertilizer delivered to Zone 2 was doubled by doubling the time. Fertigation time could be adjusted according to the expected or measured flow rate in each zone.

Figure 4 shows nitrogen concentration measured near the inlet to each zone. Nitrogen concentration was calculated using our linear calibration equation applied to the measured EC minus the baseline EC of the irrigation water measured before injection began. Note that the EC sensor for Zone 1 measured the EC of the fertigation water even when Zone 1 was not fertigating. While it was possible to place the EC sensor downstream of the valve, we intentionally placed the sensor along the mainline to demonstrate that a single EC sensor could be used near the injector to provide feedback for site-specific fertilizer control of multiple zones. The shaded area under each curve represents the amount of fertilizer applied in each zone. Integration of the shaded regions showed that Zone 2 applied about twice as much fertilizer as Zone 1 and EC measurement of the collected water from each zone confirmed this.

For site-specific fertigation, long lines could pose a challenge due to uncertainties in the flow time to each zone. The flow time to individual zones may be known, but since multiple zones will likely be fertigated simultaneously, the flow time to each zone may depend on the flow rates of zones that share the same irrigation mainlines. To ensure accurate application, there must be adequate time for fertigation and flushing in each zone. If fertigation duration for zones must be relatively short, EC sensors could be used to detect the fertilizer head and tail at distant points in the system to ensure proper fertilizer application. Extensive spreading of the fertilizer head and tail could also be problematic if the application time were short and a zone valve was open during a dilute portion of the head or tail. However, our tests conducted with long fertigation lines indicate that fertilizer mixing did not cause a substantial spreading of the fertilizer head or tail, though pipes with more turbulent flow should be tested.

We demonstrated the capability for site-specific control by varying the durations of irrigation and fertigation in each zone. As with conventional fertigation, this method requires that the emitter rates in each zone are known in order to calculate the actual amount of fertilizer applied. EC meters could be used to improve the accuracy of fertilizer to each zone so long as proper calibration was maintained. A flow meter could be connected to a wireless node with an EC meter to provide system-side monitoring of applied water and fertilizer and detection of faults. Additional tests will be conducted in large fertigation systems to determine how these site-specific fertigation strategies perform.

CONCLUSIONS

We developed and deployed a wireless valve controller network for site-specific irrigation and fertigation. Wireless nodes eliminate the need for wired valves and sensors. This allows simpler installation and management of small hydrozones. We developed fertigation control strategies for use with a site-specific system. The amount of fertilizer delivered to each zone can be controlled by varying the durations of irrigation and fertilizer injection. EC sensors were useful for detection of the fertilizer head and tail in long fertigation lines and for quantifying the amount of fertilizer being applied in each zone. Addition of a flow meter connected to a wireless node would allow more comprehensive monitoring of irrigation and fertigation activities with this system.

LITERATURE CITED

- Coates, R.W. and M.J. Delwiche. 2009. Wireless Mesh Network for Irrigation Control and Sensing. *Transactions of the ASABE* 52(3): 971-981.
- Delwiche, M.J., R.W. Coates, P.H. Brown, B.R. Hanson, R.Y. Evans, and L.R. Oki. 2008. Using Site-Specific Fertilization in Orchards, Nurseries, and Landscapes. Pages 39-45 in of the Sixteenth Annual Fertilizer Research and Education Program Conference Proceedings, California Department of Food and Agriculture, Sacramento, California.

ACKNOWLEDGEMENTS

This research was supported by grants from the California Department of Food and Agriculture Fertilizer Research and Education Program, the Slosson Research Endowment for Ornamental Horticulture, and the California Association of Nurseries and Garden Centers.

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

PROJECT LEADER

Carol J. Lovatt
Professor
Department of Botany and
Plant Sciences
4130 Batchelor Hall
University of California
Riverside, CA 92521-0124
(951) 827-4663
carol.lovatt@ucr.edu

PROJECT LEADER

Richard Rosecrance
Associate Professor
College of Agriculture
California State University
Chico, CA 95926-0310
(530) 898-5699
rosecrance@csuchico.edu

PROJECT LEADER

Ben Faber
Farm Advisor
UC Cooperative Extension, Ventura
County
669 County Square Drive, #100
Ventura, CA 93003
(805) 645-1451
bafaber@ucdavis.edu

COOPERATOR

Yusheng Zheng
Research Specialist
Department of Botany and Plant
Sciences
University of California
Riverside, CA 92521-0124
(951) 827-4663
yusheng.zheng@ucr.edu

COOPERATOR

Gary S. Bender
Farm Advisor
UC Cooperative Extension,
San Diego County
5555 Overland Ave., Suite B4
San Diego, CA 92123-1219
(858) 694-2845
gsbender@ucdavis.edu
(805) 781-5949
mlbianchi@ucdavis.edu

COOPERATOR

Mary Bianchi
Farm Advisor
UC Cooperative Extension,
San Luis Obispo County
2156 Sierra Way Suite C
San Luis Obispo, CA 93401
mlbianchi@ucdavis.edu

AVOCADO SITES AND
COOPERATING GROWERS

Pauma Valley
Chuck Bandy
Director of Business Expansion
and Grower Relations
McMillan Farming
29379 Rancho California Road,
Suite 201
Temecula, CA 92591
(951) 676-2045
mcmillanfarmingmgmt@msn.com

Irvine

Jesus M. Ruiz
Orchard Manager
Irvine Valencia Growers-Irvine Ranch
11501 Jeffrey Road
Irvine, CA 92602
(949) 936-8095
jrui@irvinecompany.com

Santa Paula

Gus Gunderson
Director of Southern Operations
Limoneira Company
1141 Cummings Road
Santa Paula, CA 93060
(805) 207-1902
ggunderson@limoneira.com

Santa Barbara

Rick Shade
Farm Manager
Shade Farm Management
P.O. Box 957
Summerland, CA 93607
(805) 684-6984
rtrincon1@cox.net

San Luis Obispo

Brycen Ikeda
Farm Manager
Ikeda Bros.
145 South Halcyon
Arroyo Grande, CA 93420
(805) 489-2613
brycenikdea@gmail.com

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 nitrogen, zinc and iron (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). Alarming, 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 two-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 best management practices (BMP) N (25 pounds N/acre in July, August, November and April; 100 pounds N/acre/year), BMP NPK (25 pounds N, 3.75 pounds P, and 22.5 pounds of K in July, August, November and April; 100 pounds N, 15 pounds P and 90 pounds K/acre/year), 0.5x N (25 pounds N/acre in July and August; 50 pounds N/acre/year) and 0.5x NPK (25 pounds N, 3.75 pounds P, and 22.5 pounds of K in July and August.; 50 pounds N, 7.5 pounds P and 45 pounds K/acre/year) at a new research site in Santa Barbara.

- 3 Tissues were analyzed for nitrogen, sulfur, phosphorus, potassium, magnesium, calcium, iron, zinc, manganese, boron and copper (N, S, P, K, Mg, Ca, Fe, Zn, Mn, B and Cu). At harvest, yield (number and kilogram fruit), fruit size distribution and fruit quality were determined per tree.

RESULTS AND DISCUSSION

The research was initiated with the start of funding in July 2007. Due to the freeze on January 18, 2007, orchards we had planned to use had to be replaced with new ones. This included the trees in Year 4 of an experiment comparing rates of N versus NPK soil-applied fertilizers. As a result, we did not have the benefit of using trees that had received fertilizer treatments at different rates of N, P, and K for multiple years. Instead, the fertilizer treatments were initiated with the start of the project. In addition, temperatures exceeded 100°F on June 20, 21, and 22, 2008, causing a significant proportion of the setting fruit to abscise from trees in our research orchards located in San Luis Obispo, Santa Barbara and Santa Paula. Despite these constraints, the results we obtained have proven adequate for meeting the objectives of the research.

Nutrient concentrations of cauliflower stage (Young inflorescences, March) and full bloom stage (Mature inflorescences, April) collected

from 'Hass' avocado trees in Irvine were significantly greater than pedicels (stems) of mature fruit collected in March and April, respectively, (Table 1). Similarly, for 'Hass' avocado trees in Pauma Valley, cauliflower stage inflorescence had significantly greater nutrient concentrations than the pedicels of mature fruit collected from the same trees in March, with the exception of K and Fe (Table 1). For inflorescences collected from these same trees at full bloom (April), only concentrations of K, S, B, Ca, Zn, Mn, and Cu, but not N, P, Mg or Fe, were greater than those of pedicels of mature fruit also collected in April. It is of great interest that for all trees in the fertilizer experiment in Santa Barbara, regardless of NPK treatment, inflorescences collected at the cauliflower stage (Y. inflorescences) and at full bloom (M. inflorescences) had significantly greater nutrient concentrations for all nutrients (except K in a few cases) than the pedicels of mature fruit collected from the same trees at the same time in March and April, respectively (Table 2).

For the five orchards in which we collected inflorescences at both the cauliflower and full bloom stage of inflorescence development, cauliflower stage inflorescences always had significantly greater concentrations of N, P, Zn, and Cu, but significantly lower concentrations of K and Fe than full bloom inflorescences (data not shown). The results in Santa Barbara were similar. For each fertilizer treatment cauliflower stage inflorescences had significantly greater concentrations of N, P, K, Zn and S, and a significantly lower concentration of Fe. Neither tissue showed differences in concentrations of N, P or K related to the soil fertilization treatments.

Mature leaves (M. leaf) on spring flush, non-fruiting terminal shoots collected in September, the standard time for avocado leaf analysis, had significantly greater concentrations of nutrients than pedicels collected from young fruit (Y. fruit stem) that developed contemporaneously

on spring flush, fruiting terminal shoots (Table 1). For avocado trees in Irvine, all nutrient concentrations were greater in leaves than pedicels, but for trees at Pauma Valley and trees in the fertilizer experiment in Santa Barbara, P and/or K concentrations were not significantly greater in leaves (Tables 1 and 2). In Santa Barbara, the N, P, and K concentrations of pedicels from young fruit collected in September did not reflect the NPK fertilization rates in Year 1 or Year 2. Regardless of fertilizer treatment, N, P and K concentrations of the pedicels from young fruit were greater in Year 1 of the experiment than in Year 2 (data not shown).

The failure of pedicels collected from young fruit in June, September and November or mature fruit in March and April to reflect soil-applied fertilizer treatments can be seen in Figure 1. There was a dramatic increase in the P and Mg concentrations of pedicels from young fruit sampled in June in the 0.5x NPK treatment that was not related to a fertilizer application, as trees in this treatment receive NPK fertilizer only in July and August. It was of interest that nutrient concentrations of pedicels increased in most cases over the six-month period from October 2007 (pedicels from young fruit) to April 2008 (pedicels of mature fruit) and by April were typically greater for each treatment than the nutrient concentrations of pedicels from young fruit collected two months later in June (Figure 1). A notable exception was boron. Pedicel boron concentrations were greatest in mature pedicels collected in March. Surprisingly, these relationships, though less pronounced, were evident in the four other avocado orchards, with the exceptions of pedicel S concentrations at Irvine and Pauma Valley and pedicel zinc at Pauma Valley (Figure 2). From our data we cannot tell whether the differences in nutrient concentrations in pedicels from mature fruit in April and young fruit in June reflect the effect of the heavy 2007-2008 on-crop of mature fruit on the lighter 2008-2009 off-crop of young

developing fruit in all orchards or whether most nutrients accumulate in the pedicel of fruit throughout their development from June through April the following year; both are intriguing and potentially useful possibilities.

We determined which nutrients in each tissue significantly influenced total yield and yield of commercially valuable large size fruit of packing carton sizes 60 + 48 + 40 (fruit weighing 178 to 325 grams). Using stepwise regression analyses, we determined the most important combination of nutrients for each yield parameter across all orchards. 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 cauliflower stage inflorescences were more strongly related to yield and yield of commercially valuable large size fruit. In this tissue, Cu, Mg and P explained 67% of the variation in yield of fruit of packing carton sizes 60 + 48 + 40 ($P = 0.0049$). However, since the project started in July 2007, we only have one set of tissue samples and corresponding yield data. Using pedicels from young fruit collected in September or November for which we have tissue samples and yield data for two years at four of five sites, we found no significant relationships between tissue nutrient concentrations and yield parameters. The strongest relationships were found with leaf samples, for which we had two years of samples and corresponding yield data at Santa Barbara, Santa Paula, Pauma Valley and Irvine. There was no relationship between leaf nutrient concentrations and total yield. Leaf Ca, Fe, S and Zn concentrations predicted 50% of the variation in yield of commercially valuable large size fruit of packing carton sizes 60 + 48 + 40 ($P = 0.0003$). These same nutrients predicted the yield of all fruit greater than packing carton size 60, accounting for 51% of the variation in yield ($P = 0.0002$).

CONCLUSION

We had a sufficient number of sampling dates, orchards and corresponding yield data, to be able to conclude that pedicels from young or mature fruit of the 'Hass' avocado in California had low nutrient concentrations that were not responsive to the soil fertilizer treatments. However, if it could be determined whether the mature fruit on the tree impact pedicel nutrient concentrations of the setting young crop of fruit or whether pedicel nutrient concentrations increase throughout fruit development, valuable information might be obtained from pedicel nutrient analysis. The nutrient status of the cauliflower stage inflorescence was also not responsive to the NPK soil fertilizer treatments. In addition, we only had one year of paired tissue analysis and yield, but these results were promising. 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 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 (178-325 grams per fruit) ($r^2 = 0.50$; $P = 0.0003$) across all five orchards and fertilizer treatments.

Now that we have identified this relationship, we are looking forward to testing it further with existing data sets. For the final report, we will also analyze all data with yield expressed as number of fruit per tree to compare with the present analyses based on kilograms of fruit per tree. We will also complete the analysis of the huge data set relating tissue nutrient concentrations and fruit quality.

LITERATURE CITED

- Crowley, D.E. 1992. Soil fertility and the mineral nutrition of avocado: the physical, chemical, and biological properties of soil and their importance in the culture of avocado. California Avocado Development Organization and The California Avocado Society, Circular No. CAS-92/1. Page 26.
- Crowley, D.E. and W. Smith. 1996. Zinc fertilization of avocado trees. HortScience 31:224-229.
- Lovatt, C.J. and G. Witney. 2001. AvoResearch 1(3):1-4, 11.
- Razeto, B. and C. Granger. 2001. Análisis químico del pedúnculo del fruto y la inflorescencia, posibles herramientas de diagnóstico nutricional en palto (*Persea americana* Mill.). Page 73. In: Resúmenes. 52º Congreso Agronómico de Chile, Quillota, Chile.
- Razeto, B., C. Granger and T. Fichet. 2003. Análisis de diferentes tejidos como indicadores del nivel de boro en el árbol de aguacate (*Persea americana* Mill.). [Analysis of different tissues as indicators of boron level in avocado (*Persea americana* Mill.)]. Proceedings V World Avocado Congress 1:359-363.
- Razeto, B. and J. Salgado. 2004. The influence of fruit peduncle as indicators of nitrogen status of the avocado tree. HortScience 39(6):1173-1174.

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
<i>P-value</i>	<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
<i>P-value</i>	<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
<i>P-value</i>	<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
<i>P-value</i>	<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
<i>P-value</i>	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
<i>P-value</i>	<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.

