Proceedings of the Fourth Annual

FERTILIZER RESEARCH AND EDUCATION PROGRAM CONFERENCE

OCTOBER 16, 1996 • MODESTO, CALIFORNIA

Sponsored By

California Department of Food and Agriculture • California Fertilizer Association
Stanislaus County Cooperative Extension • UC Sustainable Agriculture Research and Education Program

Proceedings of the
FOURTH ANNUAL

FERTILIZER RESEARCH AND EDUCATION PROGRAM CONFERENCE

OCTOBER 16, 1996

RED LION HOTEL

MODESTO, CALIFORNIA

Sponsored by:

California Department of Food and Agriculture

California Fertilizer Association

Stanislaus County Cooperative Extension

University of California Sustainable Agriculture Research and Education Program

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CONFERENCE PROGRAM

7:30 **Registration**

8:00-8:10 **Welcome**–*Michael Chrisman, Undersecretary, California Department of Food and Agriculture*

8:10-8:20 **Opening Remarks**–*Kent Johnson, President, California Fertilizer Association*

8:20-8:50 **Fertilizer Research and Education Program: An Update**–
Jacques Franco, Program Coordinator, FREP - CDFA

8:50-10:00 **Brief Updates**

Local Water Quality Activities
Phil Osterli, UC Cooperative Extension, Stanislaus County

Certified Crop Advisor Program
Robert Dixon, CCA State Board Member

Overview of Nitrate in Groundwater
Thomas Harter, UC Kearney Agricultural Center

Citrus Nitrogen Management and Groundwater Nitrate in Florida
Ashok Alva, University of Florida Citrus Research Center

10:00-10:40 **Break, Poster Viewing and Demonstrations**

10:40-11:50 **Project Reports**

Development of Diagnostic Measures of Tree Nitrogen Status to Optimize Nitrogen Fertilizer Use
Patrick Brown, Associate Professor, Department of Pomology, UC Davis

Effects of Nitrogen Rates on Fungal Diseases of Almonds
Beth Teviotdale, Extension Specialist, UC Kearney Agricultural Center

Using Foliar Urea to Replace Soil-Applied Fertilizer in Peaches
Scott Johnson, Extension Pomologist, UC Kearney Agricultural Center

11:50-1:00 **Lunch**

1:00-1:25 **Agriculture and Nitrate in Ground Water: Conflict or Cooperation?**

Peter Rooney, *Undersecretary, California Environmental Protection Agency*

1:25-2:10 **Project Reports**

Diagnostic Tools For Nitrogen Management of Desert Vegetables

Charles Sanchez, Soil and Water Research Scientist, University of Arizona

Nitrogen Quick Tests for Determining N Fertilizer Needs of Vegetables

Richard Smith, Farm Advisor, UC Cooperative Extension, San Benito County

2:10-2:30 **Break, Poster Viewing and Demonstrations**

2:30-4:00 **Diagnostic Tool Use in Crop Production: The Nuts and Bolts - Practitioners' Perspectives**

Moderator:

Richard Smith, UC Coperative Extension, San Benito County

Panelists:

Lynn Wierdsma, Bettaravia Farms, Santa Maria, CA

Eric Overeem, Western Farm Service, Watsonville, CA

Patrick Brown, Department of Pomology, UC Davis

Fourth Panelist –TBA

POSTER SESSION

Nitrogen Management Through Intensive On-Farm Monitoring in Vegetable Production

Relationship Between Nitrogen Fertilization and Bacterial Canker Disease in French Prune

Best Nitrogen Management Practices for Broccoli Production in the San Joaquin Valley

Western States Agricultural Laboratory Proficiency Testing Program

Nitrogen and Water Use Efficiencies in Vegetable Cropping Systems

Avocado Growers Can Reduce Soil Nitrate Groundwater Pollution and Increase Yield and Profit

Use of Ion Exchange Resin Bags to Monitor Soil Nitrate in Tomato Cropping Systems

Site-Specific Farming Information for Cropping Systems in California

Updated Guidelines for Cotton Nutrition

Phosphorus Placements on No-Till Barley Production

II. BRIEF UPDATES

FERTILIZER RESEARCH AND EDUCATION PROGRAM: AN UPDATE

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Fertilizer Research and Education Program
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The Fertilizer Research and Education Program (FREP) was created to advance the environmentally safe and agronomically sound use and handling of fertilizer materials. Most of FREP's current work is concerned with nitrate contamination of groundwater.

FREP facilitates and coordinates research and demonstration projects by providing funding, developing and disseminating information, and serving as a clearinghouse on information on this topic. FREP serves growers, agricultural supply and service professionals, extension personnel, public agencies, consultants, and other interested parties.

BACKGROUND

In January of 1990, the Nitrate Management Program (NMP) was established by the Director of the California Department of Food and Agriculture (CDFA). Its objectives were to identify and prioritize nitrate sensitive areas throughout California, and to develop research and demonstration projects to reduce agriculture's contribution to groundwater contamination from fertilizer use.

FREP's first–year activities concentrated on helping secure technical expertise and funding to start these research and demonstration projects. Initial projects were developed in the Salinas Valley and the Fall River Valley. The Salinas project developed improved vegetable farming practices to reduce nitrate contamination, while increasing the efficiency of fertilization and irrigation.

COMPETITIVE GRANTS PROGRAM

In 1990 the Department was authorized to increase the mill tax on fertilizers to conduct research and education projects to advance the environmentally safe and agronomically sound use and handling of fertilizer materials. The program supports fifty-one projects at a projected cost of $2.4 million dollars and $2.2 million dollars in matching funds. Of these fifty-one projects, about half have been completed. Details about these projects, and the information products available can be found in these and last year's proceedings, and our Resource Guide.

The review, selection, and funding recommendations for projects is done by the Technical Advisory Subcommittee of the Fertilizer Inspection Advisory Board. This committee includes growers, fertilizer industry professionals, and State government and university scientists.

Recently, ten new projects were approved for funding at a projected multiyear cost of over $600,000 and matching funds of about $320,000. Section V of these proceedings describes the new projects.

MONITORING AND ASSESSMENT

The program's ongoing monitoring and assessment activities help improve access to information developed by other parties, and supports the program's education, outreach and public service activities.

These activities include participation in interagency activities to reduce non-point sources of contamination, participation in a University of California study team that developed methods to assess the environmental and agronomic performance of various Best Management Practices, and membership in various advisory committees. Regulatory and legislative trends on nitrogen management across the country are also monitored.

FREP also maintains baseline information on

fertilizer practices of target crops. Additional activities include monitoring of scientific, technical, agricultural, industry, and policy developments, and issues related to the program goals.

RECENT ACCOMPLISHMENTS

FREP has made a significant impact developing quick diagnostic tools for cool season vegetable production. Only six years ago Salinas Valley growers told me that soil and tissue tests were of very limited use because of the long turnaround time needed to obtain results. Since then, about fourteen FREP-sponsored projects are tackling various aspects of this topic and have made outstanding progress. These projects have developed and tested, under field conditions, the agronomic and economic advantages of various diagnostic techniques such as quick soil tests, plant sap N analysis, etc. It has now been clearly shown that growers can save, many times over, the costs of closer crop nutrient monitoring with these tools. A clear win-win situation for growers and the environment. Today we will have a panel of practitioners that will share their successes in using these tools.

Our Internet Web site recently went on-line. The site contains up-to-date summaries of FREP activities, information products with on-line ordering capability, and a powerful search engine that allows the user to quickly find the information he or she might be looking for. Please visit us at: http://www.sarep.ucdavis.edu/frep/

This year we will release our fourth video: "The Fruits of their Labor: Nitrogen Management in Stone Fruits and Almond Production". The video and handbook provide practical, research-based information to help fruit growers improve their orchard nutrient management programs and profitability. Another win-win proposition for grower's bottom line and the environment. The program will surely follow in the success of its predecessors. A preview will be shown to the conference participants today.

Our recently released Resource Guide has been in demand and quite effective. The Resource Guide describes close to one hundred information products available through FREP, including educational videos and technical research reports. Topics covered include vegetable, orchard and field crops, and plant and soil testing and monitoring.

Two additional information products, "Compost Production and Utilization: A Grower's Guide" and the award-winning video "Drip Irrigation and Nitrogen Fertigation for Vegetables" continue to be in strong demand. Overall, the number of information product requests has increased by 62% over the last year. Over the recent years, we have made available, in response to clientele requests, thousands of copies of these materials, and continue to improve our ability to promptly respond to these requests. A large percentage of the individuals requesting materials from us are directly involved in production agriculture. This is a strong indication that our materials are of value.

We are currently working on additional publications that will be released in 1997-98. These include an updated practitioner handbook on quick tests for vegetable growers featuring newly developed field data, and a comprehensive best management practices guide for cool season vegetable production produced with the assistance of innovative growers. In 1998, we will be releasing the findings of a state-wide survey of fertilization and irrigation practices.

We are also pleased to report that we continue to work with the California Chapter of the American Society of Agronomy (CA-ASA) to disseminate new nutrient management information. At this year's CA-ASA annual conference, we will be holding a session highlighting results of FREP-sponsored research. The conference is scheduled for January 15 and 16, 1997, in Visalia.

FREP will again co-sponsor and help plan the annual Salinas Valley Irrigation and Nutrient Management Conference, now in its fifth year. This highly regarded and well-attended conference is organized by the Monterey County

Water Resources Agency and Monterey County Cooperative Extension.

The Certified Crop Advisor (CCA) program, now in its fourth year of operation, is helping crop production professionals improve their technical proficiency. Hundreds of crop production professionals are benefiting from this program. Robert Dixon, of the CCA State Board, will provide more details about this outstanding program.

CONFERENCE PROGRAM HIGHLIGHTS

This year's conference program has benefited from the comments made by prior year's participants. In addition to the projects' progress reports, this year we will again include a poster session that will highlight early results of FREP-supported projects. This format will allow for more interaction between conference participants and project leaders.

The brief update section is intended to bring you "the big picture" and details of activities related to FREP's mission, to help you improve your understanding of how these developments might affect you. The afternoon panel session, facilitated by Richard Smith, will provide practitioners' perspectives on the nuts and bolts of quick diagnostic tool use. I hope this session will generate good discussion on the topic. This year we will again feature a world premiere. Our new video, "The Fruits of their Labor: Nitrogen Management in Stone Fruit and Almond Production" will be shown during the conference.

Our special out-of-state guest this year is Dr. Ashok Alva of the University of Florida Citrus Research Center. He will be providing us with an update on nutrient management activities in that agriculturally important state.

We are very proud to present a continually improving conference proceedings. We hope it will help you get the most out of your participation in the conference. You are welcome to browse through FREP's information products display table during the breaks, and order any material you may need.

Please fill out the evaluation forms in your conference packet or call us any time with suggestions to help us better serve your needs.

ACKNOWLEDGMENTS

Many people deserve recognition for their assistance, insight, and support in the process of developing the Fertilizer Research and Education Program (FREP), including growers, the fertilizer industry, government officials, university people, and individuals concerned about the future of California.

Special recognition goes to Carl Bruice, Al Ludwick, Steve Purcell, Wynette Sills, Brock Taylor, Jack Williams, Tom Beardsley and Charles Tyson, members of the Technical Advisory Subcommittee (TASC), and to all the members of the Fertilizer Inspection Advisory Board. TASC members' dedication, insight and professionalism have been invaluable in helping make FREP a success.

Casey Walsh Cady continues to provide invaluable assistance and dedicated service in carrying out many of the activities required to keep the program going. Special thanks to Debbie Scott for her outstanding service with FREP. Debbie recently took other responsibilities in our organization. Welcome and thanks to Kertrina Anderson who took over Debbie's responsibilities. Thanks too to Joanna Stokes for her assistance. I wish to also thank the staff at CDFA's Agricultural Commodities & Regulatory Services Branch for their ongoing assistance and support.

Many thanks to Jill Auburn, Barbara Wetzel, and Bev Ransom for their assistance with our publications.

Many people from the California Department of Food and Agriculture (CDFA) saw this program develop from its infancy and provided their full support and insight. We owe tremendous thanks to Vashek Cervinka, Steve Wong and Stan Buscombe. We would also like to acknowledge the efforts of Ezio Delfino, retired Assistant Director of Inspection Services; Bob Wynn, Director of Inspection Services; Henry Voss, late Secretary of CDFA

and A.J. Yates, Deputy Secretary, for their ongoing support and assistance.

We also greatly value the input and support received from Steve Beckley, and the staff at the California Fertilizer Association. Others deserving mention include the project leaders and cooperators, as well as the dozens of professionals who review project proposals and help enhance the quality of FREP's work.

CITRUS NITROGEN MANAGEMENT AND GROUNDWATER NITRATE IN FLORIDA

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Water quality issues, in particular groundwater contamination from agricultural chemicals including nitrates, have risen to the top of the agricultural and environmental policy agenda. Over 50% of the total fresh water used in Florida comes from groundwater, and over 90% of the public rely on groundwater supplies for their drinking water. During the summer months in Florida, rainfall exceeds the evapotranspiration. This excess water is recharge to groundwater. The quality of this water is an important consideration since this water comes in contact with a number of chemicals and heavy metals prior to returning to groundwater. Florida's unique hydrogeologic features, i.e., a thin soil layer, high water table, and porous limestone make the soil vulnerable to downward movement of soil applied chemicals which may contaminate the groundwater.

Florida ranks second in the nation to California with regard to the quantity of agrichemicals used on an annual basis. This is due to warm humid climate, sandy soils, and large acreage under cultivation. Although best management practice (BMP) recommendations are important to minimize leaching and groundwater contamination of most agrichemicals, only problems related to nitrate contamination of groundwater are discussed in this report.

In order to examine the magnitude of groundwater contamination by agrichemicals, the Department of Environmental Protection (DEP) has conducted analyses of drinking well water samples taken from homeowner wells in several counties. DEP has very little background information on the depth of well and depth of casing, etc., of the wells that are being sampled. In most cases, the drinking water wells in remote rural areas are 50-100 feet deep. The data reported by DEP as of May 1993, showed that 19% of 2771 total drinking water wells being sampled in Highlands, Lake, and Polk Counties, in the citrus growing region of Central Florida, contained nitrate-N concentrations above 10 mg per liter (10 ppm) which is considered the maximum contamination limit (MCL) for drinking water (Environmental Protection Agency). According to DEP, the background nitrate-N in groundwater in undisturbed areas is 0.1 mg per liter which could increase to 1.0 mg per liter in residential areas. Therefore, nitrate-N concentration > 1 mg per liter in groundwater near an agricultural area could be attributed to non-point source pollution of nitrate-N through routine application of N fertilizers for crop production. The drinking water quality monitoring data on a county basis showed that nearly 33% of sampled wells in Highlands County contained nitrate-N above the MCL.

Although drinking water quality monitoring data appeared to indicate some potential problems with respect to the extent of nitrate (NO_3) contamination of groundwater in some counties in Central Florida, further studies are required to address the following issues as related to Florida citrus N management:

(i) An evaluation of the extent of nitrate contamination of groundwater directly

underneath citrus groves, and

(ii) The development of best management practices for nitrogen fertilization of citrus aimed to minimize leaching loss of N and to maximize nitrogen use efficiency.

GROUNDWATER NITRATE STATUS

To address the first issue, a major monitoring study is in progress jointly funded and conducted by the Department of Agriculture and Consumer Services (DACS), Department of Environmental Protection (DEP), Southwest Florida Water Management District (SWFWMD), and the University of Florida Department of Agricultural Engineering and Citrus Research and Education Center. Nitrate levels at various depths in groundwater (down to 20 feet below the water table) are being monitored at bi-monthly intervals in five commercial citrus groves representing a range of production practices, tree ages, soil types, and depths to groundwater, etc. An undisturbed site, which is on native vegetation, was also included for monitoring to determine the background nitrate levels in groundwater in a site which was not affected by agricultural production practices.

Among the five commercial grove sites, one was on an Alfisol, which is characterized by poor drainage status, high water table due to the presence of a restrictive soil horizon (clay pan) which is high in clay and iron content. This horizon restricts the downward transport of water. The groundwater NO_3-N in this site was well below 10 mg/l; i.e., maximum contaminant level (MCL) according to drinking water quality standards. The rest of the four groves are on Entisols, characterized by high sand content, extremely low cation exchange capacity and organic matter, and no impervious soil horizon. Groundwater NO_3 levels in these sites were either close to the MCL or much greater than the MCL. No detectable nitrate has been measured at the native vegetation site. Therefore, this study raises some concern regarding the potential for groundwater NO_3 contamination in areas of vulnerable soils under intensive citrus production practices.

After establishing the baseline levels of nitrate in groundwater for the respective sites, the N management program was modified with the aim of decreasing the nitrate loading into groundwater. These approaches include reduction of N rate, improved timing of fertilizer application, N source variation; i.e., fertigation, controlled-release fertilizer, foliar application, etc., and improved scheduling of irrigation. Irrigation plays a major role in N use efficiency. The depth of wetting is very critical, since the waterfront which moves below the depth of rooting is likely to carry nitrate which cannot be absorbed by the trees. Tensiometers are installed at 6 and 12 inch depth, which are used as basis for scheduling irrigation, and at 24, 36, and 48 inch depth to evaluate the depth of wetting after each irrigation or rain events. Evaluation of nitrate status in the groundwater is continuing during the course of modified N and irrigation management program to examine the effects changes in N and irrigation practices have on groundwater nitrate.

Throughout the duration of this monitoring study, additional evaluations are being conducted on leaf mineral concentrations, fruit and juice quality and fruit yield. These evaluations are important to understand the impact of changes in N fertilization practice on the mineral nutrient status of the trees and ultimately on fruit production, fruit and juice quality.

DEVELOPMENT OF CITRUS NITROGEN BMPS

Long-term field experiments are required to evaluate the effects of various N application practices, with precise irrigation scheduling, to supply the absolute minimum N required for production of economically acceptable fruit yield, and to support tree growth and to minimize nitrate leaching losses. In addition, consideration will be given to annual N contribution from mineralization of leaf debris and dead roots. A two-year study has been

completed to examine the N mineralization in mature citrus groves in typical ridge (Entisols) and flatwoods (spodosols and alfisols) soil situations. Additional studies are in progress to examine other losses of N under grove conditions.

Research is also currently in progress to develop N BMPs for non-bearing and bearing orange trees grown on the deep sandy Entisols (which are often classified as vulnerable soils) and for bearing grapefruit trees on poorly drained spodosols. These projects are supported by the University of Florida Institute of Food and Agricultural Sciences, Department of Environmental Protection, Department of Agriculture and Consumer Services, Citrus Production Research Advisory Council, St. Johns River Water Management District, South Florida Water Management District, and the Southwest Florida Water Management District.

These studies include evaluation of various sources and rates of N with optional irrigation scheduling to maintain the depth of wetting within 3 feet for the ridge (vulnerable) soils and 2 feet for the Flatwoods (spodosols) soils. Tree growth, leaf nutritional status, root distribution, fruit production, fruit quality, and nutrient removed by fruits are measured. Fate of N in the soil was evaluated by soil sampling and soil solution sampling using suction lysimeters. The soil solution sampling was done both within and below the rootzone to measure the status of NO_3 available to the trees and that which is leached past the rootzone. The sampling from below the rootzone is very critical to examine the leaching losses which is potentially the source of groundwater contamination. Irrigation scheduling is done by measuring lost moisture using tensiometers at various depths. Tensiometer readings at 6 and 12 inch depths are used for scheduling irrigation. Soil moisture changes are also measured using capacitance based soil moisture sensing probes installed at various depths.

Four to five years of field data are required to develop BMP recommendations. These new studies are required since the past N studies were conducted using almost exclusively dry soluble N sources, and often unirrigated or using overhead irrigation. During recent years, the citrus industry has undergone substantial changes in the production practices and rootstock usage. Currently, low volume microsprinkler irrigation is commonly used on citrus. Fertigation usage is increasing rapidly with specific reference to fertigation program for bearing and non-bearing trees. We have very little information on the effects of rates of N, frequency and timing of N applications, leaching losses, and N use efficiency. Although fertigation could improve nutrient use efficiency by application of nutrients in small doses over the growing period, poor irrigation management could negate any benefits. The above factors suggest that new field experiments are necessary under conditions as they exist today with the citrus industry. The following measures may be adapted to fine-tune the fertilizer management program in an effort to minimize leaching losses of N in sandy soils and to increase N use efficiency.

1. **Adjustment of application rates based on leaf analysis**: Leaf analysis, an important tool in monitoring the nutritional status of trees, can be used as a guideline for determining fertilizer needs. The optimum concentration of N in 5-month-old spring flush of citrus trees is 2.5-2.7%. Leaf N levels exceeding the above range is considered as an indication of luxury consumption, and will not increase returns in terms of fruit yield. Nitrogen is a very mobile element and its deficiency can be corrected relatively rapidly by its application. Annual leaf analysis is a well-recognized method of monitoring N nutrition of the trees. If the spring flush leaf N concentration is above 2.7, subsequent N application rate should be decreased.

2. **Application timing**: As most conventional dry-soluble N sources are extremely soluble, heavy rainfall or irrigation following the application results in rapid leaching of nitrate below the root zone. Since nearly 60% of annual rainfall in Florida is received between June to

September, high application rates of fertilizer should be avoided during these months. There is evidence to support reduced leaching of N by increasing the frequency of application. For the groves which are under fertigation programs, the frequency of application can be increased with minimum additional effort and cost.

3. **Improved irrigation scheduling**: Proper irrigation scheduling is the key to efficient utilization of fertilizers. Fertigation should be scheduled towards the end of the irrigation event to minimize nutrient leaching. A light irrigation soon after spreading dry soluble granular form of N may be beneficial to stabilize the fertilizer and work it into the top soil. This could enhance uptake of nutrients by the roots and minimize volatilization losses. Under Florida conditions ammonium forms of N left on the soil surface may be subject to rapid volatilization losses.

4. **Sources of nitrogen**: These can have a significant impact on the cost of production. Under soil and climatic conditions which favor nitrate leaching, application of dry soluble materials in large doses is not recommended. Use of fertilizer formulations containing controlled-release sources, which release nutrients slowly over an extended period of time, can be advantageous in terms of decreasing leaching losses of nitrate. Field experiments are in progress on both young and bearing trees to evaluate the potential to minimize leaching of nitrate using controlled-release formulations, and determine tree growth and production responses. In some situations, a blend of controlled-release and soluble sources of N may be used to moderate the cost of the fertilizer program.

5. **Foliar N feeding**: While very little work has been done in Florida, data from California studies show that up to 50% of N required for citrus trees can be supplied through foliar application. Some foliar application will reduce the total N applied to the soil and therefore minimize leaching losses. Field studies are in progress under Florida conditions to investigate the role of foliar N applications, for non-bearing and bearing trees, to evaluate the N use efficiency and nitrate leaching.

COOPERATIVE EFFORTS

The 1994 amendments to the Florida Fertilizer Law authorized DACS to develop nitrate BMPs. The Legislature authorized DACS to impose supplemental fees on users of all fertilizer materials to fund the development of research-based BMPs. As of July 1, 1994, fees increased for fertilizer distribution licenses, product registrations, and for the sale of fertilizers containing nitrogen.

DACS must use these funds to contract with the University of Florida Institute of Food and Agricultural Sciences (IFAS) and the Florida Agricultural and Mechanical University (FAMU) for the development of the BMPs. In addition, the funds must be used to reimburse the Florida Department of Environmental Protection (FDEP), to the extent funds are available, for the cost of restoring and replacing private drinking water wells contaminated by nitrates resulting from the application of fertilizers or other soil applied materials containing nitrogen.

The BMP must be research-based, economically and technically feasible, and designed to meet nitrate groundwater quality standards. This means that the nitrate practices (BMPs) adopted by DACS must be shown in research to prevent nitrates from fertilizers or other soil-applied nutritional materials from entering groundwater at levels in excess of state water quality standards.

Under the provisions of Section 376.30(3)(c)1, F.S., the FDEP must restore or replace contaminated private drinking water wells to a level which meets applicable water quality standards. In addition, Section 376.307(5), F.S., obligates the FDEP to recover the costs to restore or replace such a well to the extent

possible from the responsible party. A landowner or leaseholder is not liable to the state under these provisions for any costs associated with the remediation of nitrate contamination of groundwater resulting from the application of fertilizers containing nitrogen, provided the property owner or leaseholder; a) provides DACS with a notice of intent to implement applicable BMPs adopted by DACS, and, b) implements applicable interim measures and/or BMPs as soon as practicable according to rules adopted by DACS or no longer applies fertilizers or other soil-applied nutritional materials containing nitrogen.

In addition, once a BMP has been verified by the state as effective in protecting groundwater, growers who implement them are presumed to be in compliance with nitrate groundwater quality standards and will not have to monitor groundwater.

The rule will initially contain the BMP for ferns and the interim measure for citrus. In addition, the Legislature requires DACS to establish procedures for landowners and leaseholders to submit the notice of intent to comply with interim measures and/or BMPs, schedules for the implementation of interim measures and BMPs, and record keeping requirements. Record keeping requirements will be developed specifically for each interim measure and BMP.

This program is not an enforcement-based program. The landowner's records, kept in accordance with the provisions contained in DACS's rules, will provide the necessary documentation that the landowner has implemented the BMPs or interim measures. DACS, as part of its routine inspections regarding pesticides and fertilizers, will offer a voluntary inspection of the appropriate records to those landowners signed up for the program. If the records are not complete in regards to the requirements in the rule, the landowner will be so advised. Adequate records are very important as documentation of BMP or interim measure implementation.

ACKNOWLEDGEMENTS

These studies were made possible with support from The Department of Agriculture and Consumer Services, Department of Environmental Protection, Citrus Production Research Advisory Council, Southwest Florida Water Management District, St. John's River Water Management District, and South Florida Water Management District. We also appreciate several growers for their continued cooperation in these projects.

LOCAL WATER QUALITY ACTIVITIES IN STANISLAUS COUNTY

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The West Stanislaus Hydrologic Unit Area, through inter-agency cooperation, is an example of achieving significant accomplishments in water quality. The project is a coordinated effort between University of California Cooperative Extension, USDA Natural Resources Conservation Service, USDA Farm Services Agency and the West Stanislaus Resource Conservation District. Over the past five years, UCCE has taken the lead for informational and educational activities that has resulted in over 95% of growers becoming aware of the project's objectives.

As part of the its educational activities, UCCE has sponsored or participated in over 81 meetings and 17 tours, including grower workshops and seminars on the new agricultural polyacrylamide (PAM) technology. UCCE also published 28 newsletters, 2 brochures, 13 BMP fact sheets and produced 4 videos.

UCCE conducted a series of demonstration trials that evaluated the potential for agricultural PAM to become an aditional effective and economical tool for Westside growers to use in their efforts to achieve cleaner drainwater. The results to date have shown that PAM virtually eliminates soil erosion during furrow irrigation and also increases infiltration. 1996 preliminary results suggest the polymer may also improve yields.

CALIFORNIA CERTIFIED CROP ADVISER PROGRAM

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OBJECTIVES

The specific objective of the Certified Crop Advisor program (CCA) is to offer a certification program to the agriculture industry that can acknowledge those individuals who meet a level of expertise both educationally and professionally.

Agriculture, specifically the fertilizer industry, faces increasing pressure from both state and federal regulations on the suspected generation of non-point source pollution. This is illustrated by the development of Coastal Planning Zones by regional water boards and federal regulations that will be implemented in the Clean Water Act being developed by the U.S. EPA. These regulations will require that growers be able to provide water quality agencies with soil and water management plans that have been developed or approved by professionally certified advisors or consultants. Currently, there is no definable standard for establishing the expertise level of an individual making soil nutrient recommendations.

DESCRIPTION

The approach that will be used is one of an education program, developed by a coalition of interest groups, including industry, regulatory agencies, growers and educators, that will raise or verify the level of professional knowledge of individuals making recommendations.

Individuals who enter the program will be provided with recommended written study material, and classroom style training provided by the CCA Board, and cooperating organizations. Participants in the certificatoin program are required to pass two exams, a national and a state exam, to validate that they have acquired sufficient professional knowledge. The national exam covers broad issues in soil fertility, soil and water management, pest control, and plant development, and a state exam closely examines issues unique to California, primarily in soil fertility, and soil and water management issues. After passing these exams, individuals must satisfy continuing education requirements by attending seminars or training in the required areas, and by signing a professional code of ethics. Growers can request or require field representatives to obtain this certification. Manufacturing, retailing, and individual consultants will be encouraged to gain a professional certification to meet the combination of regulatory and grower demands.

The program's goals are based on education. Success rests on its ability to raise or reinforce knowledge that individuals acquire so they can pass the exam and validate their professional expertise. The program is utilized by independent consultants, fertilizer manufacturers, and retailers, in raising the level of expertise of

consultants and field representatives. It is utilized by growers to assure them that the soil and water nutrient programs they implement will be accepted by environmental regulatory agencies.

In the three years since the program was begun, over 550 individuals have been certified within California through the CCA certification program. Nationwide, over 3500 individuals have been certified. Almost all of the major manufacturers and retailers now require the certification of their representatives, and many of the individual retail organizations are now involved in the program. Additionally, the program is now drawing a large sector of public agency representatives who make recommendations in urban settings.

In the past year, the program provided ongoing education information to members in coordination with the Soil Improvement Committee of the California Fertilizer Association and the Fertilizer Research and Education Program. The first series of seminars were held last fall and participation was exceptional. Well over 250 individuals attended these seminars, with an approval rating well over 90 percent. This year the program will again provide educational seminars by coordinating its efforts with other organizations. The CCA program expects to have an even stronger program this year by utilizing the input that was provided by attendees from last year's seminar series. The CCA program is also coordinating with the California Chapter of the American Society of Agronomy to promote their annual conference and provide educational information to CCA's.