17TH ANNUAL CDFA FERTILIZER RESEARCH & EDUCATION PROGRAM CONFERENCE
SUMMARIES OF PRESENTED FREP RESEARCH PROJECTS

Table 2.

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

Tissue ²	N %	P %	K %	S %	B ppm	Ca %	Mg %	Zn ppm	Mn ppm	Fe ppm	Cu ppm
	BMP N July, August, November and April ¹										
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

² Y. inflorescence-cauliflower stage of inflorescence development (March); M. fruit stem 1-pedicle of mature fruit (March); M. inflorescence-inflorescence at full bloom (April); M. fruit stem 2-pedicle 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-pedicle of young fruit (September).

¹ 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 NPK (-▲-) (25 lb N, 3.75 lb P, 22.5 lb K 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).

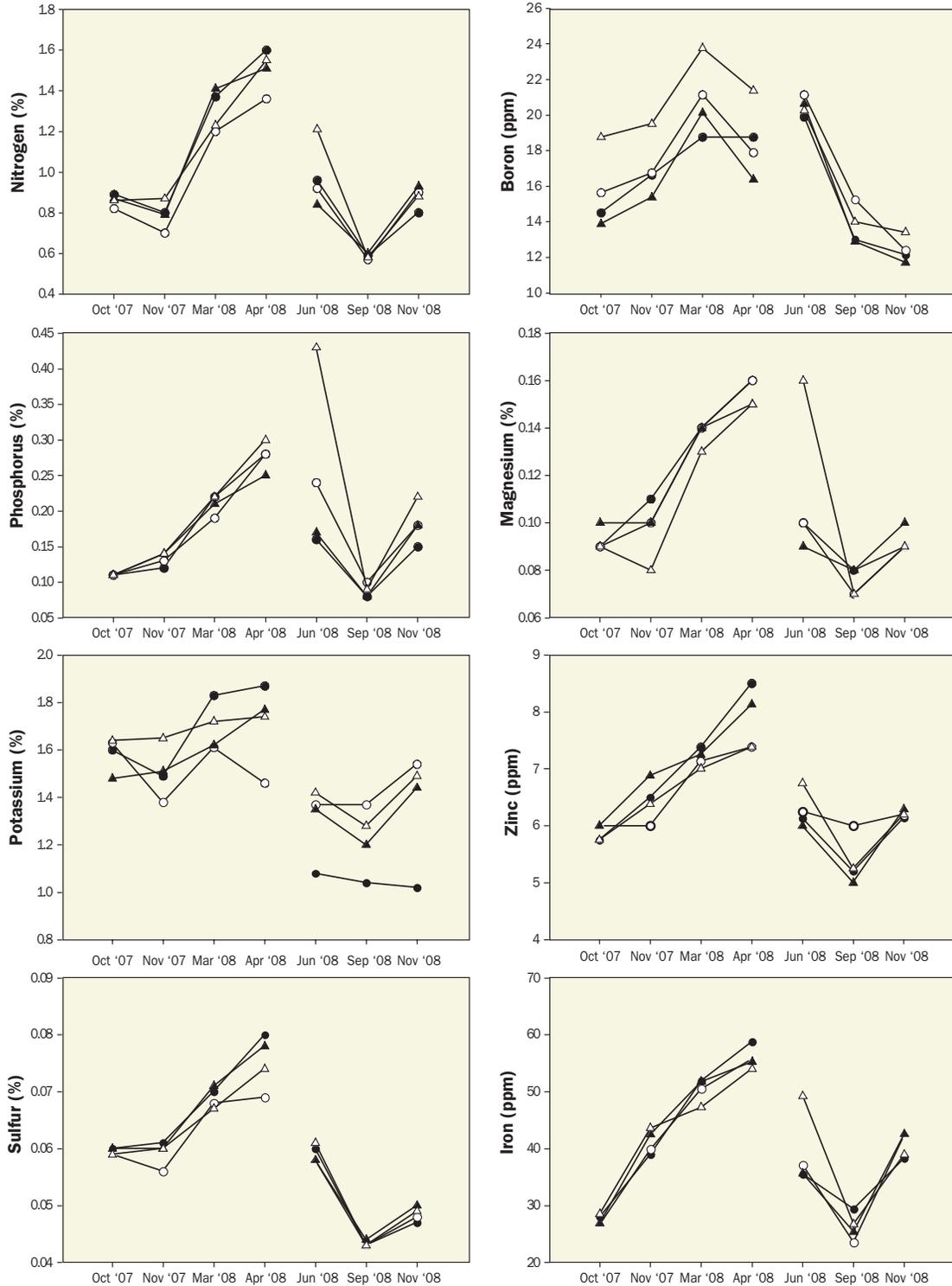
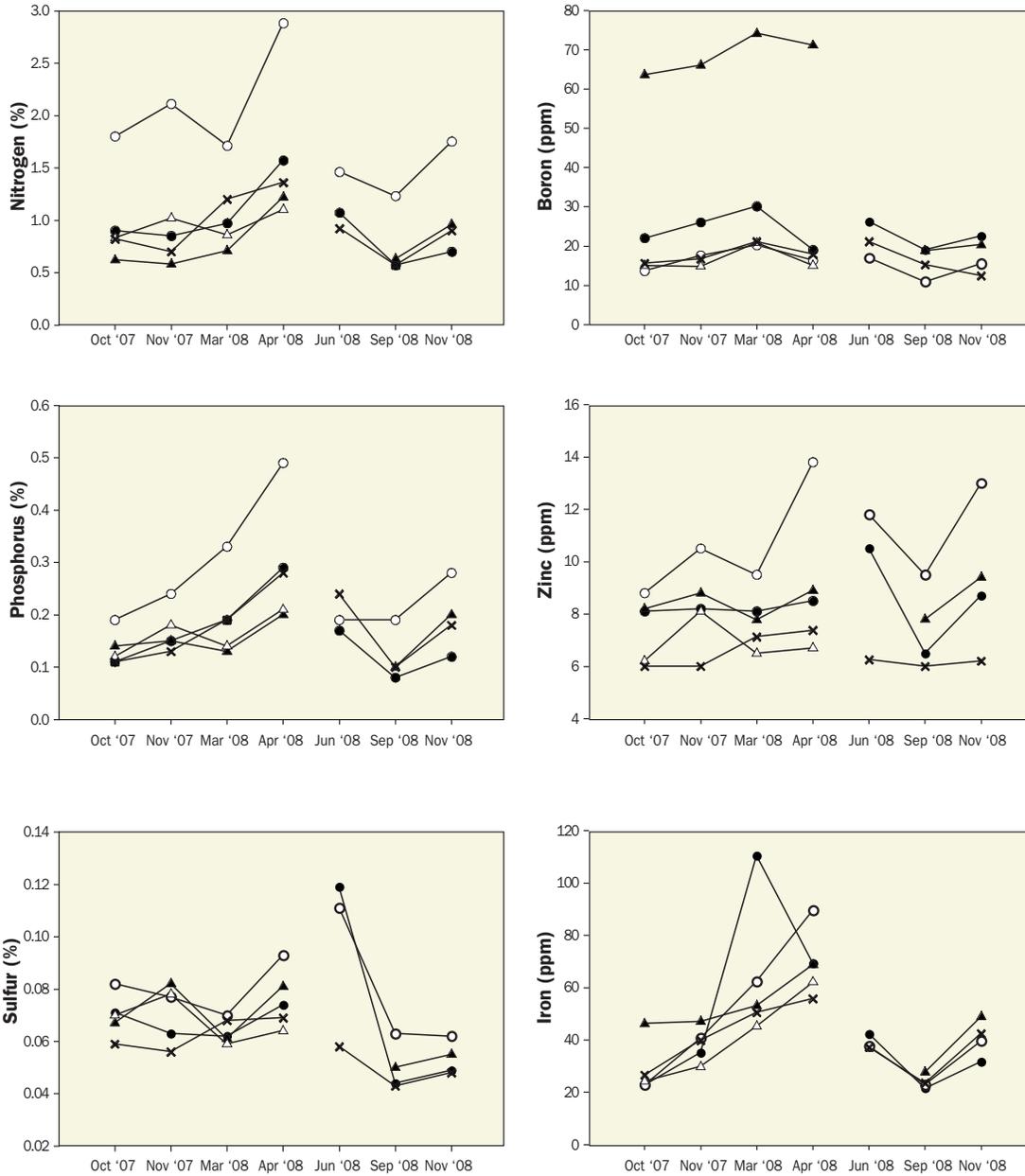


Figure 2.

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).



California Certified Crop Adviser Educational Project

PROJECT LEADER

Dan Putnam

Extension Specialist
Department of Plant Sciences
University of California
One Shields Avenue, MS #1
Davis, California 95616-8780
(530) 752-8982
dhputnam@ucdavis.edu

COOPERATOR

Terry W. Stark

President/CEO
California Association of Pest Control
Advisers (CAPCA)
1143 North Market Blvd., Suite 7
Sacramento, CA 95834
(916) 928-1625, ext 202
terry@capca.com

INTRODUCTION

The California Certified Crop Adviser (CaCCA) program is a voluntary, non-profit organization that represents the Certified Crop Advisers who provide nutrient recommendations to private applicators, agricultural producers such as the dairy industry, growers, and governmental agencies tasked with the stewardship of the state's natural resources.

The CaCCA program continues to establish its value as an asset in public education related to fertilizers, soil resource management, and crop production. There exists many opportunities in the CaCCA program to work with growers and to develop incentives for growers to utilize the more active with regards to environment regulations. Specifically, nutrient management plans (NMPs) will likely be an important component of the future of many types of farming operations, driven by permitting and public agencies.

Funding received during the seventeen month (August 2007-December 2008) for the CaCCA educational project from CDFA-FREP enabled the all-volunteer CaCCA board to achieve work objectives to improve the educational opportunities of California agriculture related to fertilizers, farm management and agricultural sustainability.

OBJECTIVES

- 1 Broaden CaCCA's identification and role in the California regulatory environment.
- 2 Increase and strengthen CaCCA 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 CaCCA and keep the flow of information to CaCCA members.

ACCOMPLISHMENTS

- Increased the number of CCAs in California from 408 in October 2007 to 452 at end of December 2008.
- Increased the number of individuals taking the exam in February 2007 from 37 to 64 in February 2008 and from 19 in August 2007 to 36 in August 2008.
- Exhibited at 15 meetings during the grant period, including the California Association of Pest Control Advisers (CAPCA) Conference, Western Alfalfa and Forage Conference, Malcolm Media Producer Conferences, California Small Farm Conference, California Plant and Soil Conference, Western United Dairyman Convention and other venues.
- Gave presentations on the CaCCA program at 29 various meetings including area CAPCA meeting and other nutrient and crop consultant conferences. Also gave brief presentations on the program at Western Plant Health Association (WPHA) and CAPCA student dinners.
- Worked with California dairy industry, including Western United Dairyman, on CCA role in developing nutrient management plans for dairies to be in compliance with the Waste Discharge Requirements of the Central Valley Regional Water Quality Board.
- Published articles in the *CAPCA Adviser*.
- Advertised in the *Western Dairyman* and *Agribusiness Dairyman* to inform the dairy industry of the CCA role in waste discharge plans for dairies.
- Provided training sessions for exam candidates in Fresno and Sacramento prior to each CCA exam.
- Engaged in continuous discussions with representatives of California fertilizer and agricultural retail industry on benefits of the program.
- Established public relations committee by the CaCCA state board.
- Sponsored CCA session at 2007 CAPCA Annual Conference.
- Prepared and distributed news releases on the CaCCA program and upcoming exam opportunities.
- Started planning for CaCCA Annual Meeting that was held in conjunction with the 2009 Soil and Plant Conference in February 2009 at Fresno.
- E-mailed electronic CaCCA Newsletter to current CCAs—five editions during grant period.
- Maintained and updated CaCCA Web site (www.cacca.org) on a regular basis.
- Met with various regulators regarding the CaCCA program.
- Obtained various sponsorships for CaCCA events from California fertilizer and agricultural retailers to help with events.
- CaCCA Chairman Allan Romander was selected International CCA (ICCA) of the Year in 2008.
- Met with representatives of various water quality groups to explain the role of CaCCAs.
- Worked with Stuart Pettygrove, in cooperation with his FREP grant, “Developing Certified Crop Adviser Specialty Certification and Continuing Education in Manure Nutrient Management.” Gave presentations of the program at each training session.

- Supported awareness and student involvement in “Pathway to PCA” program being developed by the education foundation of CAPCA.
- 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.
- 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.
- CAPCA compiles the quarterly reports for the project leader for the CDFA-FREP grant.

CONCLUSION

Thanks to the support of the CDFA-FREP grant, the CaCCA program has been very successful in continuing its growth. CaCCAs are well trained to help serve the agricultural industry in assuring their practices are environmentally sound and economically feasible.

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

PROJECT LEADER

Kitren Glozer

Associate Project Scientist
Department of Plant Sciences
University of California
One Shields Avenue
Davis, CA 95616
(530) 754-4096
kglozer@ucdavis.edu

PROJECT LEADER

Gregory Lang

Professor
Department of Horticulture
Michigan State University
Plant and Soil Sciences Building
East Lansing, MI 48824
(517) 355-5191, ext. 1388
langg@msu.edu

COOPERATOR

Steve DaValle

Grupe Operating Company
3255 West March Lane, Suite 400
Stockton, CA 95219
(209) 368-3314
sdavalle@grupe.com

PROJECT LEADER

Joe Grant

Farm Advisor
UC Cooperative Extension,
San Joaquin County
2101 East Earhart, Suite 200
Stockton, CA 95206
(209) 953-6115
jagrant@ucdavis.edu

COOPERATOR

Lawrence Sambado

Prima Frutta Packing
P.O. Box 419
Linden, CA 95236
(209) 931-2568
primav2@attglobal.net

INTRODUCTION

Average sweet cherry yields in California (~3.4 tons/acre) are typically less than those in the Pacific Northwest (~5.5 tons/acre), due partly 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, due to the higher chilling requirements of cherry than peach or almond, dormancy-breaking treatments in winter often are applied that further impact nutrient (particularly N) storage in, and demand by, tissues and organs.

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. Rates of dormancy-release chemicals (CAN and KNO₃), as included in the N treatments, were reduced in 2009 from levels used in 2008 due to warm weather in January.

Leaf size for bearing and non-bearing spurs, and vegetative shoot leaves (new season growth) were measured in 2008 by digital image analysis. Only slight differences were found among treatments within a given orchard in leaf size (2008); current season shoot and bearing spur leaves (and small fruits as in 2008) were collected in 2009, when only bearing spur leaves were measured for leaf area, as well as weighed for dry tissue weight. These measures represent an additional indicator of vegetative vigor, specifically as photosynthetic and carbohydrate tissues primarily supporting fruit production. Tissue N sampling protocol has been adapted, based on results of tissue analyses for Year 1 (2008) to reflect N fluxes (rising and falling tissue levels) as the appropriate periods of nutrient sampling. Nitrogen content on a leaf area basis was tested as an alternative to dry weight basis to compare treatment effects, however, better means separation was found using the latter method, confirming the standard practice.