The program is also now in the process of improving the tracking and reporting of continuing education credits for CCA's and increasing awareness about the educational

OVERVIEW OF NITRATE IN GROUNDWATER

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opportunities for CCA's statewide.

NITRATE OCCURRENCE IN CALIFORNIA GROUNDWATER

In California, the number of groundwater wells affected by elevated levels of nitrate is far larger than that of wells affected by contamination from pesticides or by industrial contamination. Groundwater nitrate contamination is very common near large metropolitan areas and in intensively used agricultural areas, particularly the Central and Salinas Valleys. Smaller groundwater basins along the coastal range and in California's northeastern counties are locally also exposed to critical levels of nitrate. Typically, nitrate concentrations near or above the health standard of 45 mg/l are found only in the upper groundwater at depths of less than 200 feet.

Sources of nitrate are classified as either point-sources or nonpoint-sources. Point-sources of nitrate are distinct, measurable sources of limited extent such as the discharge point of municipal or industrial sewage effluent. Point sources related to agricultural activities are found in fertilizer production and storage facilities and in confined animal facilities. Nonpoint-sources are of larger areal extent often with multiple sources. Fertilizer applied to a field, certain cultivation practices conducted over an entire farm, or nutrient leaching from septic tank systems throughout a rural community are examples of potential nonpoint-sources of nitrate. In only a few instances, nitrate is of geological origin.

AGRICULTURAL PRACTICES AND GROUNDWATER QUALITY

Nitrate concentrations in groundwater have gradually increased throughout California's agricultural regions since chemical fertilizer became widely available in the 1950s. In different areas, however, groundwater is not equally affected by fertilizer application. Even within a farm or a large field, nitrate leaching rates may vary significantly. Those areas with the highest levels of groundwater nitrate are primarily found where shallow water levels (less than 50 feet deep) and relatively permeable soils prevail, for example, on the east side of the San Joaquin Valley. Where groundwater levels are deeper and soils contain extensive clay layers above the water table, nitrate is not yet of concern.

Time is an important factor in the relationship between agricultural practices and groundwater quality. Areas with groundwater levels at depths of 100 feet and more may experience significant delays between changes in agricultural impacts, even in areas with shallow water table.

Care must be taken to raise realistic expectations about future improvements in groundwater quality that result from currently implemented improvements in agricultural practices. Farmers, regulatory agencies, and the public should be aware of the complex interaction between agricultural practices and groundwater quality. Research and education programs must help build an appreciation for the tremendous local and regional differences in nitrate leaching potential, and the potentially long time-frame of subsurface leaching and transport processes.

III. ONGOING PROJECTS

WESTERN STATES AGRICULTURAL LABORATORY PROFICIENCY TESTING PROGRAM

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OBJECTIVES

The Western States Agricultural Laboratory Sample Exchange Program was initiated in 1994 with the prime objective of developing an external quality control program for the laboratory industry. The program is based on the quarterly exchange of three soils and three plant material samples, on which standard agricultural analysis is conducted using standard methods. The program is being well-received by the industry and results have been published in the popular press and in scientific proceedings. The specific objectives of the project are to:

1. Provide an external measure of individual laboratory accuracy.
2. Develop a framework for improving the long-term quality of agricultural analyses.
3. Identify levels of accuracy and precision of specific analytical methods.

Results presented here are from the 1995 Western States Proficiency Testing Program jointly developed by the UC Davis and Utah State University. In 1995, 102 laboratories participated in the Western States Proficiency Testing Program across 26 states, Canadian provinces and foreign countries, providing 26,700 analytical results. The program involves the quarterly exchange of three soil and three plant samples on which inorganic analysis of thirty-five soil and fourteen plant constituents are performed using established analytical methods. Quarterly statistical evaluations are provided to individual laboratory participants.

SOIL RESULTS

Soils used in the 1995 program were collected from the Western United States and represented a diverse range of chemical properties as illustrated by: salinity, 0.4 to 2.4 dS m-1; pH, 5.2 to 8.0; and soil nitrate (NO_3-N), 5.0 to 110 mg/kg.

Table 1. Soil nitrate (NO_3-N) mg/kg for four soils by four methodologies, Western States Program 1995.

Nitrate Method	Sample 95103 mean 1 ± 95% CI	Sample 95104 mean 1 ± 95% CI	Sample 95106 mean 1 ± 95% CI	Sample 95111 mean 1 ± 95% CI
Cadmium Reduction (Cd-Rd)	36.0 ± 0.6	16.4 ± 0.3	12.6 ± 0.5	41.0 ± 0.9
Ion Selective Electrode (ISE)	34.3 ± 2.3	17.1 ± 1.5	12.7 ± 1.1	40.1 ± 4.6
Chromatropic Acid (CTA)	35.0 ± 2.0	17.1 ± 1.3	13.1 ± 0.9	40.7 ± 2.8
Other Methods (Combined)	36.3 ± 5.6	20.6 ± 3.7	14.7 ± 2.2	40.6 ± 11.2

[1] Reduced mean and Confidence Interval based on reduced data set, outlier(s) removed using procedure of Dixon and Massey (1951).

Soil extractable P was determined by five methods: sodium bicarbonate, Bray P-1, Mehlich 3, AB-DTPA, and Modified Morgan. Generally, all methods exhibited very high RSDs (> 30%) independent of soil. Results for soil bicarbonate PO_4-P were less skewed (Figure 1), depicting a high bias, as they were in 1994 for four of the 12 soils tested. Variability in Bray P-1 and Mehlich 3 extractable phosphorus increased with increasing soil pH (1:2), is likely associated with the dissolution of alkaline calcium phosphate minerals. The variability and high bias of extractable soil PO_4-P results remains a concern to the agricultural industry, since these methods are extensively used as the basis for phosphorus fertilizer recommendations in the United States.

Results for extractable cations and micronutrients indicated that these elements have differing levels of precision. For ammonium acetate extractable X-K and X-Mg, variability ranged from 8-22% across soils. Variability of ammonium acetate extractable X-Ca consistently exceeded 30% on alkaline soils containing free carbonates and averaged 10% on other soils.

Results for soil organic matter show a large discrepancy between the Walkley-Black (OM-WB) and loss on ignition methods (OM-LOI). Consistently in 1994 and 1995, the LOI soil values were higher and less precise than the Walkley-Black method. These differences were independent of soil and were most pronounced on soils low in organic matter. Soil pH (1:2), SMP buffer pH, extractable soil NH_4-N and soil cation exchange capacity (CEC) were added to the program bringing the total to thirty-five soil analytical methods in the program. Generally, soil saturated paste pH was approximately 0.25 units lower than that obtained by 1:2 soil:water extraction. Soil SMP buffer pH results indicate a precision level equivalent to that obtained by other pH

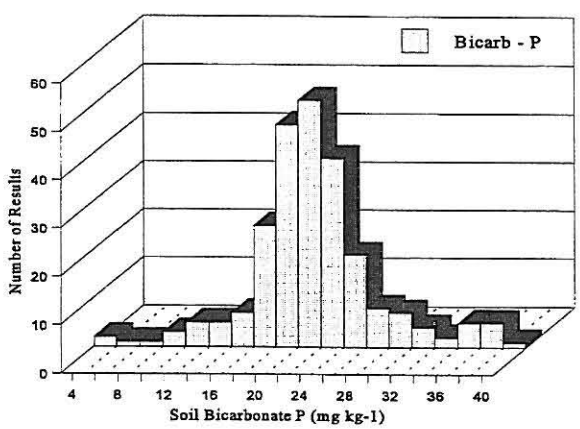

Figure 1. Histogram of soil bicarbonate P, Idaho soil 1995

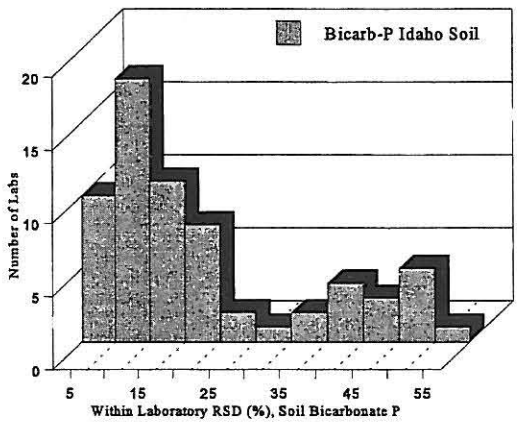

Figure 2. Histogram of lab precision, soil bicarbonate P

methods. Soil CEC was relatively imprecise, averaging an RSD > 40% for the 1st quarter, but improved through the next three quarters of 1995.

The Idaho soil was replicated through all four quarters of 1995 as saturated paste percentage, pH (saturated paste and 1:2), EC, extractable X-K, extractable X-Mg, and DTPA-Zn mean values were reproducible within 3.0% or less between quarters. Saturated paste soluble cations, B, soil NO_3-N, OM-WB and CEC precision was greater than 10% between quarters. From quarterly replicates of the Idaho sample, within laboratory precision was calculated. Results for soil bicarbonate PO_4-P lab precision (Figure 2), indicate that a majority of labs could reproduce the PO_4-P value to within 15%, however, for several variations within lab exceeded 35%. Within laboratory RSD values for X-K were substantially lower, with 65% of labs having within lab RSD values less than 12% on the replicated Idaho soils (samples 95103, 95105, 95108 and 95110.)

Two soil samples from the 1994 and 1995 Western States Program were exchanged during 1995 with the Nebraska Check Sample Program managed by Charles Focht, Soil Survey Officer of the Nebraska Check Sample Program (Table 2). There was good agreement between the soil analyte levels between the two programs and that these closely approximate the true values for these soils. Soil sample exchanges are currently in progress with other state programs using 1995 and 1996 soil materials.

Table 2. Comparison of eleven soil analytical results for two soils used in the Western States Program and the Nebraska Check Sample Program.

Soil Analysis	Soil 94103		Soil 95101	
	Western States Program[1]	Nebraska Check Program [2]	Western States Program[1]	Nebraska Check Program [2]
pH	7.8	7.9	8.4	8.5
NO_3-N (mg/kg)	7.1	6	5.0	5.0
P - Bicarb. (mg/kg)	7.8	6	2.8	2.0
P - Bray (mg/kg)	12	15	1.3	2.0
X - K (mg/kg)	620	612	94	98
X - Ca (mg/kg)	5475	5160	4875	4068
X - Mg (mg/kg)	691	654	444	435
Zn - DTPA (mg/kg)	1.07	0.8	0.60	0.6
Cu - DTPA (mg/kg)	1.65	1.8	1.12	1.1
B - Hot Water (mg/kg)	0.6	0.8	0.4	0.5
OM - WB (%)	2.9	2.6	0.3	0.4

[1] Based on mean of reduced data set, outlier(s) removed using the procedure of Dixon and Massey (1951)
[2] Based on mean, eleven laboratories.

Table 3. Analyte recovery for NIST peach leaf sample 1574 submitted as plant sample 95205 in the 1995 Western States Program.

Analyte	NIST Certified Value	Nitric/Perchloric Digestion[1]	Dry Ash Digestion [1]	Microwave Digestion[1]
	mean ± 95% CI	mean ± 95% CI	mean ± 95% CI	mean ± 95% CI
P (%)	0.137 ± 0.007	0.143 ± 0.005	0.145 ± 0.004	0.144 ± 0.007
K (%)	2.43 ± 0.03	2.29 ± 0.07	2.41 ± 0.05	2.36 ± 0.13
Ca (%)	1.56 ± 0.02	1.57 ± 0.06	1.59 ± 0.04	1.55 ± 0.06
Mg (%)	0.432 ± 0.008	0.413 ± 0.011	0.435 ± 0.009	0.416 ± 0.016
B (mg/kg)	29 ± 2	26.4 ± 1.3	28.7 ± 1.1	28.0 ± 1.1
Zn (mg/kg)	17.9 ± 0.4	18.5 ± 0.8	18.5 ± 0.5	18.7 ± 0.7
Mn (mg/kg)	98 ± 3	93 ± 2	93 ± 3	97 ± 5
Fe (mg/kg)	218 ± 14	203 ± 8	200 ± 6	190 ± 14
Cu (mg/kg)	3.7 ± 0.4	4.5 ± 0.6	4.0 ± 0.3	3.8 ± 0.2

[1]Mean and Confidence Interval based on reduced data set, outlier(s) removed using the procedure of Dixon and Massey (1951).

PLANT RESULTS

The 1995 program plant tissue samples were collected from vegetable, tree and cover cropped fields across the Western United States and represented a diverse range of chemical constituents based on: total nitrogen (N), 1.72 to 3.70%; K 1.19 to 4.66%; and Fe 101 to 1800 mg/kg. To evaluate absolute accuracy a National Institute of Standards and Technology Certified Reference Sample, NIST 1574, peach leaves, was submitted as a blind sample during the second quarter exchange as sample 95205. Results for total Ca, Mg, and B were highly accurate (Table 3). Results for total P, Zn and Cu, although comparable between methods, were slightly higher than the certified reference value. Results for total Fe were lower than the certified value of 218 mg/kg independent of the method. Results for total K and Mn were method dependent and slightly lower than the certified value. Precision, as based on standard deviation of reduced data set, is greater for all elements than the 95% confidence interval, with the exception of B and Cu values reported for microwave digestion. As a group, microwave digestion analyte values were equal or greater precision than either the nitric/perchloric or dry ash digestion methods with the exception of Zn and Fe.

SUMMARY

The focus of the Western States Proficiency Testing Program has been to provide an external measure of both accuracy and precision for the individual laboratory and address reliability of specific analytical methods. Although no certified soil sample is currently available, results of the 1995 program based on samples replicated with other programs, indicate that the accuracy of several soils is very high. These include soil pH (1:2), ECe, NO_3-N (cadmium reduction and chromatropic acid), ammonium acetate extractable K and organic matter Walkley-Black. Precise results, as measured by a replicated sample, indicate

that a majority of laboratory participants are capable of reproducing analytical values within 10% through a twelve–month period. Accuracy of plant results, as evaluated by certified samples, indicate that a majority of the laboratories can accurately determine elemental plant constituents. Although precision is greater than 10% for soluble anions (i.e. NO_3-N, PO_4-P and Cl) that for total nitrogen as measured by the combustion method, is less than 4.0%. Based on the results of 1994 and 1995, this program has demonstrated an overall improvement in both the level of precision of individual analyses, and the number of laboratories providing acceptable values within prescribed warning limits.

For 1996 the Western States Laboratory Proficiency Testing Program will add soil pH (1:1), extractable soil SO_4-S and plant SO_4-S methods. Collaborative work will continue to address potential methodology problems associated with soil extractable bicarbonate PO_4-P, Bray P-1 PO_4-P, and ammonium acetate extractable Ca. Work will begin on developing certified reference soil materials. This program will continue in 1996 to address laboratory proficiency and issues related to the quality of soil and plant analysis in the agricultural laboratory industry.

A complete report on the project is available by calling FREP or ordering through FREP's Resource Guide.

ESTABLISHING UPDATED GUIDELINES FOR COTTON NUTRITION

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INTRODUCTION

This project is in its final year of a four-year effort to update potassium and nitrogen fertilization guidelines for cotton. Revised guidelines for K fertilization have been established and appear in Table 1. Guidelines for N fertilization are being developed.

Nutritional guidelines for California cotton were established over 30 years ago using Acala 4-42. Yield from Acala varieties has increased 12.7 lbs/acre per year due to genetic improvement since cotton production began in the San Joaquin Valley in 1918. Nitrogen and potassium are both required at high levels during cotton boll development. However, many cotton growers use only historical values when determining application rates for nitrogen. Additionally, nitrogen fertilizer is often applied well in advance of the time it is required by the plant. Potassium fertilization is even less precise. However, potassium nutrition appears to be affected by soil mineralogy.

OBJECTIVES

1. Establish the relationship between tissue nitrate level and leaf function in cotton. Early season levels of nitrate typically occurring under present fertilization practices are believed to be much higher than necessary to maintain leaf function. Before adjustments can be made in either the quantity or timing of nitrogen applications, the critical level for optimum leaf function must be established.

2. Determine if yields can be maintained, and potential nitrogen losses impacting groundwater quality minimized, when nitrogen is supplied on an as needed basis instead of preplant (or split-applied at preplant and as a side dress at the early square stage).

3. Improve the predictive ability of current soil K test procedures. Ammonium acetate extractable K is the soil test currently used to identify potassium sufficiency. Soils with montmorillonitic

or vermicullitic clays exhibit K fixation, which can make accurate testing difficult. Current procedures will be compared to two new possible methods under development.

4. Develop potassium and nitrogen recommendations that simultaneously consider the soil supply rate, the quantity of nutrients stored in plant vegetative structures which can be mobilized without affecting leaf function, and the demand (timing and intensity) by developing bolls.

DESCRIPTION AND RESULTS

Critical Nitrate Levels

Plots were established at the UC Westside Research and Extension Center under drip irrigation. Nine combinations of nitrogen application included variation in the quantity of nitrogen and the time during the season when it was applied. Field sampling of nitrogen rate and timing plots has been completed for the first two years, and are ongoing. Leaves at three positions on the plants were sampled when they were first fully expanded, the subtending boll was at bloom, bloom plus 21 days, and bloom plus 42 days. Detailed enzyme work to establish the effect of nitrogen rate and timing on leaf function and longevity has been completed. All plots were sampled for nitrate on the appropriate sample dates, and tissue analysis has been completed. Growth and development data were collected throughout the season. All in-season samples have been summarized.

In-Season Versus Preplant Nitrogen Application

Nitrogen deficiency symptoms were detected in the water run nitrogen treatments (no preplant N) at the UC Westside Research and Extension Center. Tissue analyses are not yet available. Final plant mapping has been completed. Plots where 200 lbs/acre nitrogen were applied with the three in-season irrigations were 4.4 inches shorter than plots where all the nitrogen was applied prior to the first in-season irrigation. Delayed nitrogen also decreased the number of fruiting branches, decreased fruit retention approximately 6 percent at the first position of the first 10 fruiting branches, and caused a 12–percent reduction in total number of harvestable bolls per plant at the end of the season.

Testing for K Fixation

A new laboratory analyses method was developed to determine percent K fixation of a soil. A known amount of K is added to a column of soil and leached with several aliquots of water. When all soil solution K is leached, the amount missing from that originally applied is the fixed K. If 70% is fixed, and not available to the crop, it is recommended that 400 pounds K_2O be applied.

Soil Nutrient Tests Compared

Eleven soil nutrient tests were compared, including the Mehlich 3 and AB DTPA methods. None were found to be significantly more predictive than the widely used ammonium acetate testing method.

Potassium Nutritional Guidelines

Approximately 50 field locations in all six San Joaquin Valley cotton growing counties were screened for soil potassium at two or three depths. After screening of these sites, three locations in each of six counties were selected for intensive study. These 18 field locations represented a wide range of soil K levels, geographic location and level of K fixation. Prior to the first irrigation, 0 or 400 lbs/acre of potassium was applied to large scale plots. Petiole and plant growth data were collected four times during the season. Data from the first three years have been summarized.

Table 1. Revised guidelines for potassium fertilization for cotton

If soil level is 110-120 ppm:	Apply 100 pounds K_2O/acre
If soil level is 80-100 ppm:	Apply 200 pounds K_2O/acre
If soil level is less than 80 ppm:	Apply 400 pounds K_2O/acre
If K fixation is greater than 70%:	Apply 400 pounds K_2O/acre
Critical petiole levels are:	a) first bloom: 3.5% b) bloom + 2 weeks: 2.75% c) cutout + 10 days: 1.5%

Supplemental K can be applied as foliar or water run after first bloom.

*Soil samples must be taken from 5-15 inch depths.

Guidelines for Nitrogen Fertilization

Data for nitrogen fertilizer guidelines is still being gathered. It is expected that recommendations will be available after two more research seasons.

A complete project report is available by calling FREP or ordering through FREP's Resource Guide.

USING HIGH RATES OF FOLIAR UREA TO REPLACE SOIL APPLIED FERTILIZER IN EARLY MATURING PEACHES

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INTRODUCTION

Foliar nitrogen sprays offer an alternative to soil applied fertilizers. This practice could greatly reduce the potential for nitrate leaching into the groundwater.

We have been investigating an approach with early season peach trees of applying a relatively high concentration of low biuret urea in the fall when leaf damage is not a major concern. Results so far have indicated that the urea is quickly taken into the leaf (80% in 24 hrs) and largely transported out of the leaf within one week, before extensive leaffall occurs. Therefore, this appears to be a very efficient way of supplying the tree with N.

The objectives of this project are to:

1. Determine the optimum timing and concentration of 1 or 2 foliar urea sprays in the fall on early season peach trees.
2. Study the effects of foliar urea sprays over several years on tree productivity, fruit quality, and vegetative growth.
3. Study the distribution within the tree of N from foliar urea sprays using ^{15}N as a tracer.
4. Disseminate information to growers about foliar urea using newsletters, meetings, radio and popular journals.

RESULTS

Experiments addressing the first objective were initiated in the fall of 1995. ^{15}N tagged foliar urea was used to compare uptake by nectarine leaves in early October vs. early November. Trees with high and low N status were also compared. The results are preliminary but suggest high uptake efficiency (90%) at both dates and higher remobilization of N out of the leaf in October. There appears to be very rapid movement of nitrogen within the trees at this time of year, especially in those trees with high N status. This emphasizes the need for whole tree studies.

We have now conducted 3 or 4 independent studies which support the conclusion that foliar urea is taken up quite efficiently in the fall by peach and nectarine leaves. As this project

Table 1. Dormant root and shoot N content, spring leaf N and summer pruning weights as influenced by soil applied or foliar nitrogen.

	Treatments				
	Significance	Soil Applied Fertilizer	Foliar Urea 2-3 Applics.	Foliar Urea 1 Application	Unfertilized Control
Dormant Root N (%)					
Jan. 94	.78 b	1.61 a	1.58 a	1.39 a	.0002
Dec. 94	.63 b	1.27 a	1.29 a	1.18 a	.002
Dormant Shoot N (%)					
Jan. 94	1.31 b	1.76 a	1.76 a	1.63 a	.0001
Dec. 94	1.05 c	1.60 a	1.34 b	1.35 b	.0001
Spring Leaf N (%)					
4/13/94	3.38 c	3.46 c	3.71 b	3.93 a	.0002
4/10/95	3.17	3.21	3.34	3.23	NS
Summer Pruning Weight (kg/Tree)					
7/21/94	4.3 b	8.9 a	9.7 a	9.3 a	.001
7/31/95	2.5 b	5.5 a	5.3 a	3.8 b	.005

continues, greater emphasis will be placed on the distribution within the tree of nitrogen from foliar sprays and subsequent effects on flower bud development, fruit growth, shoot growth and tree productivity.

To study long-term productivity, an experiment on Early Maycrest peach was initiated in the fall of 1993 at the UC Kearney Agricultural Center. Treatments were set up comparing soil-applied nitrogen fertilizer to foliar urea sprays applied in October. Two foliar treatments were applied, one supplying all the nitrogen in a single dose and the other supplying the same amount of nitrogen over 2 or 3 sprays, each 2 weeks apart. All treatments received 100 to 150 lbs N/acre.

Results from the 2 years show that foliar urea is taken up efficiently by the leaves and exported to the roots before the trees go dormant. All 3 fertilizer treatments doubled the dormant root nitrogen content compared to the unfertilized control (Table 1). Dormant shoot nitrogen content was also increased by the foliar treatments but was increased more by the soil applied treatment in 1994. Spring leaf N and vegetative growth provide further evidence that nitrogen from foliar sprays is being stored and utilized the following year. Vegetative growth, as measured by summer pruning weights, was consistently stimulated by both the soil applied treatment and the foliar treatment of 2-3 applications (Table 1).

All 3 fertilizer treatments were able to maintain the yields of this early season peach variety (Table 2). However, average fruit weight was consistently greater in the soil applied treatment than either of the foliar treatments. We are currently testing several hypotheses that may explain why there appear to be differences in fruit growth.

Table 2. Yield and fruit weight of Early Maycrest peach as influenced by soil applied or foliar nitrogen.

	Treatments				
	Significance	Soil Applied Fertilizer	Foliar Urea 2-3 Applics.	Foliar Urea 1 Application	Unfertilized Control
Yield (kg/tree)					
May 94	39.7	36.5	37.7	40.1	NS
May 95	22.3 b	36.4 a	30.9 a	34.3 a	.02
Dormant Shoot N (%)					
May 94	102.7 c	117.5 a	110.2 b	110.2 b	.0009
May 95	87.8 b	108.6 a	92.1 b	91.9 b	.008

This experiment demonstrated that nitrogen can be effectively taken up, stored and utilized by peach and nectarine trees. However, the concern over fruit size has given rise to some new experiments where combinations of soil applied and foliar treatments are being evaluated. Three new experiments were initiated in 1995. Because of the significant potential for substantially reducing leachable soil nitrates (Table 3), this work needs to be continued so that reasonable treatments can be developed which supply nitrogen to the tree but do not adversely affect productivity or fruit size.

A preliminary study on N distribution within the whole tree (objective 3) was initiated in 1995. ^{15}N tagged urea was applied to 2 low N and 2 high N Fantasia nectarine trees in October. Leaves were collected as they fell, prunings were also collected, and the whole trees were excavated in mid January, 1996. Results are currently being analyzed and tabulated. This objective will be a major emphasis in the fall of 1996 and should help answer some questions from the second objective.

Since the project has just begun, we have not yet placed on outreach. A field meeting was held in early October, 1995, to talk about applying foliar urea with fall zinc sprays. There were about 25 growers in attendance, many of whom tried our recommendations. We will continue to disseminate information from this project as we obtain more results.

Table 3. Soil nitrate levels in December 1994 as influenced by soil applied or foliar nitrogen.

	Treatments				
	Significance	Soil Applied Fertilizer	Foliar Urea 2-3 Applics.	Foliar Urea 1 Application	Unfertilized Control
Soil Nitrate (ppm)					
Dec. 94					
6"	1.6 b	7.0 a	2.3 b	4.6 ab	.01
12"	1.6 b	24.2 a	1.7 b	3.0 b	.003
24"	1.4 b	13.7 a	1.4 b	1.5 b	.0008
36"	1.8 b	12.7 a	1.5 b	1.5 b	.0001

DEVELOPMENT AND PROMOTION OF NITROGEN QUICK TESTS FOR DETERMINING NITROGEN FERTILIZER NEEDS OF VEGETABLES

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OBJECTIVES

1. Continue to refine correlations between fresh sap and dry tissue nitrate levels for vegetable crops through split sample analysis by the Cardy specific ion meter and at the UC Davis DANR Lab.
2. Evaluate integrated monitoring, using quick tests of the soil nitrate status and petiole nitrate-N as a technique to reduce nitrogen fertilization.
3. Evaluate the uniformity of nitrate levels throughout typical growers fields, in order to make better recommendations to growers on site selection and number of samples needed to adequately monitor nitrate levels.
4. Promote the use of nitrate quick tests for managing fertilizer applications through meetings and mass media.

DESCRIPTION

The purpose of this project is to continue to evaluate and develop quick test technology as an aid in making fertilization application decisions including the development of critical levels for nitrate in fresh sap for selected vegetables. Critical levels are the levels of nitrate in the plant tissue, above which the crop is adequately fertilized. Critical levels were developed using linear correlation to convert already existing dry tissue critical values into fresh sap critical levels. Correlations between fresh sap and dry tissue were developed for broccoli, cabbage, cauliflower, celery, lettuce, onions, and sweet corn. The correlations developed in this project gave similar fresh sap critical values to what has previously been reported for cauliflower and broccoli; somewhat higher critical levels for lettuce; and much higher critical levels for celery. Data for cabbage, sweet corn and onions were newly developed (Table 1).

Another major objective of this project is to evaluate the accuracy of the quick test method. Plant-to-plant variability was evaluated by separately measuring nitrate levels in single petioles from 20 adjacent plants. This variability was then analyzed to estimate the appropriate number of petioles or midribs needed to obtain a representative sample. Representative sample sizes were calculated for different crops at different growth stages and ranged from 13 to 42 petioles to give a margin of error of plus or minus 10%. However, most of the tests gave required sample sizes of about 20 petioles which has commonly been recommended in other studies. In-field nitrate variability was also measured in four drip irrigated fields. All four fields were extremely uniform, with coefficients of variation (CV) from 7 to 9%.

The variability between different Cardy meters was also examined. The agreement between the meters was found to be very good. The CV in the tests was about 5% when measuring samples in the range near the calibration point (450 ppm nitrate-N) and about 10% in the higher and lower ranges. One source of error encountered was differences in nitrate concentration in the calibration solutions. Taken together, these sources of error are small enough that quick tests should be able to supply reasonably accurate and reliable information.

A case study using quick tests to determine fertilizer needs was evaluated in a drip irrigated field of broccoli near Soledad. Both petiole and soil nitrate levels were monitored. For soil testing, both the quick test developed by Tim Hartz and soil solution access tubes were used. The quick test was found to be easier to collect and less variable than the soil solution access tube method. After the spray banding of ammonium nitrate, additional fertilizer was withheld from the crop until the nitrate levels in the broccoli petioles fell to near the critical level. This delayed the fertilizer application by about 2 weeks compared to what the grower would have normally done. The use of drip irrigation in combination with the quick tests reduced water-run nitrogen by about 80 lbs. per acre when compared to the normal fertilizer program in sprinkler irrigated fields. Part of this reduction in nitrogen use was due to the use of drip irrigation and part of it was due to the delay in beginning the fertilizer applications.

Overall, with N fertilizer at about 38¢ per lb., the reduced fertilizer application resulted in a saving of $30.40 per acre or $547.20 for this 18-acre field. In a report to the Iceberg Lettuce Research Advisory board, Louise Jackson estimated the cost to sample a 20-acre lettuce field to be $312.00 or about $15.60 per acre. Sampling costs for broccoli would probably be similar. This data indicates that using quick tests may be an economical way to reduce fertilizer applications in some fields.