Effects of CAN-17 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) were also evaluated as potential for crop load reduction. Harvest for all orchards was a single 'strip pick'; crop load for each tree was obtained and fruit sampled from pickers' bins for fruit quality measures of maturity, firmness, size, stem/fruit removal force (FRF) and soluble solids.

RESULTS AND DISCUSSION

Nutrient analyses completed in 2009 since all treatments had been applied within a 12-month period (Table 1; bloom treatments 2008 through dormancy-breaking treatments in 2009) included those of dormant vegetative and reproductive buds (Table 2). Highest vegetative bud values (ranged from 1.28 to 1.45) tended to be found in treatments that included bloom and post bloom treatments made in 2008. Lowest tissue

N levels were found in one or both types of bud at Mahaleb and Gisela sites for treatments that included both dormancy-inducing defoliation and CAN; at the Mazzard site, however, highest tissue levels were found in spur buds treated with dormancy-inducing defoliation and either CAN or KNO_3 . Some bloom and postbloom treatments resulted in high N or low N, in all three sites, thus, there was not a clear pattern of N level of dormant buds based on N treatment.

As in 2008, in all orchards and treatments, %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 budbreak. 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.

When N content was compared in tissues sampled in April, prior to postbloom treatments, results varied among the orchards with respect to treatment differences and tissue levels. The Mahaleb/Lodi orchard (Table 3) had no differences in tissue N among treatments when shoot leaves were evaluated; all had %N within a 3.15 to 3.49 range. Fruit tissue N content was not different either among treatments (Table 3) and all were within 2.61 to 3.01 range. Treatments varied in response of tissue N, surface area and dry weight when bearing spur leaves were analyzed, however no clear relationship was apparent based on treatments as low and high N values were found among similar treatments, nor was a clear relationship found between tissue N and leaf area or weight of leaf tissues (dry weight). Lowest tissue N was found with both lowest and highest leaf area and dry weight. No measure of tissue N, spur leaf size or weight was different in the Gisela/Linden orchard (Table 4), except in shoot leaves, yet no clear pattern for leaf N level differences could be detected

in this orchard either. In the Mazzard/Linden orchard (Table 5), only the spur bearing leaves treated with both dormancy inducing and dormancy ending applications exhibited higher N concentration than all other treatments.

Vegetative vigor, measured by number of shoot breaks and new shoot growth (length) in Mahaleb (Table 6), 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. Vigor was also somewhat reduced by 45 CaNO₃, PHG+N, PBLM, PLF (93.42) in this orchard. While the low level of N in this trial might be considered the reason for reduced growth, a similarly low annual rate was also found in 45 CaNO₃, PBLM (47.3) without reduced vigor. No significant differences in measures of vegetative vigor were found at Gisela and Mazzard sites (Tables 7 and 8). Measurement of TCSA has not yet occurred for 2009.

At the Mahaleb/Lodi orchard, yield and yield efficiency were increased in treatments that included bloom and petal fall applications of Pacific HortGrow Plus N (PHG+N; Table 9) and lowest in the treatment with 'reduced' CaNO₃ PH, dormancy-inducing and -breaking (CAN) treatment. It is doubtful that the reduction in yield and efficiency were due to the reduced CaNO₃ (45) used in many other treatments, DI defoliation treatment (also found in the highest-yielding treatment) or the CAN DR treatment, which did not reduce yield or efficiency in another treatment. 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 DR treatments greatly advanced bloom ahead of pollenizers and induced bloom during a period of late freeze. An estimate of freeze-killed buds was made in the adjacent Gisela orchard (25% bud death), which probably contributed to the reduced yield in Mazzard, although this was not ultimately the case for Gisela, which tends to have a high bloom density due to the dwarfing rootstock. Thus, while the loss of some of the bloom in Gisela did not appear to affect yield (no significant differences in yield or efficiency), the loss of bloom and lack of overlap with pollenizers clearly negatively affected Mazzard.

Fruit quality measures are being analyzed for all orchards and treatments and any relationship to N treatments will be reported in the annual report. At this time, it appears that yield and yield efficiency may show some relationship to N treatment in the Mahaleb site, which is the heaviest cropping of the three orchards, and vegetative vigor control appears to show some good results with time-managed applications of N. Cropping was limited at the Linden orchards by delayed bloom and freeze loss of buds, thus likely exerting more of an effect on vigor than N supply.

Table 1.

Nitrogen (N) treatments applied to ‘Bing’ (*Prunus avium*) sweet cherry at three orchards* in 2008-9, comparing ‘standard’ postharvest (PH) soil application (CaNO₃ 15.5% N) with reduced soil-applied CaNO₃ supplemented with foliar N applications ‘timed’ to phenological events. Foliar N treatments include: CAN-17 (16.7% v/v, 17% N) or KNO₃ (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 pounds/acre ZnSO₄ 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 †				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

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

†DR treatment applied either 150 gal/acre or 75 gal/acre for ‘Gisela 6’ trees (dwarfing rootstock); for CAN-17 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.

Table 2.

Nitrogen (N) tissue levels in ‘Bing’ (*Prunus avium*) sweet cherry at three orchards* in January 2009 prior to dormancy release treatments, comparing ‘standard’ postharvest (PH) soil application (CaNO₃ 15.5% N) with reduced soil-applied CaNO₃ supplemented with foliar N applications ‘timed’ to phenological events. Foliar N treatments include: CAN-17 (16.7% v/v, 17% N) or KNO₃ (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 pounds/acre ZnSO₄ for dormancy induction (DI).

Rootstock and orchard location	Mahaleb		Gisela 6		Mazzard	
	shoot	spur	shoot	spur	shoot	spur
90 CaNO ₃ (90)	1.39 ab [‡]	1.46 ab	1.52 bcd	1.87 ab	1.26	1.45 ab
90 CaNO ₃ , DR (KNO ₃), DI (99.9)	1.36 ab	1.46 ab	1.52 bcd	1.85 abc	1.31	1.48 a
90 CaNO ₃ , DR (CAN), DI (126 or 152.7)	1.30 b	1.41 b	1.52 bcd	1.87 ab	1.34	1.46 a
45 CaNO ₃ , DR (CAN), DI (81 or 98.5)	1.28 b	1.36 b	1.47 d	1.93 ab	1.23	1.34 cd
45 CaNO ₃ , PLF (90)	1.40 ab	1.54 a	1.62 b	1.96 ab	1.27	1.44 ab
45 CaNO ₃ , PHG+N (46.12)	1.33 ab	1.39 b	1.52 bcd	1.82 bc	1.23	1.28 d
45 CaNO ₃ , PHG+N, PLF (91.12)	1.45 a	1.56 a	1.73 a	1.98 a	1.29	1.46 ab
45 CaNO ₃ , PBLM (47.3)	1.33 ab	1.40 b	1.49 cd	1.72 c	1.22	1.36 bcd
45 CaNO ₃ , PBLM, PLF (92.3)	1.45 a	1.59 a	1.62 b	1.96 ab	1.28	1.41 abc
45 CaNO ₃ , PHG+N, PBLM, PLF (93.42)	1.44 a	1.58 a	1.61 bc	1.99 a	1.34	1.50 a
Significance	**	***	***	**	NS	**

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

†DR treatment applied either 150 gal/acre or 75 gal/acre for ‘Gisela 6’ trees (dwarfing rootstock); for CAN-17 actual N was either 53.5 or 26.8 lb/acre.

‡ 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[†] in 'Bing' (*Prunus avium*) sweet cherry at 'Mahaleb/Lodi' orchard in April 2009 prior to postbloom treatment, comparing 'standard' postharvest (PH) soil application (CaNO₃ 15.5% N) with reduced soil-applied CaNO₃ supplemented with foliar N applications 'timed' to phenological events. Foliar N treatments include: CAN-17 (16.7% v/v, 17% N) or KNO₃ (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 pounds/acre ZnSO₄ for dormancy induction (DI). Bearing spur leaf area (in²) 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 *	3.93 abc	9.47 bc	1.78 bc	3.01
90 CaNO ₃ , DR (KNO ₃), 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

[†]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.

[‡]%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 (CaNO₃ 15.5% N) with reduced soil-applied CaNO₃ supplemented with foliar N applications 'timed' to phenological events. Foliar N treatments include: CAN-17 (16.7% v/v, 17% N) or KNO₃ (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 pounds/acre ZnSO₄ for dormancy induction (DI). Bearing spur leaf area (cm²) 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 *	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

[†]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.

[‡]%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 CaNO₃ supplemented with foliar N applications 'timed' to phenological events. Foliar N treatments include: CAN-17 (16.7% v/v, 17% N) or KNO₃ (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). Bearing spur leaf area (cm²) 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

^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.

^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 (CaNO₃ 15.5% N) with reduced soil-applied CaNO₃ supplemented with foliar N applications 'timed' to phenological events. Foliar N treatments include: CAN-17 (16.7% v/v, 17% N) or KNO₃ (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 pounds/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.

Current season shoot growth in ‘Bing’ (*Prunus avium*) sweet cherry at ‘Mazzard/Linden’ orchard in 2009 in response to nitrogen (N) fertilization, comparing ‘standard’ postharvest (PH) soil application (CaNO₃ 15.5% N) with reduced soil-applied CaNO₃ supplemented with foliar N applications ‘timed’ to phenological events. Foliar N treatments include: CAN-17 (16.7% v/v, 17% N) or KNO₃ (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 pounds/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)	9.7 ^x	21.7	191.9
90 CaNO ₃ , DR (KNO ₃), DI (99.9)	7.0	15.0	109.4
90 CaNO ₃ , DR (CAN), DI (152.7)	8.8	19.2	162.3
45 CaNO ₃ , DR (CAN), DI (98.5)	10.2	17.5	169.8
45 CaNO ₃ , PLF (90)	8.7	18.3	134.6
45 CaNO ₃ , PHG+N (46.12)	10.0	17.4	172.9
45 CaNO ₃ , PHG+N, PLF (91.12)	7.5	16.1	125.2
45 CaNO ₃ , PBLM (47.3)	7.0	19.3	130.8
45 CaNO ₃ , PBLM, PLF (92.3)	8.5	12.3	167.8
45 CaNO ₃ , PHG+N, PBLM, PLF (93.42)	8.2	17.7	146.6
Significance	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.

Current season shoot growth in ‘Bing’ (*Prunus avium*) sweet cherry at ‘Gisela/Linden’ orchard in 2009 in response to nitrogen (N) fertilization, comparing ‘standard’ postharvest (PH) soil application (CaNO₃ 15.5% N) with reduced soil-applied CaNO₃ supplemented with foliar N applications ‘timed’ to phenological events. Foliar N treatments include: CAN-17 (16.7% v/v, 17% N) or KNO₃ (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 pounds/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)	10.3 ^x	15.4	148.5
90 CaNO ₃ , DR (KNO ₃), DI (99.9)	8.3	14.5	121.9
90 CaNO ₃ , DR (CAN), DI (126)	11.3	13.0	138.9
45 CaNO ₃ , DR (CAN), DI (81)	12.3	13.6	173.5
45 CaNO ₃ , PLF (90)	11.2	15.7	178.9
45 CaNO ₃ , PHG+N (46.12)	13.8	14.3	195.0
45 CaNO ₃ , PHG+N, PLF (91.12)	10.2	13.1	133.7
45 CaNO ₃ , PBLM (47.3)	12.2	17.2	205.0
45 CaNO ₃ , PBLM, PLF (92.3)	11.0	16.0	172.6
45 CaNO ₃ , PHG+N, PBLM, PLF (93.42)	8.5	16.1	134.3
Significance	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 9.

Yield (lb) and yield efficiency in 'Bing' (*Prunus avium*) sweet cherry at three different orchards in 2009 in response to nitrogen (N) fertilization, comparing 'standard' postharvest (PH) soil application (CaNO₃ 15.5% N) with reduced soil-applied CaNO₃ supplemented with foliar N applications 'timed' to phenological events. Foliar N treatments include: CAN-17 (16.7% v/v, 17% N) or KNO₃ (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 pounds/acre ZnSO₄ for dormancy induction (DI).

Rootstock and orchard location	Mahaleb Lodi		Gisela 6 Linden		Mazzard Linden	
	Yield	Efficiency	Yield	Efficiency	Yield	Efficiency
90 CaNO ₃ (90)	153 a*	0.14 abc	50.9	0.12	59.5	0.06
90 CaNO ₃ , DR (KNO ₃), DI (99.9)	153 a	0.11 b-e	53.6	0.10	55.1	0.06
90 CaNO ₃ , DR (CAN), DI (126)	149 a	0.10 cde	50.0	0.09	41.9	0.04
45 CaNO ₃ , DR (CAN), DI (81)	96 b	0.06 e	64.6	0.13	31.1	0.03
45 CaNO ₃ , PLF (90)	152 a	0.11 b-e	62.2	0.11	67.9	0.08
45 CaNO ₃ , PHG+N (46.12)	176 a	0.17 a	42.1	0.09	64.6	0.06
45 CaNO ₃ , PHG+N, PLF (91.12)	186 a	0.14 ab	45.0	0.10	59.5	0.06
45 CaNO ₃ , PBLM (47.3)	134 ab	0.10 b-e	65.8	0.12	62.8	0.07
45 CaNO ₃ , PBLM, PLF (92.3)	136 ab	0.09 de	62.2	0.12	53.1	0.06
45 CaNO ₃ , PHG+N, PBLM, PLF (93.42)	152 a	0.11 bcd	54.2	0.10	61.3	0.06
Significance	*	***	NS	NS	NS	NS

*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.

Summaries of Other Ongoing FREP Research Projects



Development of Leaf Sampling and Interpretation Methods for Almond

PROJECT LEADER

Patrick Brown

Professor

Department of Plant Sciences

University of California

One Shields Avenue

Davis, CA 95616

(530) 752-0929

phbrown@ucdavis.edu

INTRODUCTION

In tree crop production in California, leaf sampling and critical value analysis represents the primary tool for fertilizer decision-making (Brown and Uriu, 1996). Ninety percent of growers and consultants participating in the CDFA FREP-funded focus groups on nutrition and subsequent surveys of growers, felt that University of California (UC) Critical Values (CVs) were not appropriate for current yield levels, were not useful early in the season and did not provide sufficient guidance for nutrient management. Two explanations for this observation are possible: 1) the current CVs are limited in application and are possibly incorrect; or 2) that there are systematic errors in the manner in which critical values are used. While it is not known if UC CVs 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 CVs have been used. We conclude, that the “problem” with current CVs 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 also noted that CVs are of no use early in the season when in-season adjustments could still be made, and many noted that even if a sound leaf sample is taken that the analysis cannot be used to determine a specific fertilization response.

This project aims to correct this situation by developing new approaches and interpretation tools that better quantify field and temporal variability, are sensitive to yield and provide for in-season monitoring and fertilizer optimization in almond. This project will also offer the unique opportunity to verify current CVs and determine the utility of nutrient ratios as a diagnostic tool.

OBJECTIVES

- 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 CVs 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.

DESCRIPTION

A large-scale survey of within-field, between-field, within-tree and between-organ nutrient concentration and variance will be conducted in mature almond orchards. The interaction between yield and nutrient status will be determined at four sites on >600 individual trees.