Table 1. Fresh petiole sap critical levels (adequacy range)

CROP	CROP STAGE	NO_3-N (IN PPM)
Broccoli	Mid growth	1000-1600
	Button formation	800-1200
	Preharvest	600-1000
Cabbage[1]*	**Cupping**	**1200-1500**
	Early heading	**1000-1200**
	Mid heading	**700-900**
Cantaloupe	Early flower	1000-1200
	Fruit bulking	800-1000
	First harvest	700-800
Cauliflower	**Mid growth**	**1000-1600**
	Curd development	**700-1000**
	Preharvest	**500-800**
Celery	**Mid growth**	**600-800**
	Preharvest	**400-600**
Lettuce	**Early head formation**	**400-600**
	Preharvest	**350-500**
Onion[2]	**Bulbs 0.5 - 1.5 inches**	**350-500**
Pepper	Vegetative growth	900-1200
	Early flower/fruit	700-1000
	Fruit bulking	700-1000
	Preharvest	700-900
Sweet Corn	**Entire season**	**600-700**
Tomato	Vegetative growth	700-900
	Early flower/fruit	600- 800
	Fruit bulking	500-700
	Preharvest	400-600
Watermelon	Early flower	900-1100
	Fruit bulking	700-900
	First harvest	500-700

* Bold indicates data developed by this project
1-Based on one year of data
2-Long-day type of onions

DIAGNOSTIC TOOLS FOR EFFICIENT NITROGEN MANAGEMENT OF VEGETABLES PRODUCED IN THE LOW DESERT

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OBJECTIVES

This project seeks to evaluate several diagnostic approaches as tools to aid in the efficient N management of vegetables in the low desert and to conduct an outreach program. Our objectives during 1995-1996 were:

1. Verify and/or modify diagnostic tissue test for lettuce, broccoli, and cauliflower.
2. Evaluate quick techniques for monitoring N status, such as quick sap test and the chlorophyll meter.
3. Evaluate reflectance technologies as potential tools for monitoring N status, including aerial photographic surveys.

DESCRIPTION

The low desert regions of the southwestern United States are a major area of vegetable production during the winter months. Nitrogen is the nutrient most limiting to crop production in the region. Because of rigid produce quality standards enforced by the market, lettuce, cole crops, and other vegetables receive appreciable amounts of N fertilizer for optimal yield and quality. Researchers have found that optimal N management practices for crops in the low desert region consist of a modest preplant application with subsequent sidedress (or water run) applications based on crop monitoring. However, many vegetable growers have been reluctant to adopt N fertilization practices based on tissue monitoring.

This project is designed to evaluate several diagnostic approaches as tools to aid in the efficient N management of vegetables produced in the low desert. Approaches include the traditional dry midrib or petiole test, the sap midrib or petiole test using the Cardy meter, absorbance using the chlorophyll meter, and various reflectance technologies including digital analysis of aerial photographs. We selected sites in the lower Colorado River Valley, the Imperial Valley, and the Coachella Valley.

All field experiments included N rate as a variable with three to five replications in

randomized complete block designs. N rates ranged from 0 to 270 lbs N/acre (300 kg N/ha). Our purpose was to evaluate all diagnostic technologies under conditions of sub-optimal, optimal, and supra-optimal levels of N nutrition. The more site-seasons from which data are collected, the more reliable are the diagnostic standards. The results reported herein are based on 16 site-seasons with lettuce, five site-seasons with cauliflower, and four site-seasons with broccoli.

RESULTS AND CONCLUSIONS

Yield Response: Lettuce responded to N fertilization in 14 out of 16 sites, cauliflower responded to N in three out of five sites and broccoli responded to N in two out of four sites. Generally, the responses to N were curvilinear which allows an excellent opportunity for evaluating diagnostic technologies for assessing N nutritional status. The lower portion of the response curve, where yield response is proportional to N rate, indicate N deficiencies. The upper portion of the response curve, the points beyond maximum yield, correspond to excess N nutrition. Hence, we can correlate several diagnostic technologies to growth and yield. This report will focus on iceberg lettuce since we have the largest data base for this crop. We will discuss broccoli and cauliflower in more detail in subsequent reports as we enlarge our database for these commodities.

Dry midrib nitrate-N: Dry midrib nitrate levels increased with N fertilization in most experiments. However, the midrib nitrate-N test was not a sensitive indicator during the early growth stages of lettuce. It is our opinion that this test is not consistently reliable before the folding stage of growth. Additionally, it is possible that different standards may be required during the earliest planting slot. We have correlated midrib nitrate-N levels to marketable yield during the heading stages. Generally, these data suggest the critical midrib nitrate-N value is 8000 ppm, although 6000 ppm seemed to be sufficient for some site-seasons. Recent work in England suggest that it may be more appropriate to correlate tissue to growth rate, rather than yield. We have growth rate data for most experiments and are in the process of conducting this correlation of growth rate over specific growth periods to midrib nitrate-N. We will cover this data in our next report.

Sap nitrate-N: Sap nitrate-N increased with N rate in most experiments. The sap nitrate test is correlated to the midrib nitrate-N test, although there is variability. We believe some of the variability is associated with variation in plant water status and interference due to chloride. The dry midrib nitrate-N test is standardized by drying the tissue and chloride interference is minimized through the use of a buffer extracting solution. Despite these limitations, based on the data we collected to date, we believe the sap nitrate-N test would be a useful test after the folding stage of growth. We will conduct additional correlations to growth rate, as we are doing with the dry midrib nitrate-N test.

Chlorophyll meter readings: There was a general increase in chlorophyll meter readings with N rate. Nevertheless, the values were not a sensitive indicator of N nutritional status. The range in values between low and high chlorophyll meter readings was generally less than 5 units, although yields increased by 80%. There were also frequently reversals in readings among N rates. Furthermore, chlorophyll meter readings varied substantially with cultivar. An evaluation of variance components shows extreme variation in readings on different locations on an individual leaf relative to other sources of error. Although the chlorophyll meter has been successfully used to diagnose N deficiencies on corn in the midwestern United States, lettuce leaves have more color variation than corn leaves. This variation, in combination with the small sensor size on the SPAD 502, likely confounded readings. Evaluation of the chlorophyll meter as a tool to diagnose N deficiencies in lettuce and cole crops has been discontinued.

Canopy reflectance: Canopy reflectance measurements using a spectraradiometer

showed sensitivity to N stresses at the 550 nanometer (green), 650 to 700 nm (red), and 750 to 900 nm (near infrared) regions of the light spectrum. Data from a digital analysis of aerial photographs show good relationships between red gray scale values and relative marketable lettuce yield. Blue and green gray scale values were generally not sensitive. Preliminary evaluations show canopy reflectance technologies are correlated to N stresses in lettuce. However, this may be primarily the result of the fact that in the controlled N rate experiments, N was the predominate stress. A preliminary evaluation on large fields suggest that it may be difficult to separate N stress from other stresses. Hence, at present, aerial photographs are at best a qualitative tool which can be used to troubleshoot fields. However, the nature of the stress must be verified or determined by data collection on the ground. During the 1996-1997 year, we will reduce our effort in this area and focus on more quantitative diagnostic tools.

Soil nitrate N test: We have collected limited information on the soil nitrate-N test. However, because plant tests do not appear to be sensitive indicators of N nutrition during early growth stages (before folding), a post thinning (and pre-sidedress) soil nitrate-N test will be a major focus during the 1996-1997 growing season.

AVOCADO GROWERS CAN REDUCE NITRATE GROUND-WATER POLLUTION AND INCREASE YIELD AND PROFIT

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OBJECTIVES

The goal of this research project is to reduce the amount of nitrate entering the groundwater and the amount of boron added to soils from avocado production by providing avocado growers with an economically viable alternative to the use of soil-applied nitrate and/or boron.

The specific objectives are to:

1. Test in a well replicated field trial the results of preliminary research suggesting that a single application of urea to the canopy during early bloom will increase yield and net return to the grower over untreated control trees at the 5% level and will significantly increase yield over trees receiving canopy applications of boron;
2. Determine if nitrogen applied to the canopy during expansion of the spring flush leaves (approximately May 30) increases yield alone and/or in combination with the bloom canopy application of urea;
3. Determine if canopy applications of urea during bloom or during leaf expansion of the spring flush can replace part of the nitrogen annually applied to the soil in avocado production; and
4. Disseminate the results of this research to avocado growers through talks to growers and publications in grower magazines and the California Avocado Society Yearbook.

DESCRIPTION

Treatments were applied to 16 individual tree replicates per treatment in a randomized block design. The trees are mature, healthy commercially-producing 'Hass' avocados on Duke 7 rootstocks at a site owned by Limoneira Co. in Santa Paula, CA. During year one, voucher specimens were collected to insure that trees could be treated at the same stage of flower development in each subsequent year. At pre-bloom (cauliflower stage), trees received a canopy spray of 30 g Solubor (Solubor is 20.5% boron) in 4 gallons of water/tree (all 4 gallons were applied to the bloom and foliage to thoroughly cover the tree), 475 ml Unocal PLUS in 4 gallons of water per tree or 30 g Solubor plus 475 ml Unocal PLUS in 4 gallons of water per tree. In addition, two sets of trees received a foliar application of Unocal PLUS at the rate of 475 ml in 4 gallons of water per tree when the spring flush leaves were two thirds fully expanded, alone or in combination with a prior bloom application of Unocal PLUS. Forty spring flush leaves from non-fruiting terminals were collected at chest height around each data tree in September. In addition, leaves were collected just before the spring flush urea application and one week after the application. The leaves were immediately stored on ice, washed thoroughly, oven-dried, ground and sent to the laboratory for analysis of total nitrogen and boron. Harvest data included total lbs of fruit/tree and the weight of 100 randomly selected individual fruit per tree, which were used to calculate packout per tree, evaluation of internal fruit quality, and a cost-benefit analysis of each treatment.

RESULTS AND CONCLUSIONS

The harvest for the first year of this field experiment was May 31-June 1, 1995. No treatment significantly increased the weight of fruit per tree at the 5% level. The bloom spray of low-biuret urea increased the number of larger fruit, (packinghouse sizes 40 and 36), compared to all other treatments at P=0.06. There were no significant differences in the number of fruit in any other size category. While not statistically different at the 5% level, foliar application of urea to the canopy at bloom in combination with a second application to the spring flush (May) resulted in an average of 3 additional packing cartons (24 lbs or 10.9 kg) of fruit per tree: compare 223 kg fruit per tree to 187 kg for the control. Application of low-biuret urea to only the spring flush increased yield by 11 kg fruit per tree compared to the control. The boron spray at bloom resulted in the lowest yield, 164 kg fruit per tree. Leaf analyses have not yet been completed. There were no negative effects from any treatment on internal fruit quality.

The harvest for the second year was June 18, 1996. The yield represented an "off" year: compare 63.5 kg fruit per control tree in year two to 187 kg fruit per control tree for the previous harvest in year one of the experiment. No treatment significantly increased the total yield of fruit per tree at the 5% level. There were no significant differences in the number of fruit in any size category. While not significant at the 5% level, foliar application of urea to the canopy at bloom in combination with a second application to the spring flush (May)–the treatment which increased yield the most in year one–resulted in the lowest yield in year two, consistent with alternate bearing. Similarly, the control, which had a low yield in year one, had a high yield in year two.

The results of this two-year study provide evidence that urea applied to the canopy at bloom and again during the spring flush can increase yield. The results suggest, however, that the treatment should probably be initiated and used only in off years. This interpretation needs to be tested.

THE USE OF ION EXCHANGE RESIN BAGS TO EVALUATE NITRATE LEACHING

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The leaching potential of soil nitrate in crop production systems is of high concern in California agriculture. In 1995 a project was initiated to evaluate the use of ion exchange resin bags for monitoring nitrate leaching in tomatoes grown under conventional and organic production systems. Anion exchange resin bags, with a high affinity for nitrate, were buried in early May, 1995, at 75 cm (30") in a 5' x 5' grid in tomato plots under conventional and organic production management. Every three weeks resin bags were removed and soil samples were collected to evaluate soil nitrate supply and resin bag accumulation. Results indicate significant changes in soil profile nitrate through the course of the summer, while little changes were noted in resin bag accumulated nitrate. Based on observations nitrate accumulation in the resin bag averaged 0.35 to 0.70 lbs per acre per week in both the conventional and the organic production system. Results for both soil and ion exchange resin bag nitrate were highly spatially variable.

In November 1995, the study was repeated to evaluate nitrate leaching during the winter non-crop production period following tomatoes. Results indicate both systems had very high concentrations of soil nitrate at the initiation of the study, in excess of 55 lbs per acre. Increases in soil nitrate were noted in the conventional production system though mid January. Soil nitrate declined in both production systems at all soil depths from mid January thorough mid March. Results for the ion exchange resin bag indicated nitrate accumulated at an average rate of 0.8 lbs per acre per week during the study period. Again, as in the summer study, resin bag accumulation of nitrate was highly spatially variable.

These results indicate that the use of ion exchange resin bags for monitoring leaching of soil nitrate is limited by a high degree of soil spatial variability associated with soil nitrate concentration and water infiltration rate. Rates of nitrate leaching indicate significantly high leaching rates during the winter and the highest rates in plots under organic management.

IRRIGATION AND NUTRIENT MANAGEMENT CONFERENCE AND TRADE FAIR

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Nitrate levels in the Salinas Valley ground water basin pose a threat to municipal drinking water supplies. Agricultural crop production has been identified as a primary source of this nitrate contamination. As part of its water quality planning program, the Monterey County Water Resources Agency has led a coordinated research and outreach effort to reduce nitrate leaching through improvements to irrigation efficiency and fertilizer management. As part of the effort, the Agency sponsors an annual Irrigation and Nutrient Management Conference and Trade Fair.

The Fourth Irrigation and Nutrient Management Conference and Trade Fair was presented to a capacity audience in Salinas on February 28, 1996. The conference is the result of a coordinated effort between the following cosponsors: Fertilizer Research and Education Program, Monterey County Water Resources Agency Irrigation Training and Research Center, at Cal Poly, University of California Cooperative Extension, and University Extension.

The goal of the conference is to transfer practical knowledge to area growers about the issues and practices of irrigation and fertility management. The conference focuses on practical information and new technologies designed to efficiently manage water and fertilizer inputs. In addition to university researchers presenting recent findings, the experience of key irrigation and fertilizer industry personnel contributes to the success of the conference.

The conference is targeted specifically towards growers in the Salinas Valley and other coastal vegetable producing regions. In 1996, 75 percent of the attendees came from the coastal areas of California. The majority of them were growers and related agribusiness professionals (44% and 20% respectively). A survey of attendees indicated that the conference met their expectations (84%), enhanced their knowledge (86%), that they expect to use the information in their work (79%). 82% of the respondents said they would recommend this conference to others.

The main session conference topics included: nitrogen management through intensive on-farm monitoring, case study analysis of total farming inputs with drip irrigation, and moderated industry panel discussions about drip irrigation filtration. Concurrent session topics included: irrigation and fertility management of wine grapes, use of quick tests for nitrogen and potassium, compost and soil organic matter, and irrigation water quality.

Next year's conference will be held on February 27, 1997. Contact Danyal Kasapligil for more information.

DEVELOPING SITE-SPECIFIC FARMING INFORMATION FOR CROPPING SYSTEMS IN CALIFORNIA

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OBJECTIVES

To determine whether environmental variables (such as soil drainage class) or manageable factors (irrigation, fertilizer application) can be related to crop yield and quality by use of relatively low-cost information obtained through aerial photography and yield mapping.

DESCRIPTION

Site-specific farming, sometimes called "precision farming," involves the use of several new and not-so-new technologies, including continuous flow yield sensors, global positioning systems (GPS), aerial or satellite photography and spectrophotometry, and variable rate fertilizer and herbicide application. Most of the recent research, development, and commercial application of site-specific farming technologies has been in the US grain belt with rainfed, relatively low value crops. The premise behind the application of this technology is that agronomically significant variability in plant growth and yield, soil type, pest pressures, etc. exists within fields, can be characterized, and can be managed for the betterment of farm profit and the environment. Little work has been done on California's many irrigated cropping systems to test this premise. In the fall of 1995, a team of UC Davis scientists, Extension specialists, and farm advisors working with Yolo County grower Tony Turkovich began a project to explore and demonstrate the potential for relating within-field yield variation to variations in soil, pest pressures, plant tissue nutrient content, etc.

The team is collecting information from three fields in Yolo County ranging in size from 77 to 108 acres. These fields were cropped to irrigated wheat in the 1995-96 year and will rotate into processing tomatoes in 1997. Additional information is being collected from wheat-tomato plots at the UC Davis Long Term Research in Agricultural Systems (LTRAS) experiment. On the grower fields, grain yield was measured with a commercial yield monitor and GPS receiver installed on the grower's combine. Yields were measured at one-second intervals, corresponding to a travel distance of about three feet. Color infrared aerial photographs were taken in December before crop emergence, at early jointing in March, and during grain fill in May. Photographs were digitized (1 pixel = 6' x 6'), and a normalized vegetation index was derived from the March and May images.

Soil, plant, and crop observation data, including weed, stand density, and disease ratings, were collected on a 200' x 200' grid in each field. The wheat cultivar planted in the grower fields was 'Express', grown for its relatively high protein content, so flag leaf, head, and grain samples have been analyzed for N content. In 1997, when the fields are in tomatoes, yields will be continuously monitored using a newly developed harvester-mounted system. All data are being compiled in layers using ARC/INFO software, which is ideally suited to the integration of directly-sensed and remotely-sensed data. Although all the technologies used were off-the-shelf, several hardware glitches and challenges in data analysis arose during the project's first year. The GPS signal was lost during portions of the harvest of two of the three fields, resulting in a large amount of yield information that cannot be mapped until researchers reconstruct the location information. Also, it is a challenge to register (overlay) and compare layers of information that differ in data density and accuracy of location. Aerial photographs are distorted by the angle of the camera and must be "rubber sheeted" or undistorted, using reference point locations determined with a hand-held GPS. Another example: The GPS on the harvester is accurate (with differential correction, which in this project was not always working) only to 2-3 meters, so caution must be used in comparing yields and soil or plant analyses from supposedly identical locations.

RESULTS

In spite of hardware and data analysis difficulties, the project team has observed some interesting and potentially useful relationships during the first crop year. Wheat yields within fields ranged from about 2,000 lbs/acre to 6,500 lbs/acre, so there is no doubt that "agronomically significant" variation occurred. There were smaller but still significant variations in grain protein content. In two of the fields, grassy weeds apparently accounted for much of the variation. In one of those fields, the color IR aerial photograph taken in May, visual weed density ratings, and the grain yield map all show a similar pattern. It may be possible to determine the cost to the farmer of the weeds, something that would be impossible with only the field-average wheat yield. The research team will also be examining grain protein for any pattern that suggests affects of late-season fertigation. In one field, yield appears to be in part related to soil texture or drainage class. The value of yield maps and other geo-referenced information to the farmer will increase when information from several years is combined, and can be used to determine which of several manageable factors is causing the greatest problem.

RELATIONSHIP BETWEEN NITROGEN FERTILIZATION AND BACTERIAL CANKER DISEASE IN FRENCH PRUNE

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DESCRIPTION

Bacterial canker (BC) is a serious disease that affects apricots, prunes, plums, peaches, almonds and cherries. The disease is caused by a widespread bacterium, *Pseudomonas syringae*, that attacks trees 'stressed' by ring nematode root-feeding, poor soil drainage, cold temperature, rain and other general stresses. Over one million acres of these susceptible crops are grown in California and nearly all commercial scale farms apply some form of nitrogen fertilizer (N) to these crops.

RESULTS

Research plots have been established at the UC Davis Department of Pomology's Wolfskill Ranch to determine the effects on growth response and yield of French prune to "fertigation" (N [urea] fertilizers applied through drip irrigation). Fertigation is thought to be an efficient N delivery method and an alternative to top dressing. Unexpectedly, two of our treatment blocks which had no or very low levels of applied N developed a very high incidence of BC (60% and 32%, respectively in 1995). By June 1996, 90% of the trees in the block receiving no nitrogen had either died of BC and been replaced or showed BC symptoms. In the low N treatment (.25 lb/tree/year), 47% of the trees had to be replaced or were symptomatic of BC by June, 1996. However, in the blocks receiving higher N rates (0.5-1 lb/tree/year), 0-6% of trees had been replaced or were symptomatic by this same time.

Leaf analysis in July, 1995, showed that trees receiving no N and low N were deficient at 1.96% and 2.17% N, respectively. Adequate leaf N levels are between 2.3% and 2.8% (Uriu, 1981). Trees receiving 1 lb N and 0.5 lb N, contained 2.45% and 2.31% N. Leaf N levels in 1996 are not yet deficient in no or low N treatment blocks, but are already lower than those in treatment blocks receiving higher applied N. Soil analysis of all treatment blocks in 1994 and 1995 showed no areas of the orchard where soil nitrate from fertilizer leaching was especially high or low.

As expected, trees receiving higher N treatments grew more each year than trees receiving no N. However, no difference in prune dry yields were observed in 1995 (first good cropping year). The higher doses of N fertilizer may stimulate more shoot growth, but not necessarily higher yields. These preliminary data would support a recommendation to fertigate at the lower rate (.25 lb/tree/year) unless symptoms or a history of BC exist. On sites with a history of BC, higher N rates may reduce or eliminate BC symptoms.

NITROGEN MANAGEMENT IN CITRUS UNDER LOW VOLUME IRRIGATION

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Tulare County

Citrus fruits are a major crop in California with an annual value in excess of $700 million. The citrus industry is one of the State's largest users of nitrogen fertilizers, with growers applying 1 - 2 lbs. of actual nitrogen per tree per year to each of 30 million trees in the State. Navel orange accounts for approximately 42% of the State total citrus, and is largely situated (86% of acreage) in the San Joaquin Valley. Most soils suitable for citrus production supply adequate amounts of other macro-nutrients. California citrus growers apply nitrogen and other fertilizers to maintain production . However, most growers do not consider the impact of applied fertilizers on fruit quality, excess vegetative growth and the environment.

Considerable work was done in the 1950's, 60's, and 70's to determine the optimal nitrogen requirements of citrus and to develop leaf analysis norms used to determine fertilizer programs. However, fertilizer application technologies have changed dramatically in recent years. Fertigation, foliar applications of N, and micro-irrigation systems are now common in the industry. However, recommended application rates for N have remained constant, while leaf norms have skewed upward, with recommendations made by private leaf analysis laboratories often in the 2.8 + % range. We suspect that this has resulted in an overall decrease in fruit quality industry-wide, excess tree vegetative growth, energy waste in tree pruning, lower overall yields and potential groundwater contamination. The objectives of this five-year study are to determine the effects of:

1. Nitrogen application on navel orange fruit quality
2. Foliar versus soil applied nitrogen on fruit quality
3. Nitrogen application on nitrogen leaching
4. Nitrogen application timing on fruit quality
5. Foliar application as a replacement for soil application
6. Effect of single foliar application on fruit quality

DESCRIPTION

A grower in the Exeter-Woodlake area of Tulare County has agreed to cooperate on the project. The 15.3 acre experimental site is a mature navel orange grove (Frost Nucellar) on Troyer Citrange rootstock. The tree spacing is 22 x 20 feet. Twenty-five experimental treatments have been selected for the project (Table 1). Each experimental plot will consist of 12 trees with the central 2 trees serving as the data trees. We are in the process of modifying the cooperator's irrigation system to accommodate the differential nitrogen treatments. The differential nitrogen treatments will be imposed in January 1997.

Table 1. Schedule of Experimental Nitrogen Treatments

Treatment	Soil Applied N (lbs/tree/yr)	Timing (see key)	Foliar (# of applications)	Total N (lbs/tree/yr)
1	0	-	-	0.00
2	0	-	1	0.25
3	0	-	2	0.50
4	0	-	4	1.00
5	0.5	1	-	0.50
6	0.5	2	-	0.50
7	0.5	C	-	0.50
8	1.0	1	-	1.00
9	1.0	2	-	1.00
10	1.0	C	-	1.00
11	1.5	1	-	1.50
12	1.5	2	-	1.50
13	1.5	C	-	1.50
14	2.0	1	-	2.00
15	2.0	2	-	2.00
16	2.0	C	-	2.00
17	0.5	C	1	0.75
18	0.5	C	2	1.00
19	0.5	C	4	1.50
20	1.0	C	1	1.25
21	1.0	C	2	1.50
22	1.0	C	4	2.00
23	1.5	C	1	1.75
24	1.5	C	2	2.00
25	2.0	C	1	2.25

DETERMINATION OF BEST NITROGEN MANAGEMENT PRACTICES FOR BROCCOLI PRODUCTION IN THE SAN JOAQUIN VALLEY

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Declining profitability in food and feed grains in the 1980s stimulated an interest in alternative crops, such as fresh vegetables in the southern San Joaquin Valley. As growers sought to diversify their production base and capitalize on rising consumer demand for vegetables, broccoli acreage and value began to increase. In 1980 less than 1000 acres of broccoli was reported for the valley in local county agricultural commissioner reports, but by 1994 nearly 10,000 acres were in broccoli production.

Several areas in the San Joaquin Valley have been targeted as nitrate sensitive areas, and broccoli production in Fresno and Tulare counties overlaps several of them (1). Broccoli is a crop that can create a high potential for nitrate leaching losses because it requires high N inputs, tends to be irrigated frequently, has a relatively shallow root system, and is a high value crop. There is also a tendency to add excess nitrogen since it is apparently not harmed by excessive nitrogen.

Although several broccoli field research projects have been conducted over the years in California to investigate fertilizer timing and amounts, only a few have been grower directed and none have investigated the movement of nitrate from nitrogen fertilizer applications performed under San Joaquin Valley growing conditions. Broccoli is a cool-season vegetable that grows well year round in California's coastal valleys, but the weather conditions in the interior valleys are more extreme and severely affect produce quality and yields.

Broccoli production in the San Joaquin Valley is aimed at fall and spring markets with some growers attempting to hit the winter market. Fall harvested broccoli is planted in August and must tolerate hot temperatures above 95°F favoring rapid vegetative growth and head formation, and cold temperatures (30s at night) at the time of head maturation. For the spring market, broccoli is planted in fall and must tolerate cold, damp conditions which slows vegetative growth, and during head formation when nitrogen demand is high, the weather is extremely variable.

OBJECTIVES

1. To determine nitrogen fertilizer best management practices (BMPs) for broccoli production in the San Joaquin Valley

2. To determine if BMPs change for fall versus spring harvested broccoli
3. To identify nitrate movement and potential nitrate leaching losses of applied nitrogen fertilizer under furrow irrigation
4. To evaluate the effectiveness and utility of the Cardy meter for quick test nitrate values for decision making in broccoli nitrogen management during fall and spring growing seasons.

DESCRIPTION

Two broccoli nitrogen fertilizer field tests, one targeting a spring harvest and another targeting a fall harvest, will be planted each year. Seven nitrogen rates and three application timings (for a total of thirteen nitrogen treatments) will focus on nitrogen needs and response by the crop, and investigate nitrate leaching. Seven treatments use low nitrogen levels at preplant and first sidedress with higher rates applied as a second sidedress application.

Data measurements include sampling petioles and whole plants at key stages of broccoli production: thinning, rapid vegetative growth, button formation, preharvest and postharvest. Samples will be subject to laboratory analysis and nitrate quick testing. Results from the lab will be correlated to the quick test. Soils sampled to a depth of 59" (150 cm) will be collected before planting, during rapid vegetative growth, and at harvest. They will be sent to the lab for nitrate analysis. Ion exchange resin bags will be buried at two depths (45 cm/18" and 90 cm/35") prior to seeding and removed after harvest to investigate nitrate movement through the soil profile. Yield and quality characteristics are being assessed.

1995 SPRING BROCCOLI FIELD STUDY #1:

A spring broccoli study was direct seeded on November 20, 1995, and harvested for yield on March 11 and 14, 1996 (129 and 132 days after seeding), at the UC Westside Research and Extension Center in Five Points. Thirteen nitrogen treatments of preplant and single sidedress applications were used and are outlined below (Table 1). The initial plan called for two sidedress applications; however, winter weather kept the field too wet for machinery access, so only one sidedress application was made.

Table 1. Nitrogen treatments

Treatment Code	Pounds nitrogen per acre		
	Preplant	Sidedress	Total
1	0	0	0
2	15	15	30
3	30	30	60
4	45	45	90
5	60	60	120
6	75	75	150
7	90	90	180
8	90	90	180
9	180	—	180
10	—	180	180
11	240	—	240
12	—	240	240
13	80	80	160

Soil samples were collected from each plot prior to planting and postharvest. Samples were collected at five depths, 30, 60, 90, 120, and 150 cm, and potassium chloride extracts of each sample were sent to the UC Davis DANR Laboratory for nitrate content analysis. Prior to planting, two small resin bags were buried in eight of the 13 treatments at a 45 and 90 cm depth. The purpose of the resin bags is to collect nitrate from the soil water solution as it passes through the soil profile to determine if nitrate is being leached past the crop root zone and how much is being leached.

Broccoli petiole samples were collected at thinning and when heads were 1 to 3 and 3 to 6 inches in diameter. Fresh petiole sap was tested for nitrate with the Cardy ion meter, and dry petiole samples were sent to the UC DANR Lab for nitrate content analysis.

RESULTS

For the purpose of this study, a field low in residual soil nitrogen content was selected. Crop history was beans, fallow, and barley (with no supplemental fertilizer). Soil samples collected from the field two months prior to planting indicated that soil nitrate levels were low enough that a nitrogen response by a crop would occur. Visual observations of the field during the winter growing period showed only subtle differences between plots (e.g., color, height, vigor) with respect to nitrogen.