All trials have been initiated in eight- or nine-year-old microsprinkler-irrigated (one drip irrigated) almond orchards of good to excellent productivity planted to 'Nonpareil' (50%) in soils representative of the region and a large percentage of almond acreage. At experiment completion, trees will have reached 11 or 14 years old (after three or five years) representing their most productive years.

For each of four almond sites (Arbuckle, Salida, Madera, Bakersfield), plots are a 10-15 acre contiguous block. Both leaf and nut samples are collected at five times during the season, selected from 114 trees in each plot for a period of three to five 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 noted. Light interception, trunk diameter, and individual yields of these trees will also be measured.

Standard leaf sampling protocol is carried out on exposed, non-fruiting spurs, as well as collecting leaves from fruiting spurs with one and multiple

fruit (two) to explore different sampling methods. Composite nut samples are collected from each site. Both leaf and nut samples are processed by researchers prior to sent them to the Division of Agriculture and Natural Resources (DANR) Analytical Laboratory located on the UC Davis campus.

RESULTS AND DISCUSSION

This observational study illustrates nutrient dynamics throughout the season. Data from the first year of sample collection (2008 field season; Figure 1) suggest that nutrient concentrations and their variability depend on the nutrient sampled, sample type and sampling time.

Local fruit load, for example, appeared to significantly affect concentrations of nitrogen, phosphorus, potassium, boron, zinc, sulfur, and copper. Other nutrients, such as calcium, magnesium, manganese and iron were much less affected by local fruit load. A clear effect of local competition between fruit and leaf can be observed for some nutrients. This competition may be critical for explaining nutrient mobilization from leaves to local nut load.

Results suggest that the current standard sampling protocol, which only includes leaf samples from non-fruiting spurs, may not reflect critical local tree nutrient status. The difference in response of non-fruiting spurs (NF) and spurs with one fruit (F1) and spurs with two fruits (F2) samples, clearly visible for nitrogen and zinc, may be of particular relevance as F1 and F2 leaves were below established leaf critical values in July.

Preliminary results (Figure 2) from 2008 illustrate that the coefficient of variation for four different nutrients varies throughout the season, among nutrients, and among sample type. Knowledge of the coefficient of variation for plant nutrients is essential to establish sampling and interpretation protocols, these preliminary results illustrate the complexity and impracticality of current sampling strategies. This study is ongoing.

Figure 1. Nutrient behavior throughout the 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 during the 2008 season.

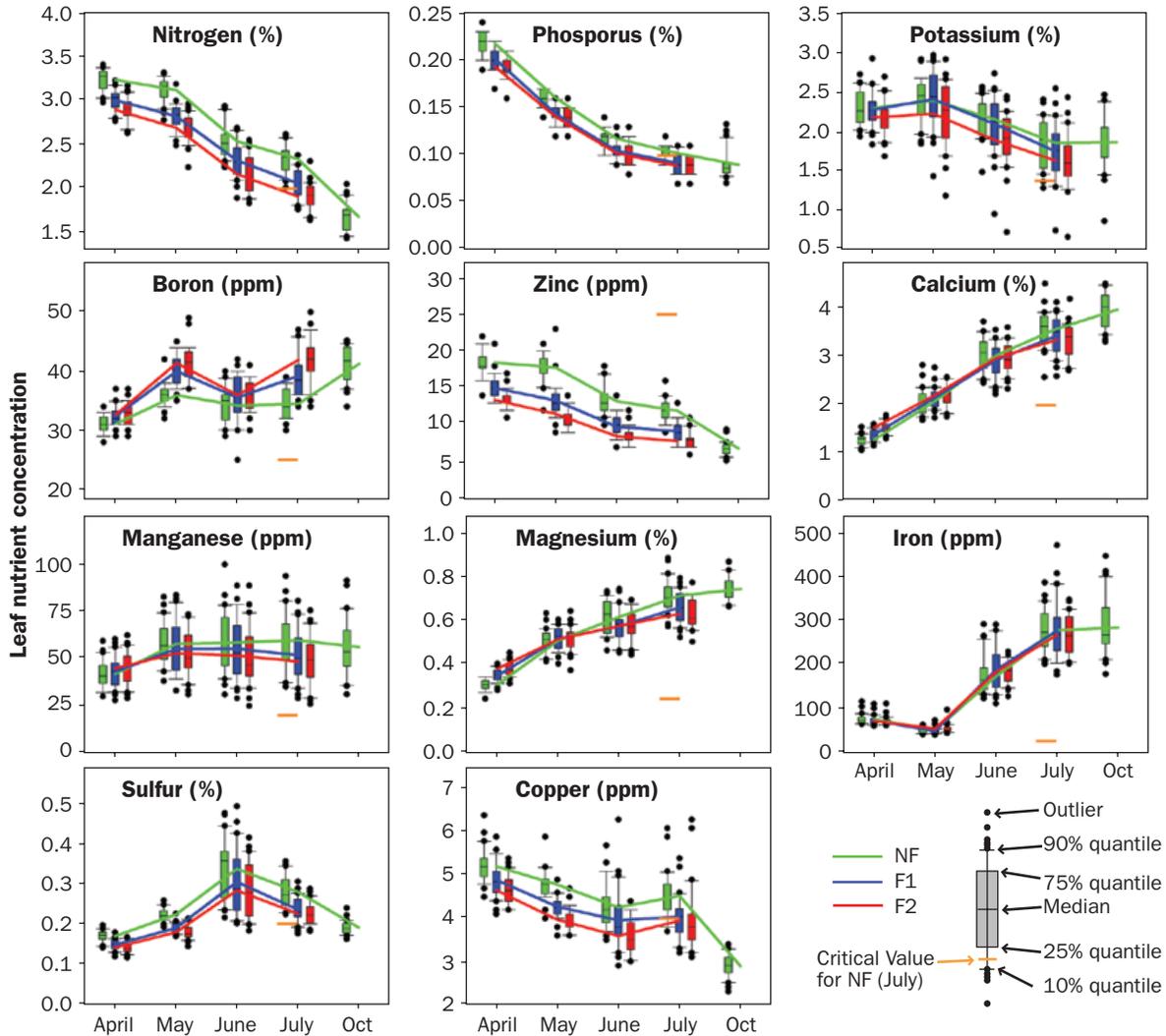
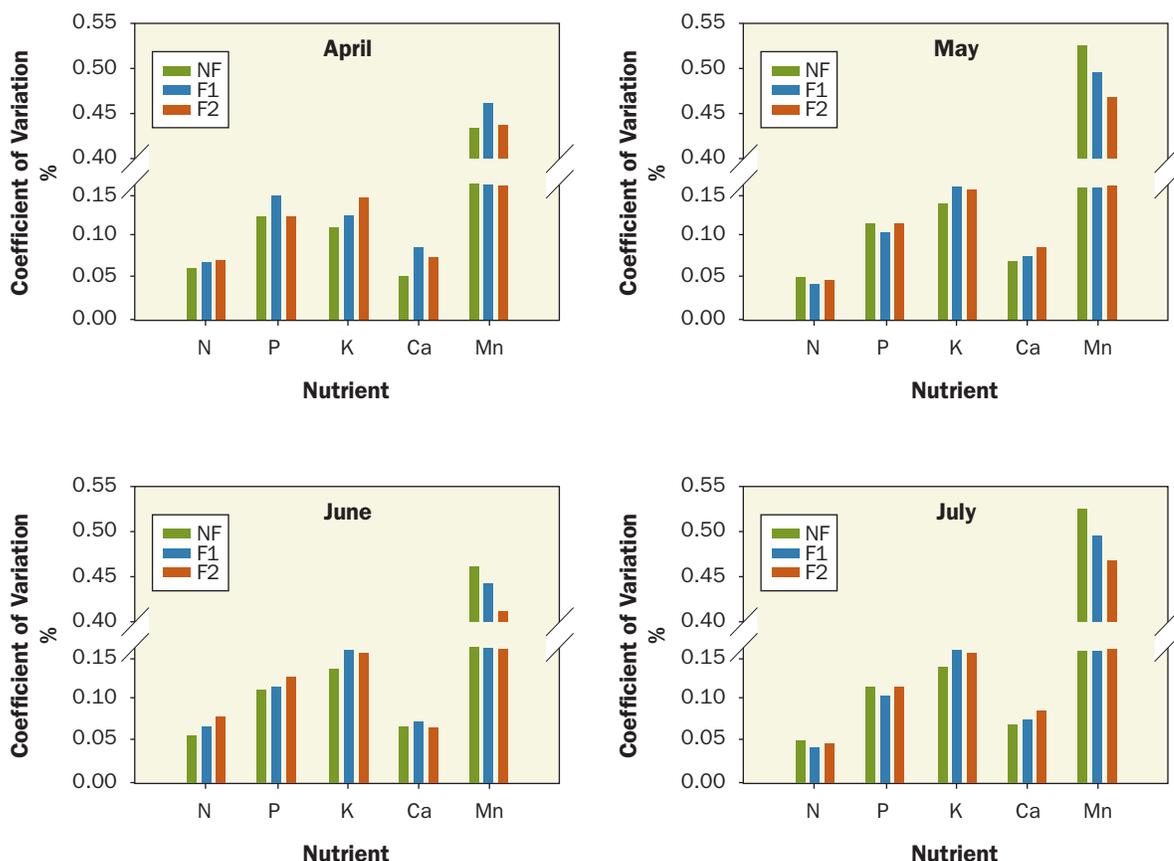


Figure 2.

Coefficients of Variation of four nutrients in three different kinds of samples during 2008 year. (NF=leaves from non-fruited spurs; F1= leaves from one fruit-spur; F2= leaves from two fruit-spur).



CONCLUSIONS

Our preliminary data suggest the following:

- Current tissue sampling protocols (non-fruited spurs) may not reflect true tree nutrient status since they ignore the nutrient status of the fruited spurs that hold the current and subsequent years yield.
- Preliminary evidence suggests that death of fruited spurs is correlated with a localized nutrient deficit in those spurs.
- As a consequence of the high coefficient of variation for plant nutrients throughout the

season, among nutrients, and among sample type, obtaining a representative leaf sample for diagnostic purposes is much more complex than previously envisioned and is likely impractical for highly variable nutrients such as manganese. New approaches to monitoring and managing nutrition in almond are required.

REFERENCES

- Brown, P.H., and K. Uriu. 1996. Nutrition deficiencies and toxicities: diagnosing and correcting imbalances. In: Almond production manual. University of California, Division of Agriculture and Natural Resources. Publication 3364.

Developing a Nutrient Budget Approach To Fertilizer Management In Almond

PROJECT LEADER

Patrick Brown
Professor
Department of Plant Sciences
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-0929
phbrown@ucdavis.edu

COOPERATOR

Saiful Muhammad
Ph.D. student
Department of Plant Sciences
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-8499
smuhammad@ucdavis.edu

INTRODUCTION

There are many different approaches to nutrient management in crops that range from the simple to the sophisticated. Currently nutrient management in almond is based on the Critical Value concept (Brown and Uriu, 1996). Critical Value (CV) represents the leaf nutrient concentration of a standard leaf sample at which yield is equal to 95% of maximum yield. (Ullrich and Hills, 1990). Ideally, CVs are established in carefully controlled experiments, in which the relationship between yield and nutrient concentration is closely monitored. In almond the majority of CVs have been determined on the basis of visual symptoms, not based on yield reduction (Beutel et al., 1978; Brown and Uriu, 1996). Yield-based CVs in almond are only available for nitrogen (N) (Uriu, 1976), potassium (K) (Meyer, 1996; Reidel, et al., 2004) and boron (B) (Nyomora et al., 1999). Weinbaum (1990) suggested that a critical

nitrogen leaf value of 2.3% in July non-fruiting spur leaves is likely adequate for almond.

In this approach leaf nutrient analysis provides only an indication of adequacy or deficiency but does 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. Not only is the collection of a representative leaf sample difficult, and generally collected too late in the season to respond, 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, employs knowledge of crop growth and development to derive nutrient demand curves that guide the quantity and timing of fertilizer applications. Nutrient budgets have been developed for corn (Karlen et al., 1988), cotton (Halevy et al., 1977), tomato (Huett 1986) and others.

The mature almond tree is well suited to a budget approach to fertility management as it is relatively determinant in its growth patterns, almonds show limited vegetative re-growth after fruits reach full size, and the majority of whole tree macronutrient demand is partitioned to nuts. Once the spur leaves are fully mature, the N and K requirements for vegetation are largely satisfied. Fruits, on the other hand, continue to accumulate N and K until harvest.

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 CVs 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 'Nonpareil' 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 'Nonpareil' trees individually. A total of 128 experimental units of 15 trees have been treated and from this 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 five fertigation events. Basal sulfate of potash (SOP) application was made in early February and fertigation was done in February, April, June and October. The total experimental area is 100 acres.

The twelve treatments include four rates of N (125, 200, 275, 350 pounds/acre, all other elements held constant) applied through UAN32; 3 rates of K (100, 200, 300 pounds/acre, applied as 60% SOP basal and 40% KTS fertigated; all other elements held constant), plus four contrasting rates of CAN-17, one KCl and one SOP treatments. Effectiveness of each treatment will be determined by changes in leaf tissue analysis, yield, and soil residual N and K over a three to five year period.

Leaf samples were collected in April, May, June, July and October. Tissue determination for the major elements nitrogen, phosphorus, potassium, sulfate, calcium, magnesium, boron, zinc, iron, manganese and copper (N, P, K, S, Ca, Mg, B, Zn, Fe, Mn and Cu) in all the collected nut samples and leaf samples was processed by the Division of Agriculture and Natural Resources (DANR) analytical laboratory at UC Davis. Tree yield and quality attributes were collected from all individual trees. All nutrient and biomass data will be cross-referenced to individual tree yield, phenology, environment and other variables to develop a phenology and yield based nutrient model for almond.

RESULTS

The accumulation of nitrogen, phosphorus, potassium, calcium, magnesium, zinc and boron in the fruit for different rates of N increased over the season is shown in Figure 1.

Nitrogen

Nitrogen accumulation in the fruit was positively correlated with nitrogen supply at all sampling dates. At 30 days after full bloom (DAFB) 100 kg ha⁻¹ N was accumulated for N rate 140 kg ha⁻¹,

Figure 1.

Nitrogen, phosphorus, potassium, calcium, magnesium, zinc and boron uptake by almond fruit from nitrogen rate treatments.