Yield results are presented in Table 2. Yields ranged from a high of 8.93 to a low of 6.13 tons per acre. In general, yields increased as the amount of preplant nitrogen increased. The highest yield was obtained with the highest rate of nitrogen applied preplant (240 lbs N/acre); however, this was not significantly different from 150 and 180 lbs nitrogen. Yield decreases were observed when all nitrogen was sidedressed and none was applied preplant. Individual head weight followed a similar trend; as preplant nitrogen increased, so did head weight. The number of heads harvested from each plot ranged from 48 to 58 heads.

Table 2. Yield Results: 1995 spring broccoli x N-rate and thinning

Code	N lbs/Acre preplant		sidedress		total	Tons/Acre	Lbs/Head	Heads/Plot
1	0	+	0	=	0	6.13 e	.33 f	56.25 ab
2	15	+	15	=	30	7.41 bcd	.41 cde	55.00 abc
3	30	+	30	=	60	7.40 bcd	.42 cde	53.25 abc
4	45	+	45	=	90	7.24 cde	.42 bcde	52.50 abc
5	60	+	60	=	120	7.13 cde	.45 abcd	48.75 c
6	75	+	75	=	150	7.73 abcd	.48 ab	49.50 ab
7	90	+	90	=	180	8.16 abc	.44 abcde	56.50 ab
Average						**7.31**	**.42**	**53.11**
LSD .05						**1.26**	**.06**	**7.47**
CV%						**11.44**	**9.57**	**9.56**
13	80	+	80	=	160	8.16 abc	.45 abcd	55.50 abc
7	90	+	90	=	180	8.16 abc	.44 abcde	56.50 ab
8	90	+	90	=	180	8.63 ab	.49 a	53.25 abc
9	180	+	0	=	180	8.52 ab	.46 abc	56.50 ab
10	0	+	80	=	180	6.83 cd	.38 ef	54.75 abc
Average						**8.03**	**.44**	55.25
11	240	+	0	=	240	8.93 a	.48 ab	57.75 a
12	0	+	240	=	240	7.73 abcd	.40 de	58.75 a
Average						**8.33**	**.44**	58.25
Grand Mean						**7.69**	**.43**	**54.48**

Dry petiole nitrate content is presented in Table 3. Nitrate content in petioles decreased from an average of 23,916 to 9501 to 3401 ppm as the season progressed. At thinning, nitrate ranged from 22,880 to 25,130 ppm, and the treatments that were the lowest were the two that had no preplant nitrogen applied. When broccoli heads had reached 1" to 3" diameter, nitrate ranged from 3728 ppm in the check plot (no nitrogen applied) to a high of 12,775 ppm in the 90 + 90 lbs N/acre treatment. Higher rates than 180 lbs N/acre did not lead to higher nitrate levels in the petioles. At harvest, nitrate content in petioles ranged from 55 to 6875 ppm nitrate. The highest level was found in treatment 12 when 240 lbs N/acre were applied as a sidedress application (this did not equate to the highest yield).

It should be emphasized that these are preliminary results from one field study. Data from several similar studies will be averaged before best nitrogen management practices are discussed. It is expected that nitrogen management will be different for spring versus fall harvested broccoli crops in the San Joaquin Valley because of large differences in soil and air temperatures which have an effect on the mineralization of nitrogen in the soil.

Table 3. 1995 Spring Broccoli x N-Rate and Timing Dry Petioles NO_3-N ppm (lab analysis)

Code	Treatment	12/20/95 Thinning	2/26/96 1"-3" diam.	3/14/96 3"-6" diam.
1	0+0	22,880 b	3728 f	55 g
3	30+30	24,900 ab	8240 e	869 fg
4	45+45	23,350 ab	8325 e	1930 ef
5	60+60	23,800 ab	9442 de	2877 de
7	90+90	23,800 ab	12,775 a	5270 b
13	80+80	23,700 ab	10.982 bc	3792 b
8	90+90	24,530 ab	11,775 ab	4200 bc
11	240+0	25,130 a	10.055 cd	4855 bc
12	0+240	23,150 b	10,187 cd	6875 a
Average		**23916**	**9501**	**3414**
LSD .05		2055	1241	1263
CV%		6	8.95	25.34

Planted 11/20/95, Harvested 3/11-15/96

EFFECTS OF IRRIGATION NONUNIFORMITY ON NITROGEN AND WATER USE EFFICIENCIES IN SHALLOW-ROOTED VEGETABLE CROPPING SYSTEMS

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OBJECTIVES

The objectives of this research are to evaluate the effectiveness of standard and alternative sprinkler lateral spacings on water and fertilizer use efficiency in commercial carrot production fields in the Southern San Joaquin Valley and to adapt existing computer simulation models to carrot production. This will allow us to assess the environmental and economic consequences of irrigation water and nitrogen fertilizer management under conventional and alternative sprinkler irrigation systems.

DESCRIPTION

The Southern San Joaquin Valley is a major production area for a number of high value vegetable crops including carrots and potatoes. Intensive sprinkler irrigation and fertilization practices are increasingly being used to achieve high levels of productivity in these crops. Most sprinkler irrigation systems commonly used in carrot and potato production systems are based on 45' by 30' spacings that have average distribution uniformities (DU's) of about 66%. The practical impact of such DU's is that significant portions of a field will be overirrigated while 12.5% or more of the field may be underirrigated.

Because both carrots and potatoes are shallow-rooted crops, typically grown on coarse soils, and with relatively high nitrogen fertilizer inputs, there may be significant potential in such cropping systems for NO_3 leaching losses and resulting groundwater quality degradation, as well as reductions in yields and product quality. Decreasing lateral spacing from 45' to 35' in sprinkler irrigation systems may increase field-measured DU's by more than 20%. Such improvements, however, typically increase the capital cost of sprinkler systems by 30 to 40%, or roughly $130/acre/year. Information on alternatives for improving water and nitrogen use efficiencies in these systems is critical for the development of best management practices for economically viable production, resource conservation and environmental preservation.

RESULTS

Preliminary results for the first year of this project are presented here.

Table 1. Irrigation set times and uniformity characteristics*

Lateral Spacing (ft)	Irrigation Set Time (hrs)	Applied Inches per Set	Intensive Plot Yield (tons/acre)	Irrigation DU (%)	Yield DU	R^2
33.3	8.25	2.02	35.95	82.6	84.3	0.044
40.0	10	2.00	37.35	85.6	81.5	0.035
46.7	12	2.04	36.20	87.9	85.4	0.034

* Measurements were made on 4/26-28/96 with average tonnage and correlation coefficients for irrigation catchcan measurements and root yield harvested from identical grids.

IRRIGATION UNIFORMITY AND YIELD DETERMINATIONS

Irrigation mobile lab results for Kern County and many tests by the Center for Irrigation Technology at CSU Fresno show that average catchcan uniformities for sprinkler irrigation systems are typically about 70% and improve as lateral spacings decrease below 45'. Despite many tests indicating this to be the case, our trial found that of the three spacings evaluated (45', 40' and 35'), 45' lateral spacing had the best uniformity for nearly every evaluation conducted. One factor contributing to this outcome was mild wind conditions for nearly the whole season and the fact that catchcan evaluations were conducted for the entire duration of a set.

Catchcan distribution uniformity (DU) is the average of the low quarter application of a field divided by the average catch. DU's varied from 78% to 90% over the season with the 35' lateral spacing usually in the low 80's, the 45' in the upper 80's and the 40' intermediate. Table 1 gives the comparison between treatment DU's measured midseason and the corresponding DU of total root tonnage from intensively sampled plots for each treatment. Figure 1 shows the yield and quality turnout for replicated plots sampled over all blocks. Figures 2 and 3 illustrate the lack of correlation for the distribution of water and total yield for the intensively sampled 45' treatment grid.

Total applied water from planting to harvest (1/28 to 6/4/96) was 24 inches. Soil water content monitoring by neutron probe indicated some leaching of irrigation water out of the root zone and a concentration effect of the carrot leaf stems channeling water to the bed and away from the furrow. Some apparent crop coefficient values (Kc's) as high as 1.8 were documented, but this is most likely due to the concentration of water extraction in the plant row around the access tube. This was verified by water extraction differentials between the bed and adjacent furrow as recorded by continuous monitoring of soil capacitance using the Sentek EnviroScan system. This system also apparently detected extremely small amounts (0.5 mm) of leaching at the 1.5m depth as long as five days after irrigation. Preliminary results indicate that carrot growth was similar during the season in all sprinkler lateral spacings.

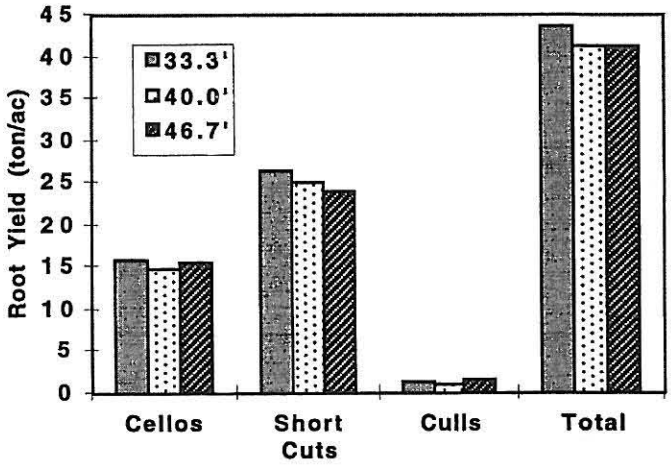

Figure 1. Root yield and packout.

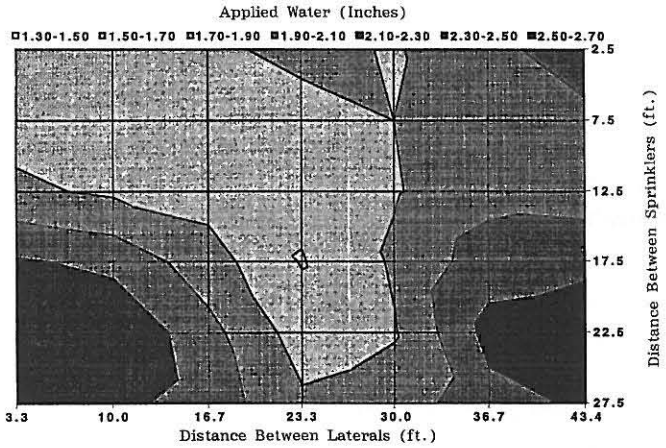

Figure 2. Contours of applied water (inches) for 12 hour set for the 46.7' lateral spacing (4/28/96).

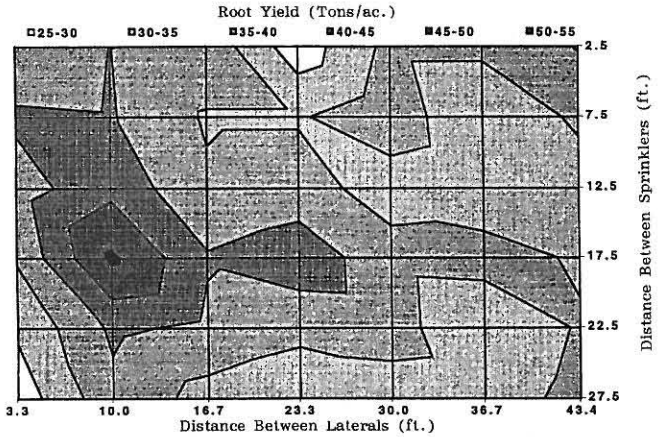

Figure 3. Contours of total root yield (tons/ac) in 46.7' lateral spacing corresponding to irrigation evaluation grid spacing.

Final statistics are still being processed but the excellent condition of the irrigation hardware used in this field, the lack of severe winds during irrigation sets and adjusted irrigation set timings based on measured DU's for each of the spacings tested, it appears that narrower lateral spacing have no effect in this trial.

NITRATE LEACHING DETERMINATIONS

Recent research has shown that ion resin bags provide a good estimate of cumulative nitrate leaching. In this study, 3 resin bags were installed at 100 cm/39" below the soil surface at "low," "medium" and "high" water application sites in each of the 12 field plots. The bags were installed in the field on February 15 about two weeks after carrot planting. They were pulled out for extracting nitrate on April 15, May 4 and June 4, respectively. Samples from the last two extractions are still under analysis. The April 15 nitrate extraction showed nitrate leaching out of the root zone (below 1 m). No statistically significant difference was found among the various sprinkler spacings.

A calibration for evaluating the efficiency of the resin bags to catch the nitrate leaching is being conducted at UC Riverside.

MODELING AND DATA ANALYSIS

The modeling effort associated with this project is aimed at extending results from this research to other soil and irrigation conditions. Currently, there is no carrot simulation model available. Our research will adapt an existing water/solute transport model and develop and incorporate a suitable carrot nitrogen uptake subroutine. A process-based, two-dimensional model is under development. The model will 1) simulate water flow and N transport and transformations in the soil root zone of a soil-plant-water system, 2) predict the dynamics of nitrate leaching, distribution of N in the soil profile, and uptake by plant under the influence of irrigation nonuniformity during the growing season, and 3) evaluate management practices . The model will be tested with the field-measured data, for example, soil water content (by neutron probe), nitrate leaching (using resin bags), nitrate distribution in the soil profile (by intensive soil sampling) and in the crop (by destructive harvests and tissue analysis). The model will consist of a number of major submodels.

SOIL HYDRAULIC PROPERTY CHARACTERIZATION

Prior to planting, undisturbed soil cores were collected in each plot to a depth of 4 feet to determine water retention curves, saturated hydraulic conductivity and textural analysis. Results from these determinations will be used in the simulation model that is being developed.

EVALUATION OF CONTROLLED RELEASE FERTILIZERS AND FERTIGATION IN STRAWBERRIES AND VEGETABLES

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INTRODUCTION

Leaching of nitrates into the groundwater is a potential hazard in the Santa Maria Valley. Strawberries and vegetable crops are grown all year and large amounts of nitrogen and other fertilizers are applied.

The use of controlled release fertilizers can significantly reduce the nitrogen leaching hazard especially during winter months.

OBJECTIVES

1. Evaluate celery, lettuce and strawberry yields and quality using different types of controlled release fertilizers at various rates in combination with standard commercial fertilizer and fertigation.
2. Monitor nutrient uptake through tissue analysis and develop baseline data for strawberries and vegetables.
3. Balance the nutrient application rate with crop requirements to establish best management practices.
4. Conduct and educational component to demonstrate to growers and agribusiness representatives the advantage of "Best Management Practices" through workshops, field days and research reports.

DESCRIPTION

Grower acceptance of new nutrient management practices need to be based on high yields that are cost effective. The relatively high cost of controlled release fertilizers has limited its use by growers. The hazard of leaching nitrogen is significantly reduced with control release fertilizers especially during winter rainfall and excessive irrigation.

The nitrogen release pattern of control release fertilizers are based on time and temperatures. The advantage of control release fertilizers is the continued availability of nutrients to the plants. The benefits of using a combination of controlled release fertilizer and fertigation is the cheaper cost and the option of adjusting the application rates to the crop requirements.

This research was conducted on commercial strawberry and vegetable fields in the Santa

Maria Valley. The controlled release fertilizers were obtained from three companies and applied with commercial fertilizer equipment.