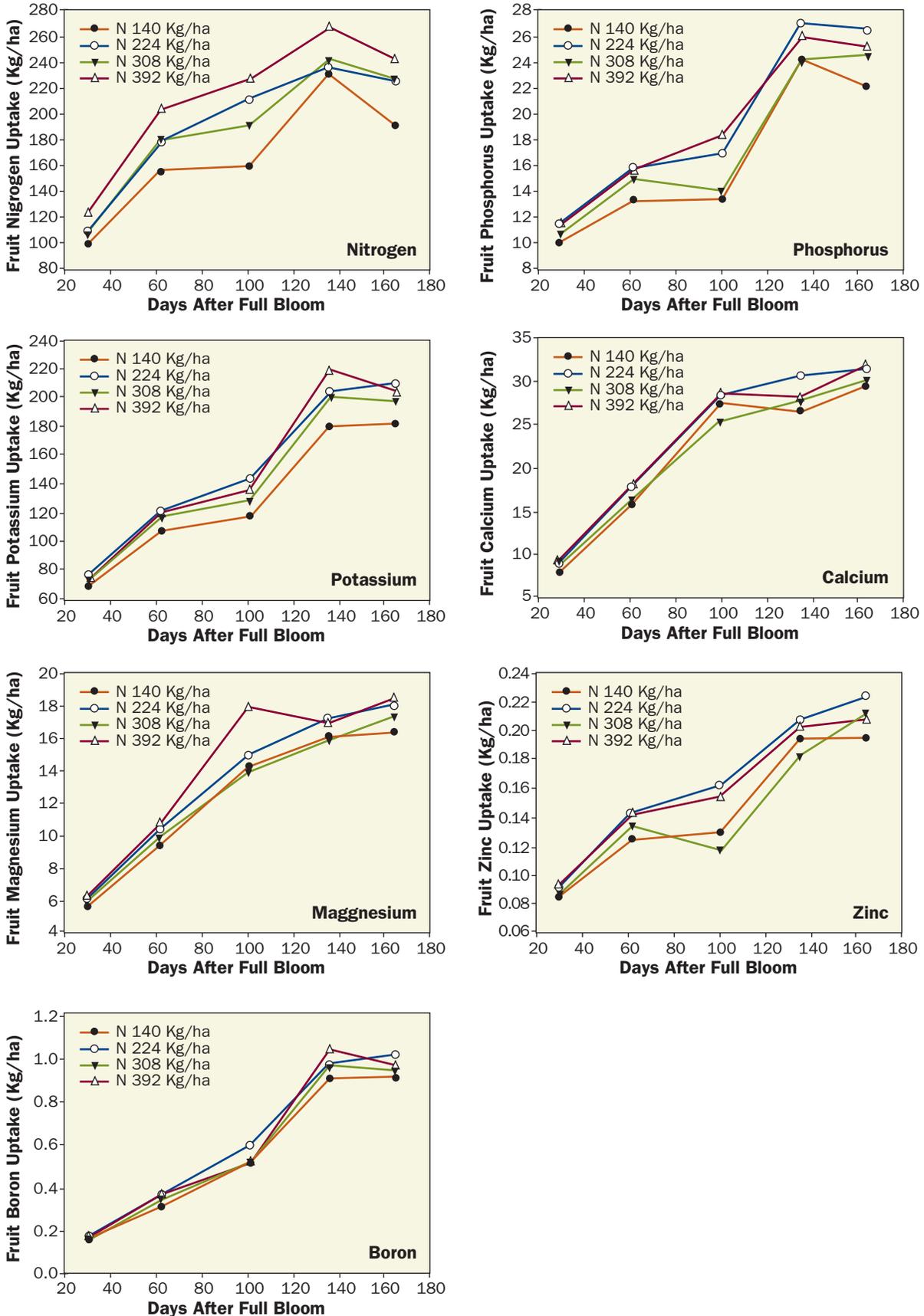
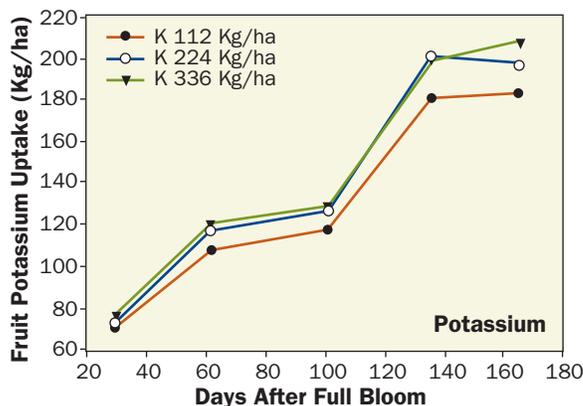


Figure 2.
Potassium uptake by almond fruit from potassium rate treatments.



109 kg ha⁻¹ for N rate 224 kg ha⁻¹ and 308 kg ha⁻¹, while 124 kg ha⁻¹ N was accumulated for N rate 392 kg ha⁻¹. Nitrogen accumulation increased in all treatments and was maximal at 136DAFB. Between 136 and 165 DAFB (harvest), however, total fruit N accumulation declined for all N rate treatments suggesting that N in fruit had been remobilized back to the tree.

Phosphorus

Phosphorus exhibited an annual trend that resembled nitrogen and increasing nitrogen supply also increased phosphorus uptake. All treatments also exhibited a small but significant decline in P concentrations between 136 and 165 DAFB (harvest). This pattern of pre-harvest decline was observed with N and P but not with any other element.

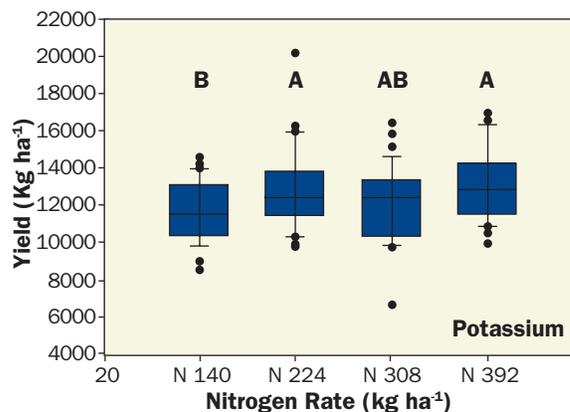
Potassium

Potassium accumulation in the fruit increased with growth (Figure 2). K uptake from K rate 224 kg ha⁻¹ and 336 kg ha⁻¹ was similar during the season except at 165 DAFB (harvest). Fruit K accumulation increased from 70.5 kg ha⁻¹ at 30DAFB to 184 kg ha⁻¹ at 165 DAFB for K rate 112 kg ha⁻¹, while for K rate 336 kg ha⁻¹ K accumulation increased from 77 kg ha⁻¹ at 30DAFB, to 208 kg ha⁻¹ at 165 DAFB.

Yield

Crop yield varied substantially throughout the orchard. Even though this experiment was only established in spring 2008, nitrogen treatments had a significant effect on crop yields in Year 1 of the experiment (Figure. 3). Maximum fruit yield (12,800 kg ha⁻¹– total dry fruit weight) was obtained from the highest N treatment (392 kg ha⁻¹), while minimum yield (11,500 kg ha⁻¹) was obtained from the lowest nitrogen treatment (140 kg ha⁻¹). The effect of the K rate treatments on fruit yield was not statistically significant.

Figure 3.
Effect of different nitrogen rates on almond yields at Belridge, California, in 2008. 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.



DISCUSSION

Results from a single year of experimentation should be interpreted with care as treatment effects may not be fully established and multi-year effects cannot be discerned. Increasing nitrogen supply, however, significantly increased fruit yield and nitrogen concentration in the plant tissues and these differences existed between treatments at all sample dates. Trends in nutrient concentrations and fruit accumulation were evident early in the season and persisted throughout the year and may imply that early

season sampling may be useful in monitoring of tree nitrogen demand. Nitrogen and phosphorus accumulation was highest at 136 DAFB and then decreased at harvest suggesting that N and P moved from the fruit to the shoot during nut maturation. The resorption of N and P was high for the lowest N rate (140 kg ha⁻¹) suggesting that relative tree demand can influence N resorption. Resorption of phloem mobile nutrients from fruit back toward tree woody structures has not, to our knowledge, been previously recorded, this effect was not seen with K, Ca, Mg and Zn.

REFERENCES

- Beutel, J., K. Uriu and O. Lilleland. 1978. Leaf analysis for California deciduous fruits. In: Reisenauer HM (ed.) soil and plant-tissue testing in California. Pages 11-14.
- Brown, P.H., and K. Uriu. 1996. Nutrition deficiencies and toxicities: diagnosing and correcting imbalances. In: Almond production manual. University of California, Division of Agriculture and Natural Resources. Publication 3364.
- Halevy, J., A. Marani and T. Markovitz. 1987. Growth and NPK uptake of high yielding cotton grown at different nitrogen levels in a permanent-plot experiment. *Plant and Soil* 103, 39-44.
- Huett, D.O. 1986. Response to nitrogen and potassium of tomatoes grown in sand culture. *Australian Journal of Experimental Agriculture. Agric.*, 1986, 26, 133-138.
- Karlen, D.L., R.L. Flannery and E.J. Sadler. 1988. Aerial Accumulation and Partitioning of Nutrients by Corn. *Agron. J.* 80:232-242.
- Meyer, R.D. 1996. Potassium fertilization/ foliar N/P/K/B studies. In: Almond Board of California. 1972-2003. Years of discovery. Pages 291-292.
- Nyomora, A.M.S., P.H. Brown and B. Krueger. 1999. Rate and time of boron application increase almond productivity and tissue boron concentration. *HortScience* 34: 242-245.
- Reidel, E.F., P.H. Brown, R.A. Duncan, R.F. Heerema and S.A. Weinbaum. 2004. Sensitivity of yield determinants to potassium deficiency in 'Nonpareil' almond (*Prunus dulcis* (Mill.) D.A. Webb). *J Hort. Sci Biotech.* 79: 906-910.
- Uriu, K. 1976. Nitrogen rate study. In: Almond Board of California. 1972-2003. Years of discovery. Page 287.
- Weinbaum, S.A., R.M. Carlson, P.H. Brown, D.A. Goldhamer, W.C. Micke, W. Asai, M. Viveros, T.T. Muraoka, J. Katcher and B. Teviotdale. 1990. Optimization of nitrogen use. In: Almond Board of California. 1972-2003. Years of discovery. Pages 289-290.
- Ulrich, A., and F.J. Hills. 1990. Plant analysis as an aid in fertilizing sugarbeet. In: Westerman R.L. (ed.) *Soil testing and plant analysis*. 3rd Edition Soil Science Society of America, Inc. Book Series 3. Madison, Wisconsin. Pages 429-447.

Evaluation of Humic Substances Used in Commercial Fertilizer Formulations

PROJECT LEADER

Timothy K. Hartz
Extension Specialist
Department of Plant Sciences
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-1738
tkhartz@ucdavis.edu

INTRODUCTION

The potential benefits of using humic acids in agriculture have been the subject of a substantial body of research. Among the benefits claimed have been improved seed germination, stimulation of root growth and soil microbial activity, enhanced nutrient uptake, chelation of micronutrients, and stimulation of crop growth and yield. Many commercial fertilizer formulations containing humic substances are currently being marketed. While the bioactivity of humic substances has been well documented in solution culture or hydroponic experiments, very few studies showing positive crop response to humic acid have been conducted in representative agricultural soils. This project systematically examined the effects of commercial humic acid formulations when applied to agricultural soils. Using laboratory, greenhouse and field experiments, humic acid effects on soil microbial activity, early plant growth, nutrient uptake, and yield of lettuce and processing tomato were documented.

OBJECTIVES

- 1 Quantify the effects of humic acid materials used in commercial fertilizer formulations on soil microbial activity, early growth, nutrient uptake, and crop yield.
- 2 Determine whether crop response to humic acid materials is soil-specific.

DESCRIPTION

Five commercial humic acid formulations (Table 1) were evaluated in greenhouse, laboratory and field experiments. In a 2007 greenhouse experiment the effect of humic acids on lettuce germination, growth and phosphorus (P) uptake was evaluated. Four field soils were collected, two from the San Joaquin Valley and two from the Sacramento Valley; the soils chosen had low P availability [< 15 PPM bicarbonate extractable (Olsen) P]. Pots of one-liter volume were filled with soil, and bands of the liquid humic acid formulations, with and without 10-34-0 fertilizer, were applied to simulate a banded preplant fertilizer application. Additional soil

was applied on top of the fertilizer, and 10 seeds of romaine lettuce ('Green Towers' variety) were planted in each pot. The experimental design was randomized complete block, with five replicate pots of each soil x treatment combination. The mean time to seedling emergence was monitored, and then each pot was thinned to a single plant. The plants were watered with a nutrient solution to supply adequate nitrogen (N). Whole plants were harvested 47 days after seeding and evaluated for dry biomass and P uptake.

A laboratory incubation experiment was conducted in 2008 to evaluate the effects of the humic acid formulations on soil microbial activity, and microbial community structure. Two agricultural soils were selected, one a low organic matter soil from the San Joaquin Valley, one a higher organic matter soil from the Salinas Valley. One hundred grams of dry soil was placed in glass jars of one-liter volume. The soil was wetted to field capacity moisture content by adding water alone, P fertilizer solution, humic acid solution, or a solution containing both humic acid and P fertilizer. The concentrations of P and humic acids were calculated to represent the concentration of these materials in a banded application of 20 pounds P_2O_5 and two pounds active ingredient (a.i.) humic acid per acre. Four replicate jars of each humic acid/P fertilizer combination per soil were prepared along with unfertilized and P-fertilized controls. The jars were sealed and placed in a 77°F chamber for seven days. After three and seven days, air samples were removed from the jars and analyzed for CO_2 concentration; from these data the amount of carbon mineralized by microbial activity was calculated. At the end of seven days the jars were removed from the chamber, and 50 grams of wet soil removed from each jar. These soil samples were analyzed for phospholipid fatty acid (PLFA) analysis by gas chromatography. This technique provides a profile of the active microbial communities in the soil (fungi, bacteria, etc.).

A drip-irrigated field experiment with processing tomato was conducted at University of California, Davis, in 2008. A field of silt loam soil with an Olsen P value of 12 ppm was prepared with 60-inch wide raised beds. On April 18, 2008, a pre-transplanting banded application of fertilizer was applied four to five inches deep, offset approximately one inch from the bed center. The treatments applied included each of the humic acid formulations at both a one- and three-pound a.i. rate applied with 10-34-0 fertilizer, a P-fertilized control, and a no P control. In all treatments receiving P fertilization 70 pounds P_2O_5 /acre was applied. The humic acid materials were thoroughly blended with the 10-34-0 before application to simulate commercial use. The control not receiving P fertilization received preplant N equivalent to that contained in the 10-34-0 fertilizer. The field was transplanted with Heinz 9780 processing tomato plants on April 24. The experimental design was randomized complete block with five replications; individual single row plots were 100 feet long. One month after transplanting four whole plants per plot were harvested, dried and analyzed for P concentration. At commercial maturity the plots were mechanically harvested and marketable yield was determined.

The processing tomato field experiment was repeated in the 2009 production season in a field with Olsen P of 13 ppm. The trial structure was similar to the 2008 trial, with minor modifications. All humic acid treatments and the fertilized control received only 40 pounds P_2O_5 /acre. Also, the manufacturer of the ESP-50 product expressed a desire to eliminate the high rate of that product, as it was not economically feasible at that rate; in its place an additional fertilized control treatment receiving 80 pounds P_2O_5 /acre was added. The trial was transplanted on April 29.

RESULTS

In the greenhouse study, humic acid application did not influence the speed of lettuce seedling emergence, or the final germination percentage. P fertilization had a profound influence on lettuce growth in all soils (Table 2); unfertilized treatments in Soils 1 and 2 were severely P-limited. Only in Soil 3 did the addition of a humic acid formulation with P fertilizer increase lettuce growth above that of P fertilization alone. In the absence on P fertilization, no humic acid formulation significantly increased lettuce growth in any soil. Similarly, humic acids did not increase lettuce P uptake (Table 3).

In the incubation experiment P fertilization stimulated soil microbial activity in both soils, while humic acids caused a small but statistically significant stimulation only after seven days, and only in the lower organic matter soil (Table 4). In that low organic matter soil humic acids increased the detectable amounts of phospholipid fatty acids that are representative of fungi, bacteria and actinomycetes (Table 5). In the higher organic matter soil the application of

humic acids was not stimulatory; in fact, the P-fertilized control had higher PLFA levels than the humic treatments.

In the field experiment P fertilization increased early plant growth and plant P concentration in 2008 (Table 6). However, humic acids had no effect on those parameters. P fertilization increased fruit yield, but humic acids did not confer any benefit beyond P fertilization alone. No treatments significantly affected fruit quality (soluble solids, pH or color, data no shown). Results of the 2009 trial were similar (Table 7). P fertilization significantly increased early growth and leaf P concentration, but the humic acids had no stimulatory effect beyond P fertilization alone. In this trial humic acids had no beneficial effects on fruit yield or quality.

CONCLUSIONS

While commercial humic acid formulations may affect crop plant performance under some conditions, this project could not document any consistent agronomic benefit from any of the commercial humic acid formulations evaluated.

Table 1.
Commercial humic acid products
being tested.

Humic formulation	Humic acid content	Form	Manufacturer
Actagro Humic Acid	10%	Liquid	Actagro, LLC
Actagro Liquid Humus ^z	11%	Liquid	Actagro, LLC
Organo Liquid Hume	6%	Liquid	Black Earth Humates, Ltd.
Quantum-H	6%	Liquid	Horizon Ag Products
ESP-50	50%	Powder	Earthgreen Products, Inc.

^z Formulation used in 2009 was 22% humic content.

Table 2.
Effect of humic acid formulation and P fertilizer on lettuce plant dry weight, greenhouse experiment.

Treatment	Lettuce dry wt (g/plant)			
	Soil 1	Soil 2	Soil 3	Soil 4
Actagro Humic Acid	0.19 b ^z	0.43 b	0.86 d	1.37 b
Actagro Liquid Humus	0.19 b	0.44 b	0.96 d	1.24 b
Organo Liquid Hume	0.28 b	0.52 b	0.92 d	1.03 b
Quantum-H	0.26 b	0.61 b	0.81 d	1.10 b
ESP-50	0.36 b	0.65 b	0.91 d	1.29 b
Actagro Humic Acid + P	1.64 a	1.72 a	3.44 a	2.96 a
Actagro liquid Humus + P	1.73 a	1.87 a	3.28 ab	2.78 a
Organo Liquid Hume + P	1.91 a	1.52 a	3.44 a	2.99 a
Quantum-H + P	1.67 a	1.91 a	3.02 abc	2.49 a
ESP-50 + P	1.91 a	1.48 a	2.63 c	3.20 a
P alone	2.08 a	1.89 a	2.69 bc	2.74 a
No humic acid or P	0.21 b	0.50 b	0.79 d	1.06 b

Contrasts				
Humics alone vs. humics + P	**	**	**	**
Humics + P vs. P alone	ns	ns	*	ns
Humics alone vs. no humics or P	ns	ns	ns	ns

^z Mean separation within columns by Duncan's multiple range test, $p < 0.05$

ns, *, ** Not significant at $p < 0.05$, or significant at $p < 0.05$ or 0.01, respectively

Table 3.
Effect of humic acid formulation and P fertilizer on lettuce P uptake, greenhouse experiment.

Treatment	Lettuce P uptake (mg/plant)			
	Soil 1	Soil 2	Soil 3	Soil 4
Actagro Humic Acid	0.36 b ^z	0.82 c	1.91 c	4.28 c
Actagro Liquid Humus	0.42 b	0.93 c	2.06 c	3.81 c
Organo Liquid Hume	0.51 b	1.11 c	1.90 c	3.10 c
Quantum-H	0.55 b	1.18 c	1.83 c	3.20 c
ESP-50	0.80 b	1.43 c	2.05 c	3.55 c
Actagro Humic Acid + P	6.72 a	6.40 ab	19.85 a	14.60 b
Actagro liquid Humus + P	6.52 a	6.74 ab	19.72 a	16.95 ab
Organo Liquid Hume + P	7.35 a	6.08 ab	17.68 a	16.63 ab
Quantum-H + P	6.59 a	7.04 a	18.80 a	14.96 b
ESP-50 + P	7.38 a	5.48 b	12.76 b	20.57 a
P alone	7.52 a	6.56 ab	15.66 ab	15.39 b
No humic acid or P	0.48 b	1.03 c	1.68 c	2.80 c

Contrasts				
Humics alone vs. humics + P	**	**	**	**
Humics + P vs. P alone	ns	ns	ns	ns
Humics alone vs. no humics or P	ns	ns	ns	ns

^z Mean separation within columns by Duncan's multiple range test, $p < 0.05$

ns, *, ** Not significant at $p < 0.05$, or significant at $p < 0.05$ or 0.01, respectively

Table 4.

Effects of humic acid formulation and P fertilization on soil microbial activity (mg carbon mineralized / jar), incubation experiment.

Treatment	Soil 1		Soil 2	
	3 days	7 days	3 days	7 days
Actagro Humic Acid	2.22 b ^z	4.27 c	6.27 e	8.86 e
Actagro Liquid Humus	2.34 b	4.06 c	6.50 de	9.36 d
Organo Liquid Hume	2.23 b	3.90 c	6.58 d	9.27 de
Quantum-H	2.24 b	3.93 c	6.25 e	8.84 e
ESP-50	2.29 b	4.19 c	6.29 de	8.91 de
Actagro Humic Acid + P	2.84 a	5.69 b	7.35 c	10.77 bc
Actagro liquid Humus + P	2.48 a	5.84 b	7.52 bc	11.06 ab
Organo Liquid Hume + P	2.85 a	5.83 b	7.90 a	11.26 a
Quantum-H + P	3.04 a	6.30 a	7.26 c	10.56 c
ESP-50 + P	3.04 a	5.89 ab	7.84 a	11.24 a
P alone	2.86 a	5.45 b	7.71 ab	11.22 a
No humic acid or P	2.32 b	3.99 c	6.40 de	9.12 de
Contrasts				
Humics alone vs. humics + P	**	**	**	**
Humics + P vs. P alone	ns	**	ns	ns
Humics alone vs. no humics or P	ns	ns	ns	ns

^z Mean separation within columns by Duncan's multiple range test, $p < 0.05$

ns, *, ** Not significant at $p < 0.05$, or significant at $p < 0.05$ or 0.01 , respectively

Table 5.

Effects of humic acid formulations and P fertilization on the amount of phospholipid fatty acids detectable in soil (nmol / g dry soil), incubation experiment.

		Phospholipid fatty acids detected (nmol/g dry soil)			
Soil	Treatment(s)	Total	Fungi	Bacteria	Actinomycetes
1	Actagro Humic Acid	26.1 ab ^z	5.7 ab	13.5 ab	1.44 ab
	Actagro Liquid Humus	27.4 ab	6.0 ab	14.2 ab	1.48 ab
	Organo Liquid Hume	25.4 ab	5.6 ab	13.2 ab	1.44 ab
	Quantum-H	29.8 a	6.3 a	15.2 a	1.59 ab
	ESP-50	26.2 ab	5.7 ab	13.9 ab	1.48 ab
	Actagro Humic Acid + P	30.2 a	6.6 a	16.0 a	1.61 ab
	Actagro liquid Humus + P	28.8 a	6.2 a	15.0 a	1.53 ab
	Organo Liquid Hume + P	28.5 a	6.1 a	15.0 a	1.53 ab
	Quantum-H + P	25.3 ab	5.4 ab	13.4 ab	1.40 ab
	ESP-50 + P	29.9 a	6.4 a	15.6 a	1.63 a
	P alone	22.0 b	4.4 b	11.6 b	1.28 bc
	No humic acid or P	14.9 c	2.6 c	8.0 c	1.09 c
	Contrasts				
Humics alone vs. humics + P		*	ns	*	ns
Humics + P vs. P alone		**	*	**	*
Humics alone vs. no humics or P		**	**	**	**
P alone vs. no humics or P		**	**	**	ns
2	Actagro Humic Acid	52.3 abc	11.9 abc	29.2 abc	3.02 abc
	Actagro Liquid Humus	58.5 a	13.4 a	32.8 a	3.34 a
	Organo Liquid Hume	49.4 abc	11.6 abc	27.7 abc	2.71 bcd
	Quantum-H	57.7 a	13.4 a	32.3 a	3.24 ab
	ESP-50	59.4 a	13.7 a	33.0 a	3.37 a
	Actagro Humic Acid + P	43.0 c	10.1 c	24.1 c	2.45 d
	Actagro liquid Humus + P	55.5 ab	12.9 ab	31.0 ab	3.11 abc
	Organo Liquid Hume + P	46.3 abc	10.7 bc	25.8 bc	2.60 cd
	Quantum-H + P	56.7 ab	13.1 ab	31.8 a	3.06 abc
	ESP-50 + P	51.5 abc	12.0 abc	29.7 abc	2.83 abcd
	P alone	59.3 a	13.6 a	33.0 a	3.32 a
	No humic acid or P	54.3 ab	12.4 abc	0.3 ab	3.10 abc
	Contrasts				
Humics alone vs. humics + P		ns	ns	ns	ns
Humics + P vs. P alone		**	**	**	**
Humics alone vs. no humics or P		ns	ns	ns	ns
P alone vs. no humics or P		ns	ns	ns	ns

^z Mean separation by Duncan's multiple range test at $p < 0.05$

ns, *, ** Not significant at $p < 0.05$, or significant at $p < 0.05$ or 0.01 , respectively

Table 6.

Effect of humic acid formulations and P fertilization on processing tomato early growth, plant P concentration and marketable fruit yield, 2008 trial.

Treatment	Humic acid rate (lb a.i./acre)	Plant dry wt (g)	Plant P concentration (% dry wt)	Mkt. fruit yield (tons/acre)
Actagro Humic Acid	1	21.0 ab ^z	0.46 a	50.6 ab
Actagro Liquid Humus		23.2 a	0.40 b	48.9 ab
Organo Liquid Hume		20.5 ab	0.39 b	51.4 a
Quantum-H		23.1 a	0.44 ab	48.2 ab
ESP-50		22.8 a	0.40 b	49.0 ab
Actagro Humic Acid	3	20.9 ab	0.43 ab	47.4 ab
Actagro liquid Humus		21.4 ab	0.44 ab	51.0 ab
Organo Liquid Hume		23.6 a	0.40 b	52.3 a
Quantum-H		20.8 ab	0.45 a	50.2 ab
ESP-50		21.6 ab	0.40 b	51.9 a
P alone		21.7 ab	0.39 b	51.4 ab
No humic acid or P		17.4 b	0.34 c	46.4 b

Contrasts				
All humic treatments vs. P alone		ns	ns	ns
All P treatments vs. no P control		**	**	*

^z Mean separation within columns by Duncan's multiple range test, $p < 0.05$

ns, *, ** Not significant at $p < 0.05$, or significant at $p < 0.05$ or 0.01, respectively

Table 7.

Effect of humic acid formulations and P fertilization on processing tomato early growth and tissue P concentration, 2009 trial.

Treatment	Humic acid rate (lb a.i./acre)	Plant dry wt (g)	Leaf P concentration (%)	Mkt. fruit yield (tons/acre)
Actagro Humic Acid	1	19.3 a ^z	0.62 b	41.3
Actagro Liquid Humus		22.1 a	0.61 b	43.5
Organo Liquid Hume		20.5 a	0.64 b	41.6
Quantum-H		19.8 a	0.63 b	42.4
ESP-50		22.2 a	0.62 b	44.2
Actagro Humic Acid	3	20.5 a	0.63 b	45.3
Actagro liquid Humus		22.7 a	0.67 b	44.5
Organo Liquid Hume		22.5 a	0.62 b	47.9
Quantum-H		21.7 a	0.64 b	44.5
P control @ 40 lb P ₂ O ₅ /acre		21.8 a	0.68 ab	44.2
P control @ 80 lb P ₂ O ₅ /acre		23.0 a	0.76 a	44.3
Control no humic acid or P		15.5 b	0.43 c	43.3

ns

Contrasts				
All humic treatments vs. 40 lb P ₂ O ₅ /acre alone		ns	ns	ns
All P treatments vs. no P control		**	**	ns

^z Mean separation within columns by Duncan's multiple range test, $p < 0.05$

ns, *, ** Not significant at $p < 0.05$, or significant at $p < 0.05$ or 0.01, respectively

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

PROJECT LEADER

Timothy K. Hartz
Extension Specialist
Department of Plant Sciences
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-1738
tkhartz@ucdavis.edu

OBJECTIVE

Develop an informational Web site on economically and environmentally efficient nutrient management for vegetable, fruit and nut crops.

DESCRIPTION

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 two-four times the federal limit of 10 ppm NO₃-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 the majority of their funding to developing more efficient and environmentally sensitive fertility and irrigation practices for vegetables, berries and 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, monitoring techniques and the environmental fate of applied nutrients.

As the regulatory processes advance, the need for grower education will increase, and documentation of that education may become a condition for continued operation. For example, the Region 3 (Central Coast) Water Quality Control Board has required growers to complete a 15-hour short course on water quality protection in order to qualify for an irrigation discharge waiver. Similarly, various types of certification of industry professionals,

including Pest Control Advisers (PCA), Certified Crop Advisers (CCA) and Technical Service Providers (TSP), require continuing education credits. In the increasingly busy life such people lead, attendance at educational events can be a significant cost and scheduling hardship.

The maturation of the Internet has brought online educational tools that enhance outreach potential. Narrated PowerPoint presentations are simple to record and publish; such presentations, which can be enhanced with video clips for added impact, are considerably more dynamic and engaging than printed materials. Online quiz features can be used to measure mastery of the material presented. Tracking and comment features can be added to monitor the degree of usage of the materials, and solicit feedback from clientele. This project will develop a Web site on which the information from all FREP projects will be archived, and which will improve the accessibility of other related Internet resources. Original educational materials relating to nutrient management of horticultural crops will be developed using Internet tools; these materials will summarize and enhance the impact of FREP-funded research.

RESULTS

Work has begun on Web site development. We are in the process of identifying and organizing existing nutrient management information from University of California sources, other universities, and industry groups. By early 2010, we intend to have a fully functional site in place

and accessible for clientele use. Development of original educational content has also begun. Three educational PowerPoint presentations and narration scripts have been created 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.

The audio tracks are in the process of being recorded. These narrated presentations will be loaded on the Web site together with interactive quizzes to allow users to test their mastery of the material. The project leader will create additional narrated PowerPoint presentations and quizzes based on other completed FREP projects, as well as topical presentations (i.e., soil quality maintenance, soil and tissue testing, etc.).

Two crop-specific irrigation and nutrient management educational packets (processing tomato and lettuce) are currently under development. The intent is to summarize irrigation and nutrient management information for these major crops from both an agronomic and environmental perspective. Once these packets are completed they will serve as templates for educational materials on other important horticultural commodities, to be solicited from the appropriate University of California specialists.

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

PROJECT LEADER

R. Scott Johnson

Extension Specialist
UC Kearney Agricultural Center
9240 South Riverbend Avenue
Parlier, CA 93648
(559) 646-6547
sjohnson@uckac.edu

COOPERATOR

Robert H. Beede

Farm Advisor
UC Cooperative Extension,
Kings County
680 North Campus Drive, Suite A
Hanford, CA 93230
(559) 582-3211, ext 2737
bbeede@ucdavis.edu

COOPERATOR

Patrick Brown

Professor
Department of Plant Sciences
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-0929
phbrown@ucdavis.edu

COOPERATOR

Kevin Day

Farm Advisor
UC Cooperative Extension,
Tulare County
4437-B South Laspina Street
Tulare, CA
(559) 685-3309, ext 211
krday@ucdavis.edu

SUPPORTERS

Monterey AgResources

Lawrence Marais
P. O. Box 35000
Fresno, CA 93745
(559) 499-2100
lmarais@montereyagresources.com

INTRODUCTION

Zinc (Zn) is commonly deficient in California fruit and nut orchards. To correct the deficiency (or to prevent its occurrence) rather large doses are often applied, especially to pistachio trees. Only a small percent is taken up through the leaves and transported to other parts of the tree. The percent uptake can vary from less than 1% to as much as 7-8%. Clearly there is potential for improved efficiency. The recent increase in fertilizer prices and the danger of environmental

contamination from excess zinc in the soil have increased the urgency of this research.

There are hundreds of zinc formulations that vary greatly in cost, solubility, chemistry, and phytotoxicity. In this FREP project we have been focusing on evaluating the effectiveness of these various materials. We are interested in not only biological efficiency but cost effectiveness as well. The project relies heavily on using labeled ^{68}Zn —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, 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 zinc treatments in commercial peach and pistachio orchards.

DESCRIPTION

Although we have incorporated the ^{68}Zn label into several formulations, our emphasis during the first year and a half of this project has been on development of a procedure for comparing zinc materials without the label. Since the analysis of ^{68}Zn is very expensive, this will allow us to focus that approach on just the most effective zinc formulations. The procedure involves Nemaguard peach seedlings grown in a greenhouse 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.

Nemaguard seedlings are grown in washed beach sand and the cotyledons are removed to cut off nutrient reserves. They are fertilized with a 10% Hoagland solution minus zinc to keep them growing steadily but not so vigorously that secondary shoots start to push. Once the seedlings are about 12 to 16 inches in height, they begin to show typical zinc deficiency symptoms of narrow, pointed, chlorotic leaves at the shoot tip. Often, lateral shoots start to grow as well and show the same symptoms.

For treatment, the plants are brought into a lab where they are sprayed thoroughly from a spray bottle. No surfactants are added to the solution so beads are clearly visible on leaves, stem and in the axils of the leaves. The plants are returned to the greenhouse where they are grown under 40% Hoagland solution to help promote vigorous growth and stimulation of lateral shoots. The effect of the zinc is to promote larger primary leaves, greater secondary growth and a higher zinc concentration in the new growth. Four experiments using this procedure have been completed so far (Table 1). We have also tested the procedure on pistachio seedlings with limited success.

Working with the chemist at Monterey AgResources, we were able to incorporate the ^{68}Zn label into a Zn EDTA formulation by June 2008 and into zinc nitrate and zinc chloride by July 2009. One experiment was conducted comparing ^{68}Zn EDTA with ^{68}Zn sulfate on peach seedlings in the greenhouse. Several other experiments are planned or underway.

Table 1.

Zinc formulations used in experiments to treat NemaGuard peach seedlings showing symptoms of zinc deficiency.

Formulations	% Zn	Name	Company	Comments
Experiment 1				
Zinc Sulfate	36	Zn Sulfate	AG Specialties	Widely used in orchards
Zinc EDTA	9	Sequestar 9% Zinc Chelate solution	Monterey Ag. Resources	Derived from Zn (NH ₄) ₂ EDTA
Zinc Oxysulfate	52	Neutral or Basic Zinc	Monterey Ag. Resources	Mostly insoluble (ZnO). Has 1.25% soluble Zn (ZnSO ₄)
Zinc Leonardite	6.5	Actagro 6.5% Zinc	Actagro	Zn from ZnSO ₄ + organic acids derived from leonardite
Zinc Polyamine	5.8	Zinc PolyAmine	Northwest Agricultural Products (NAP)	Derived from zinc sulfate; chelated with organic and amino acids.
Experiment 2				
Zinc Sulfate	36	Zn Sulfate	AG Specialties	Widely used in orchards
Zinc Nitrate Mix	3.8	Formula 1	Patrick Brown's Mixture	Mixture of Zn (NO ₃) ₂ and other chemicals
Zinc Carbohydrate	6	Zicron-F	Floratine Biosciences	Derived from zinc sulfate monohydrate
Zinc Oxide Suspension	39.8	Zintrac	Pace International (Leffingwell)	Milky suspension of insoluble ZnO
Experiment 3				
Zinc Sulfate	36	Zn Sulfate	AG Specialties	Widely used in orchards
Zinc Nitrate Mix	3.8	Formula 1	Patrick Brown's Mixture	Mixture of Zn (NO ₃) ₂ and other chemicals
Experiment 4				
Zinc Sulfate	36	Zn Sulfate	AG Specialties	Widely used in orchards
Zinc Nitrate	22.0	Lab Grade Zn (NO ₃) ₂ •6H ₂ O	J.T. Baker	
Zinc Chloride	48.0	Lab Grade Zn Cl ₂	EMD Chemicals	Very corrosive
Zinc Phosphite	6.5	VZP	Agro-K	Derived from Zn carbonate and phosphorous acid
Zinc Glycine	7	BioMin	JH Biotech	Derived from Zn sulfate, citric acid and glycine

RESULTS AND DISCUSSION

In each of the four experiments using peach seedlings the various zinc formulations all improved growth and/or zinc concentration compared to the untreated control plants. However, some of the materials were clearly more effective than others (Table 2). By completion of the fourth experiment we came to the conclusion that effectiveness of zinc formulations was related to solubility and size of the accompanying anion. Our hypothesis is: the more soluble the material and the smaller the accompanying anion, the more effective the formulation. We further observed the most effective materials to be the most phytotoxic. Table 3 summarizes these conclusions.

The current theory about the penetration of cuticles by polar molecules (like zinc salts) is that there are narrow channels through the cuticle that allow the passage of such hydrophilic substances. These channels are particularly concentrated around stomates and the base of trichomes. It makes sense that smaller molecules can transverse these channels easier than larger molecules. Therefore, a chloride ion with a

molecular weight of 35 will pass through much easier than a sulfate ion with molecular weight of 96. The zinc ion of molecular weight 65 will thus be slowed by an accompanying sulfate molecule but not chloride. We have further theorized that phytotoxicity is probably due to the accumulation of excessive zinc. Therefore, the challenge with effective zinc materials like chloride and nitrate will be to find the limits of phytotoxicity. We want to put as much zinc on as possible but not to the point of causing substantial damage to the plant.

The experiments using ^{68}Zn label supported the findings with peach seedlings. The comparison of ^{68}Zn sulfate with ^{68}Zn EDTA showed a tenfold greater uptake of zinc from ^{68}Zn sulfate. Likewise, ^{68}Zn sulfate was considerably more efficient than ^{68}Zn oxide at supplying zinc to the plant. Experiments are currently underway comparing ^{68}Zn sulfate with ^{68}Zn chloride and ^{68}Zn nitrate. The few tests using pistachio seedlings were either inconclusive or supported the conclusions arrived at on peaches.

Table 2.

The effectiveness of zinc formulations at overcoming zinc deficiency symptoms in peach seedlings. All materials sprayed on seedlings with solutions containing 500 ppm zinc unless otherwise noted.

	Formulation	Primary leaf area (cm ²)	Lateral shoot leaf area (cm ²)	Zinc in new growth (ppm)
Experiment 1				
	Untreated Control	5.8 b*	66 c	8.1 c
	Zinc Sulfate	8.9 a	274 a	12.4 a
	Zinc EDTA	9.1 a	160 b	8.8 c
	Zinc Oxysulfate-52%	8.6 a	159 b	9.9 bc
	Zinc Leonardite	8.8 a	189 b	9.7 bc
	Zinc Polyamine	8.6 a	241 a	11.0 ab
Experiment 2				
	Untreated Control	4.8 c	51 b	3.7 c
	Zinc Sulfate	10.1 a	213 a	9.5 b
	Zinc Nitrate	10.5 a	271 a	14.8 a
	Zinc Carbohydrate	10.4 a	209 a	9.5 b
	Zinc Oxide Suspension	8.1 b	77 b	6.0 c
Experiment 3				
	Untreated Control	3.8 b	49 b	8.2 b
	Zinc Sulfate – 250 ppm Zn	13.7 a	59 b	9.8 b
	Zinc Sulfate – 500 ppm Zn	16.4 a	104 b	10.2 b
	Zinc Nitrate – 250 ppm Zn	13.4 a	287 a	9.8 b
	Zinc Nitrate – 500 ppm Zn	15.8 a	322 a	17.5 a
Experiment 4				
	Untreated Control	2.5 c	26 d	
	Zinc Sulfate	6.5 b	68 cd	Data
	Zinc Nitrate	11.3 a	189 b	Lost
	Zinc Chloride	13.0 a	284 a	
	Zinc Phosphite	5.0 bc	42 d	
	Zinc Glycine	6.6 b	94 c	

*Within each experiment, values in columns followed by different letters are significantly different from each other at p = 0.05.

Table 3.

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	Solubility (g/100 H ₂ O)	Phytotoxicity
Most Effective	Zinc Chloride	35	432	High (58*)
Almost As Good	Zinc Nitrate	62	324	High (54)
	Zinc Nitrate Mix	62 and 96	324	High (59)
Next Best	Zinc Sulfate	96	50	Moderate (12)
	Zinc Carbohydrate	96 and ?	High	Moderate
	Zinc Polyamine	96 and 75-204	High	Moderate
	Zinc Glycine	96 and 75		Moderate (15)
Less Effective	Zinc EDTA	292	High	Low
	Zinc Leonardite	1000+	High	Low
	Zinc Oxyulfate	16 and 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.

CONCLUSIONS

Numerous experiments conducted to this point suggest zinc chloride and zinc nitrate are the most efficient formulations for supplying zinc to peach and pistachio trees. Zinc sulfate also worked well and, due to its low cost, may be

the most cost effective material to use. During the last year of the project we will focus on field studies to evaluate rates, timing and additives to maximize the efficiency of these materials. We will evaluate both biological and economic efficiency and develop protocols that will minimize the risks of phytotoxicity.

Balancing Fertilizer Application Rates with Water Quality Protection in Strawberry Production

PRESENTER

Thomas R. Lockhart
District Manager
Cachuma Resource
Conservation District
920 East Stowell Road
Santa Maria, CA 93454
(805) 928-9269, ext 110
tom.lockhart@ca.nacdnet.net

PROJECT LEADER

Kay Mercer
Executive Director
Central Coast Agricultural
Water Quality Coalition
750 Shannon Hill Drive
Paso Robles, CA 93446
(805) 208-8039
klmercer@cox.net

PROJECT LEADER

Adriana Morales
Biologist
Cachuma Resource
Conservation District
USDA Service Center
920 East Stowell Road
Santa Maria, CA 93454
(805) 928-9269, ext107
adriana.morales@ca.usda.gov

COOPERATOR

Mark Gaskell
Farm Advisor
UC Cooperative Extension,
Santa Barbara County
624 West Foster Road, Suite A
Santa Maria , CA 93455
(805) 934-6240
mlgaskell@ucdavis.edu

COOPERATOR

Timothy K. Hartz
Extension Specialist
Department of Plant Sciences
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-1738
tkhartz@ucdavis.edu

INTRODUCTION

The Santa Maria Valley is home to diverse horticultural crops such as strawberries, lettuce and cole crops, as well as vine and tree crops. Relatively high rates of nitrogen (N) fertilizer are required to grow these crops and they all are irrigated. The combination of irrigation and fertilizer application increases soil salinity and the way to manage this salt buildup is to irrigate with an excess leaching fraction of water, preferably with sprinklers. Over-irrigating will leach salts past the root-zone and ultimately to groundwater, and sprinklers can create runoff. The Central Coast Regional Water Quality Control Board (RWQCB) reports high nitrate concentrations in ground water and surface water. Several wells have up to 70 ppm of

nitrate. Many surface water samples have been measured in excess of the 45 ppm, the drinking water standard for nitrate established by the Environmental Protection Agency. The RWQCB's Conditional Ag Waiver of 2004 requires farmers to develop farm water quality management plans to document existing practices and to implement additional management practices to reduce agricultural water and nutrient runoff leaving their property. We have developed tools to help farmers comply with water quality regulations and reduce input costs.

We have focused on three groups of farmers in the Santa Maria Valley. Members of Group 1 are farming strawberries and/or vegetables on four to 40 acres. They have contracts with shipping and/or marketing companies (coolers). The coolers

are either the landowners or the leaseholders of the land. Group 2 members are also small acreage strawberry and vegetable farmers, but they negotiate marketing and shipping separate from the owner or primary leaser of the land. These farmers have the primary lease for the land they farm or they own it. Group 3 consists of larger acreage strawberry and vegetable farmers and their farm managers. Most of these farmers, especially in Groups 1 and 2, speak Spanish as their primary language.

This is an outreach and education project and our approach has been to provide production workshops, field demonstrations and one-on-one field consultations. In the case of Group 1, we have asked the field representatives from the coolers to help set up the outreach opportunities with their farmers. There is much overlap and similarity between Groups 1 and 2. We have conducted two strawberry production meetings that have included UC Cooperative Extension and Resource Conservation District specialists speaking on irrigation water management and scheduling, nutrient and nitrate management techniques, as well as insect and pest management. Eleven of the farmers have participated in the USDA cost-share program called Environmental Quality Incentives Program (EQIP), in which use of and increased management of each of the practices mentioned above were used. Record keeping is a significant part of each EQIP contract related to water, nutrient, and pest management.

Work performed with Group 3 has included large scale field demonstrations, which are actually replicated trials. In each trial the grower's standard irrigation and N fertilizer practices have been used as one of the treatments for comparing with the other treatments being evaluated. A great advantage to this work with Group 3 is that the information obtained from these large commercial fields can be conveyed to all three groups at workshops and field days. As part of

this FREP project we have conducted five trials in commercial strawberry fields, and two trials in commercial vegetable fields.

Trial Number 1

Trial Number 1 was with 'Albion' variety of strawberries planted in October with three rates of preplant fertilizer, 0, 65 and 130 pounds of nitrogen (N) as 19-8-13 controlled release (CR) fertilizer. In addition to these preplant N treatments, we began injecting varying weekly rates of CAN-17 in January and continued for 26 weeks. The weekly rates were 2.5, 5, and 10 pounds of N per acre. The midrange treatment was the most promising. This year we are going to repeat the preplant treatments but lower the rates of preplant N and weekly injection rates. We will be planting 'Albion' and 'San Andreas' strawberry varieties.

Trial Number 2

Trial Number 2 was with 'Albion' variety of strawberries planted in October with three different injectable organic liquid N sources and three different weekly rates of N with each material. We began injecting weekly rates of Nitroboost®, Agrilizer®, Phytamin® fertilizers but we changed to Phytamin®, Neptunes Harvest®, and True Organic® early in the season and continued injections for 26 weeks. The change in the materials was due to plugging of drip lines with Nitroboost®, and Agrilizer® lost its organic certification. The weekly rates were 6, 12, and 18 pounds of N per acre. Again the midrange treatment showed the most promising yield results. This year we are going to increase the preplant treatments to three rates of compost and then lower the weekly injection rates and use only one injectable material. We are planting 'Albion' and 'San Andreas' varieties in this trial also.

Trial Number 3—Sprinkler vs. Drip in Strawberries

Yield reductions in strawberries are reported at soil electrical conductivity (EC) of 1.0. Since

plastic mulches go down before the plants are put in the ground it becomes crucial to irrigate with sprinklers for an extended period before the plastic is applied to the strawberry beds. Plants also need a certain amount of wetting to establish. And there may also be some advantage to wetting the young transplant leaves for the first few weeks following installation. The typical grower practice in Santa Maria is to sprinkle from ¼ to ½ inch of water every day or every few days for three to four weeks after the plants are in the ground, all depending on weather, soil type, and pump scheduling. Typically, 90% of applied water goes into the furrow bottoms and does not affect the plant root zone. Our challenge is to try to reduce the amount of sprinkler-applied water without adversely affecting yield.

We set up a trial that had standard grower practice of two drip tapes installed under the drip tape and sprinklers on top of the plastic. Treatment 1 was the grower practice mentioned in the previous paragraph and only a minor amount of water is applied through the drip system during this early period. The second treatment was four drip tapes, two at the normal positions and two more at the soil surface, but no sprinklers. The third treatment was two tapes at the normal locations, which is about two inches below the soil surface. No water was applied through sprinklers on Treatments 2 or 3.

There was a slight reduction in plant survival in the non-sprinkled treatments but there was no significant difference between the treatments in fruit yield. We will duplicate this trial in the 2009/2010 season and have only one double line drip tape treatment but vary the amount of sprinkler-applied water.

Trial Number 4—Drip/Fertigation Scheduling in Strawberries

In a commercial strawberry field we adjusted the fertilizer injection towards the end of the drip irrigation cycle in order to maintain higher

concentrations of nitrate-N in the plant root-zone. Then we looked at applying the grower practice of about an hour of water application with the drip system, which was considered 100%, and then 80% and 65% of that. We measured yield but have not yet finished processing the data to determine any treatment related differences. We monitored soil moisture with tensiometers and moisture sensor gypsum blocks and we had flow meters at the head of each treatment.

Trial Number 5—Strawberry Cutback

From July to September, strawberry production in Santa Maria comes to a halt and most of the large acreage farms begin soil preparation for the upcoming season. About one-fifth of the small acreage plots are cut back, or mowed down to the crowns. Any fertilizer that is applied is injected through the drip system. We set up a replicated trial of three cutback dates spaced three weeks apart starting in late July. One-half of the treatments were fertilized with five pounds per acre per week as CAN-17 and the other treatments received 10 pounds of N per acre per week. We have begun to collect harvest data and we will be correlating it to actual strawberry market prices, in order to get a true value of production for the different cutback dates.

Trial Number 6—Iceberg Lettuce

The grower traditionally puts on a preplant fertilizer application and up to three side-dress applications. The grower requested assistance in refining his N fertility program in an effort to improve N use efficiency. We set up an N fertilizer trial in his commercial iceberg lettuce field with high initial nitrate-N, where the preplant N application was eliminated. Then at each side-dressing, conventional rates of N fertilizer were applied, and then 50% of that and a zero control. The conventional N rates corresponded to slightly higher yields, but the farmer has eliminated N application from his preplant program.

Trial Number 7—Napa Cabbage

Working with the same grower from Trial Number 6, we set up an N fertilizer trial in a commercial Napa Cabbage field with high initial nitrate-N readings, where conventional rates of N fertilizer were applied, and then 50% of that amount as the alternative treatment. There was not a zero treatment in this trial. The grower applies up to three side-dress N fertilizer applications per crop. But in this case he used the Pre-side-dress Soil Nitrate Quick Test (PSNQT) the day before side-dressing. If the PSNQT showed 25 ppm nitrate-N the day before side-dressing then the side-dress was not made. Conventional N rates again corresponded to slightly higher yields but the farmer has agreed to repeat the experiment, using the PSNQT trigger, but only with the initial side-dressing. We will also investigate irrigation application effects on seasonal nitrate concentrations in the root-zone by applying 100% of normal water application, 90% of normal and 80% of normal.

Many of them have requested assistance in developing irrigation and nutrient management plans. We have had two large group strawberry production meetings with this group, where the fertilizer trials were visited and discussed. We have had several small group meetings where we have discussed irrigation and nutrient management concepts. We are providing a “follow-up” assistance to this group, where we

try to help them use some of the technology from the fertilizer trials on their farms. Many have applied one-half of the preplant fertilizer compared to last year. An outline of the farm planning information that we are offering to these farmers is given below.

CONCLUSION

We have provided extensive technical assistance in developing irrigation and nutrient management plans to 14 growers through the USDA cost-share program EQIP. We have had two large group strawberry production meetings with this group, where the fertilizer trials were visited and discussed. We have had several small group meetings where we have discussed irrigation and nutrient management concepts. We have provided more than 60 growers with “follow-up” assistance related to helping them utilize technology from the trials. Many have applied been able to be more efficient with irrigation water and fertilizer applications.

In summary, we are extending irrigation and N management tools to three groups of farmers in the Santa Maria Valley and coastal San Luis Obispo counties. We are using workshops, field meetings and one-on-one follow-up assistance to demonstrate the tools and extend the concepts learned at the on-farm trials set up on Group 3 farms. We will continue this work for an additional season.

New Standard for the Effectiveness of Foliar Fertilizers

PROJECT LEADER

Carol J. Lovatt
Professor of Plant Physiology
Department of Botany and
Plant Sciences
4130 Batchelor Hall
University of California
Riverside, CA 92521-0124
(951) 827-4663
carol.lovatt@ucr.edu

COOPERATOR

Jim Bates, CPA
Chief of Financial Operations
Fowler Packing Company
8570 South Cedar Street
Fresno, CA 93725
(559) 834-5911, (559) 281-8446
cfo@fowlerpacking.com

MANDARIN ORCHARD SITE

David Johnson
Ranch Manager
Rustigian Ranch
Corner of Clovis and Central
Fresno, CA 93725
(559) 217-0890
davidjohnson@fowlerpacking.com

INTRODUCTION

Foliar fertilization can meet the plant's demand for a nutrient at times when soil conditions (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 which have

serious consequences on the environment and human health. Thus, 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 nitrogen (N) and boron (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 (PI) proposed 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 (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). With demonstration that foliar fertilization strategies can be used to increase yield parameters and grower net income, with reliability 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.

We are testing this theory 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 also will 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 ZnSO₄, Solubor-B, urea-N and phosphite-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:

- N [23 pound/acre, urea (46% N, 0.25% biuret)] with K and P [0.64 gallon/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.
- Zn [1 pound/acre, ZnSO₄ (36% Zn)] at 10% anthesis in the southwest tree quadrant (SWTQ) to increase fruit set and yield, without reducing fruit size.
- B [1.3 pounds/acre, Solubor (20.5% B)] at 10% anthesis in the SWTQ to increase total yield and yield of commercially valuable large size fruit.
- K and P [0.49 gallon/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.
- N [23 pounds/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.
- K (25 pounds KNO₃/acre) at dormancy (February), post bloom (~April) and summer fruit growth (July-August) to increase the yield of commercially valuable large size fruit (Boman, 2002).

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:

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

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

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

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

- N [23 pounds/acre, urea (46% N, 0.25% biuret)] with K and P [0.64 gallon/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 starting date of the project was delayed until October 2008 for the following reasons:

- 1 First, the original start date in February 2008 was after the first treatment needed to be applied, i.e., winter prebloom foliar application of urea in January. Thus, the PI would have had no data for this treatment for Year 1 and, thus, this treatment could never have been compared with the other treatments for effects on cumulative yield or effects on yield averaged across the years of the study by repeated measures analyses, an important analysis in an alternate bearing crop which 'Nules' is, ~500 fruit in the off-crop year to >1200 fruit in the on-crop year. The PI also would not have been able to compare the effects of treatments on the alternate bearing index (the calculated measure of the severity of alternate bearing).
- 2 In evaluating potential orchards that growers were willing to make available in February for the initiation of the research, the setting crop yields were very low due to the freeze the

previous winter and, thus, would not have provided a good test of the treatments.

- 3 Based on results obtained with foliar-applied urea in an on-going experiment in Grapevine, California, that suggested that December might be the optimal time apply a winter prebloom treatment instead of January as the PI had proposed, the PI thought the CDFA-FREP project would be best served by applying the urea to separate sets of trees in November, December, and January to make sure there was optimal application time for this cultivar. This new CDFA-FREP project was the perfect time and place to obtain three years of yield data to identify the optimal time for winter prebloom foliar applications of low biuret urea-N and phosphite-P+K to increase flowering and yield. The leadership of the CDFA-FREP agreed. The PI is bearing the expense of the extra trips to make the additional applications, as described above, to do the research in the way that will provide the greatest amount of information of value to the growers. The project is on schedule, but there are no results yet. The harvest for the first year will be in November 2009.

ACCOMPLISHMENTS

The PI has 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:

- Kern County Citrus Growers Meeting, "Plant Growth Regulators on Mandarins," March 25, 2008.
- Tulare County Citrus Growers Meeting, "Plant Growth Regulators on Mandarins," April 17, 2008.
- VI International Symposium on Mineral Nutrition of Fruit Crops, University of Algarve, Faro, Portugal, "Properly Timed Foliar Fertilization Can and Should Result in a Yield Benefit and Net Increase in Grower Income," May 19-23, 2008.
- CDFA-FREP Annual Meeting, "Gauging the Effectiveness of Foliar Fertilizers on Citrus," November 12-13, 2008.
- California and Plant and Soil Science Conference, "Fertilization of Perennial Tree Crops: Timing is everything!" February 3-4, 2009.

LITERATURE CITED

- Boman, B.J. 2002. KNO₃ foliar application to 'Sunburst' tangerine. Proceedings, Florida State Horticultural Society 115:6-9.
- Embleton, T.W. and W.W. Jones. 1974. Foliar-applied nitrogen for citrus fertilization. Journal of Environmental Quality 3:388-392.
- Labanauskas, C.K., W.W. Jones and T.W. Embleton. 1969. Low residue micronutrient sprays for citrus. Proceedings, First International Citrus Symposium 3:1535-1542.
- Lovatt, C. J. 1999. Timing citrus and avocado foliar nutrient applications to increase fruit set and size. HortTechnology 9:607-612.

Western Fertilizer Handbook, Turf and Ornamental Edition Book Development

PROJECT LEADER

Renee Pinel

President
Western Plant Health
Association
4460 Duckhorn Drive, Suite A
Sacramento, CA 95834
(916) 574-9744
reneep@healthyplants.org

PROJECT LEADER

Pamela Emery

Director of Programs
Western Plant Health Association
4460 Duckhorn Drive, Suite A
Sacramento, CA 95834
(916) 574-9744
pame@healthyplants.org

INTRODUCTION

The safe use of fertilizers has been an important goal of the agriculture industry as well as the Department of Food and Agriculture and the Western Plant Health Association (WPHA). Of growing concern and importance is the use of fertilizers in urban settings by both professionals in the “turf and ornamental” industry and “home and garden” users. 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 more than ten years and there are newer technologies and practices that should be incorporated into a reference book of this

type. The California Department of Food and Agriculture has provided the Western Plant Health Association with funding to hire an intern who will assist in the production of the book including creating tables and figures that will make this tool a handy reference for today's agribusiness professionals, growers, landscapers and Certified Crop Advisers 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 Western Plant Health Association'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 will be adding information on slow-release, control-release and organic fertilizers and placing more emphasis on solution culture, media mixes and turf. The text will not only be updated, but the tables and figures will be modified to have a more professional look and user-friendly format. Recently, WPHA hired an intern who will work alongside the writing team and publisher to see the development of this book to completion. 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, is organizing the text, paying attention to the details needed to publish an excellent product and is ensuring that publication procedures are followed in a timely fashion.

ACCOMPLISHMENTS

Throughout the past several years, the Western Plant Health Association's Western Fertilizer Handbook Committee, a subcommittee 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 created revised drafts of each of the chapters, compiled appropriate photographs and is in the process of obtaining peer reviews. In early 2010, the manuscript will be proof-edited and sent for publication. The final document should be available for purchase in late spring 2010.

List of Completed FREP Research Projects



List of Completed FREP Research Projects

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 Web site (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, 97-0365 M97-05*)

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

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

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

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, 97-0365 M97-02*)

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

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)

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 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)

California Certified Crop Adviser
(Crum/Stark, 02-0331)

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

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

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

Nitrogen Mineralization Rate of Biosolids and Biosolids Compost
(Tim Hartz, 97-0365 M99-10)

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

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

Agriculture and Fertilizer Education for K-12
(Pamela Emery and Richard Engel, 97-0361)

California Certified Crop Adviser Management Project
(Hank Giclas, 00-0516)

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

Nitrogen Budgeting Workshops
(Jim Tischer, 99-0757)

Irrigation and Nutrient Management Conference and Trade Fair

(Sonya Varea Hammond, 97-0365 M99-02)

Improving the Fertilization Practices of Southeast Asians in Fresno and Tulare Counties

(Richard Molinar and Manuel Jimenez, 96-0405)

Integrating Agriculture and Fertilizer Education into California's Science Framework Curriculum

(Mark Linder and Pamela Emery, 97-0361)

Survey of Changes in Irrigation Methods and Fertilizer Management Practices in California

(John Letey, Jr., 96-0371)

Irrigation and Nutrient Management Conference and Trade Fair

(Danyal Kasapligil, 97-0365 M99-02)

Western States Agricultural Laboratory Proficiency Testing Program

(Janice Kotuby-Amacher and Robert O. Miller, 95-0568)

Education through Radio

(Patrick Cavanaugh, 94-0517)

Extending Information on Fertilizer Best Management Practices and Recent Research Findings for Crops in Tulare County

(Carol Frate, 93-0570)

Determination of Soil Nitrogen Content In-Situ

(Shrini K. Updadyaya, 92-0575)

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

(Ronald Voss, c. 1993)

Nitrogen Management for Improved Wheat Yields, Grain Protein and the Reduction of Excess Nitrogen

(Bonnie Fernandez, 91-0485)

The Use of Composts to Increase Nutrient Utilization Efficiency in Agricultural Systems and Reduce Pollution from Agricultural Activities

(Mark Van Horn, 92-0628)

Practical Irrigation Management and Equipment Maintenance Workshops

(Danyal Kasapligil, Charles Burt and Eric Zilbert, 95-0419 or 96-0312)



**To order additional copies of
this publication, contact:**

California Department of Food and Agriculture
Fertilizer Research and Education Program
1220 "N" Street
Sacramento, CA 95814

Tel: (916) 445-0444

Fax: (916) 445-2171

frep@cdfa.ca.gov

www.cdfa.ca.gov/is/fflders/frep.html