The amount of the controlled release fertilizer used in the celery and lettuce trials was based on the grower production practices. In the strawberry field the nitrogen application rate of the three controlled release fertilizers was 80 and 160 pounds of nitrogen per acre.

RESULTS

This research is ongoing. The results of two celery trials, two lettuce trials and a strawberry trial are being completed and summarized. Some of the samples collected for laboratory analysis are still being analyzed and summarized. The treatments with higher rates of the controlled release fertilizers produced the highest crop yields.

Meetings on fertilizer practices were held in January, February and September. A strawberry field day was held on May 8, 1996.

THE EFFECTS OF VARIOUS PHOSPHOROUS PLACEMENTS ON "NO-TILL" BARLEY PRODUCTION

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This two-year project is studying various subsurface phosphorous placements and their effects on the growth and yield of cereal grains grown using a no-till farming system in San Luis Obispo County. The project will use a modified Cross-Slot planting system, which can place fertilizer anywhere within a 5 inch square continuous column with the seed positioned in one upper corner.

Determining optimum phosphorous placement, along with potential yield and economic advantages in no-till farming systems, will help improve grower adoption of no-till techniques. These techniques will help reduce the loss of thousands of tons of productive soil each year from often Highly Erodible Lands sites, and significantly reduce soil pollution of surface water streams.

The project is using a randomized complete block design with six replications. Measurements of actual uptake of N and P using a "difference" method—analyzing biomass production at various growth stages, yield components, *(number of headed tillers, number of kernels per spike, kernel weight, and grain: residue ratio)*, and grain yield measurements will be taken. Prior to establishment of this experiment, baseline soil samples were gathered for determinations of: nitrogen, phosphorous, organic matter, pH, soil texture, potassium, and sulfur.

Since phosphorous and nitrogen can be independently placed, the above configuration lends itself easily to a series of eighteen treatments with seed being placed in the same position in each plot (1.5" to 2.0" deep). The treatments are as follows:

Treatment #	P location**	N location**	Treatment #	P location**	N location**
1	0*	0	10	0	4
2	0	2	11	1	4
3	2	0	12	2	4
4	3	0	13	3	4
5	1	2	14	4	4
6	2	2	15	5	4
7	3	2	16	1	1
8	4	2	17	3	3
9	5	2	18	5	5

*0 = No fertilizer application
** 1 close proximity to the seed, but with a soil barrier between seed and fertilizer
2 2.5" directly below the seed
3 2.5" below and 2.5" to the side of the seed
4 5.0" below and 2.5" to the side of the seed
5 5.0" below and 5.0" to the side of the seed

RESULTS AND DISCUSSION

Planting was delayed until the last day of February 1995. While this planting date is somewhat beyond the optimal planting dates, it did not pose undue problems since rainfall continued at a normal pace for the remainder of the season.

Unforeseen space limitations caused a reduction in the number of replications in the trial from six to four, and an equipment malfunction caused treatment # 6 to be repeated and treatment # 3 eliminated.

Because the late planting date caused a compression of growth stages, plant samples were collected from the elongation and anthesis growth stages only. (Original project plans called for the data gathered to include biomass production at elongation, boot, anthesis, and ripeness.) Grain yield and yield component data were also not collected due to destruction of the site by a unexpected invasion of ground squirrels. However, valid data was collected for biomass accumulation and N and P uptake through anthesis growth stage.

It was possible to infer how much of the P taken up by barley plants came from fertilizer P by using a difference method. P uptake from the unfertilized plots was compared to each of the P placement treatments. Any P taken up by the plants in excess of the unfertilized treatments could thus be attributed to fertilizer. Since all P fertilized plots received the identical rate of P differences in uptake between treatments can be attributed to placement effect.

Analysis of the data (ANOVA) indicated that there were significant treatment effects in both dry matter production and in P uptake for this study. Overall indications would seem to imply that there are a number of possible placement combinations that are capable of generating superior growth and/or P uptake. Some of the placement combinations (a depth greater than 2.5 inches), however, would not likely be economical in practice due to excessive horsepower requirements and equipment wear.

There were treatment effects which are difficult, if not impossible, to explain in this study. Treatment # 2 (N 2.5" below/2.5" to the side) seemed to perform exceptionally and inexplicably well. Treatment # 7 (N 2.5" below/ 2.5" side; P 5.0" below. 5.0" side) likewise performed exceptionally in terms of P uptake.

By analyzing a subset of the data, made up of the most practical and most likely placements, it is possible to demonstrate more clearly that there are insignificant differences attributable to P fertilizer placement in relation to crop seeds. Both dry matter and P uptake were significantly affected at the late tillering growth stage by P fertilizer placement position (1% level).

Table 1: Barley dry matter production and P uptake at late tillering and anthesis for selected treatments

Treatment #	Dry Matter Production Late Tillering (lbs/acre)	P Uptake Late Tillering (lbs/acre)	Dry Matter Production Anthesis (lbs/acre)	P Uptake Anthesis (lbs/acre)
1	378	2.08	1,982	10.90
3	821	4.52	3,112	19.58
4	864	4.57	3,604	20.46
14	654	3.78	2,389	13.14
15	639	3.60	2,851	14.25

Dry matter production at late tillering for treatments 3 and 4 were significantly higher than treatments 14 and 15. Both treatment 14 and 15 produced significantly more dry matter than treatment 1. At the late tillering growth stage, P uptake for treatments 4, 3. and 14 was significantly higher than treatments 15 and 1.

By anthesis, dry matter production from treatment 4 was significantly greater than for treatments 14, 15, and 1, but not treatment 3. P uptake at anthesis indicated a significant increase in uptake for treatments 4 and 3 over treatments 15, 14, and 1.

It appears that placing N directly with the seed decreased dry matter production at both late tillering and anthesis growth stages. By anthesis, differences in dry matter production were becoming less clear-cut, while P uptake differences were becoming more defined.

This study will continue for another year.

IV. COMPLETED PROJECTS

The following is a list of projects completed prior to October 1995. Summaries of these projects appear in the 1995 FREP Conference Proceedings, final reports are available by calling FREP or ordering through FREP's Resource Guide.

Fruit and Nut Crops

Development of Diagnostic Measures of Tree Nitrogen Status to Optimize Nitrogen Fertilizer Use—Patrick Brown

Citrus Growers Can Reduce Nitrate Ground Water Pollution and Increase Profits by Using Foliar Urea Fertilization—Carol J. Lovatt

Crop Management for Efficient Potassium Use and Optimum Winegrape Quality—Mark A. Matthews

Potential Nitrate Movement below the Root Zone in Drip Irrigated Almonds—Roland D. Meyer

Field Evaluation of Water and Nitrate Flux through the Root Zone in a Drip/Trickle Irrigated Vineyard—Donald W. Grimes

Influence of Irrigation Management on Nitrogen Use Efficiency, Nitrate Movement and Ground Water Quality in a Peach Orchard—Scott Johnson

Nitrogen Efficiency in Drip Irrigated Almonds—Robert J. Zasoski

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

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

Educational Videos

Best Management Practices (BMPs) for Nitrogen and Water Use in Irrigated Agriculture: A Video—Larry Klaas and Thomas Doerge

Drip Irrigation and Nitrogen Fertigation Management for California Vegetable Growers Videotape—Timothy K. Hartz

Nutrient Recommendation Training in Urban Markets: A Video
—Wendy Jenks and Larry Klaas

EFFECTS OF FOUR LEVELS OF APPLIED NITROGEN ON THREE FUNGAL DISEASES OF ALMOND TREES

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Nitrogen nutrition is known to affect the amount and severity of some plant diseases, including brown rot of peach and nectarine. Generally, increased levels of nitrogen in plant tissues is accompanied by an increase in the amount of disease. We investigated the effects of four levels of applied nitrogen (500, 250, 125 and 0 lbs nitrogen per acre) on brown rot, green fruit rot and hull rot diseases of almond trees.

OBJECTIVES

1. To determine the relationship between tree nitrogen status and the natural incidence of brown rot blossom and twig blight of almond and on infection of flowers and shoots by *M. fructicola* and *M. laxa*.
2. To determine the relationship between tree nitrogen status and infection of green fruit of almond by *B. cinerea*, *M. fructicola* and *M. laxa*.
3. To determine the relationship between tree nitrogen status and the natural incidence of hull rot of almond and on hull infection and leaf death caused by *M. fructicola* and *R. stolonifer*.

DESCRIPTION

All experiments were conducted in an orchard in Stanislaus County. Trees received 500, 250, 125 or 0 lbs nitrogen per acre for 5 consecutive years. There were four replications of each treatment.

Flower inoculation. Almond flowers are invaded by the brown rot fungi through the stamens and pistils. In 1994, Nonpareil shoots at the pink bud stage of development were covered with plastic bags for about 24 hours during application of fungicide to the orchard. These shoots were collected when most of the flowers on them were in full bloom, and returned to the laboratory where they were spray-inoculated with *M. laxa* or *M. fructicola*. The total number of stamens and the number of infected stamens were counted on 20 flowers per replication 3 days after inoculation. Percent infection was calculated from these figures.

In 1995, high humidity incubation chambers were prepared by lining the bottoms of plastic crispers with sterile river sand dampened with sterile deionized water. On 10 February, immediately before the trees were sprayed with a fungicide by the grower, 10 to 12 shoots bearing open flowers were collected from one Carmel and one Price tree in each plot and transported to the laboratory. Twenty fully-opened flowers per replication of each treatment from each cultivar were removed and placed, with stamens and pistils facing up, on the sand in the incubation chambers. Flowers were spray-inoculated with an aqueous suspension of *M. laxa* and incubated at room temperature for 3 days when the total number of stamens and the number infected stamens were counted. The experiment was repeated using Carmel flowers collected and inoculated, as above, on 15 February. Price flowers were not included in the second experiment because most were too mature to provide sufficient samples from all replications.

In these experiments, percent infected stamens generally increased with increase in the amount of applied nitrogen (Table 1). Infection amounts were similar or greater in the two highest rates of applied nitrogen (500 and 250 lbs per acre) compared to the two lower rates (125 and 0 lbs nitrogen per acre). The inoculation in 1994 and the first inoculation in 1995 were performed on flowers that were not treated with fungicide; flowers in the second inoculation in 1995 had been sprayed with fungicide by the grower five days prior to inoculation. Despite fungicide treatment, infection was greatest in the two higher nitrogen treatments, and least where no nitrogen was added. Stamen infection was generally greater on the second than the first inoculation in 1995. Although the flowers appeared to be healthy, in full bloom and with intact petals on both inoculation dates, perhaps the flowers on the second date were nonetheless older and more susceptible to infection. *M. fructicola* was much less pathogenic than was *M. laxa*.

Shoot infection. Four 2- or 3-yr-old shoots on one Nonpareil and one Carmel tree per replication were inoculated with *M. laxa* and *M. fructicola* on 10 May 1994. Small pieces of agar cultures of each pathogen were inserted under bark flaps about 0.5 inch wide, and wrapped with tape for 7 days. Canker length was measured on 20 June 1994. There were no significant differences among the nitrogen treatments in the length of lesions on Nonpareil trees or on Carmel trees inoculated with *M. laxa* (Table 2). The significant differences found in Carmel trees inoculated with *M. fructicola* did not reflect the nitrogen treatments.

Table 1. Effect of four levels of applied nitrogen on infection of almond flowers by *Monilinia laxa*, Stanislaus County.

	Infected stamens, %[y]				
	M. laxa			M. fructicola	
Nitrogen, lbs/acre	Nonpareil 4 Mar 94	Carmel 10 Feb 95	Carmel 15 Feb 95	Price 10 Feb 95	Nonpareil 4 Mar 94
500	15.1 a[z]	9.5 a	68.4 a	5.3 ab	5.5 a
250	14.6 a	9.2 a	68.9 a	7.3 a	0.2 b
125	8.2 b	5.2 b	51.9 b	3.6 b	0.2 b
0	7.5 b	4.7 b	36.3 c	4.5 b	0.0 b

[y] Twenty-five flowers per replication, inoculated within 4 hours of collection. Number infected and total stamens counted three days after inoculation.

[z] Means followed by the same letter do not differ significantly according to Duncan's multiple range test, P = 0.05.

Table 2. Effect of four levels of applied nitrogen on lesion length of cv Nonpareil and Carmel shoots inoculated with *Monilinia laxa* and *M. fructicola*.

	Average lesion length, cm[y]			
	M. laxa		*M. fructicola*	
Nitrogen, lbs/acre	Nonpareil	Carmel	Nonpareil	Carmel
500	11.1	11.7	10.4	10.5 ab[z]
250	9.0	9.9	9.1	7.5 a
125	11.6	9.6	10.9	12.9 b
0	8.8	9.3	10.2	9.8 ab
	NS	NS	NS	

[y] Four 2-or-3-yr-old shoots per replication inoculated 10 May and lesion length measured 20 June 1994.

[z] Means followed by the same letter do not differ significantly according to Duncan's multiple range test, P = 0.05.

Sporodochia development. Lesions on the inoculated shoots just described were observed monthly from December 1994 through February 1995. Twenty-four naturally-infected spurs remaining from spring 1994 also were inspected. Sporodochia were not found on any inoculated shoots or the 24 naturally-infected spurs. Apparently, inoculum production was very limited in this orchard this season and we did not happen to see any.

Cast floral cups were collected from each tree and used for inoculation of green fruit. The floral cups were incubated with water suspensions of conidia of *M. laxa* or *Botrytis cinerea* for 24 hours. The incubated floral cups were then placed onto green fruit and held in place with a twistem tie. Floral cups incubated in water and similarly affixed to green fruit were used as controls. Inoculated and control fruit were covered with plastic and paper bags for 48 hours. The length of each test fruit was measured on the day the bags were removed. The floral cups and twistem ties remained throughout the experiment. Twenty fruit per replication were inoculated on 29 March and 5 April with *M. laxa* and on 7 April with *B. cinerea*, and evaluated for rot on 24 May 1995.

No significant differences were found among nitrogen treatments in green fruit rot (Table 3). Infections by *M. laxa* ranged from small, depressed lesions to rot of the entire fruit. *B. cinerea* essentially caused no rot; infection was restricted to slight discoloration of the fruit surface. In no case was leaf or shoot death observed. (The leaf and shoot death so prevalent with brown rot fruit infection in commercial orchards in 1993 and in experimental inoculations in 1994 were not observed either in our experiments or in commercial orchards during 1995.) The limited amount of infection likely is attributable to the size of the fruit when inoculated. In previous work, fruit at 15 to 25 mm in length were more susceptible. In past years, fruit was at this more susceptible stage in late March and early April. Our timing probably was late this year.

Table 3. Effect of four levels of applied nitrogen on susceptibility of young cv Nonpareil almond fruit to infection by *Monilinia laxa* and *Botrytis cinerea*.

Nitrogen, lbs/acre	Infected fruit, %[x]			Fruit length, mm[y]	
	M. laxa		*B. cinerea*		
	29 Mar	5Apr	7 Apr	29 Mar	5 & 7Apr
500	35.2	14.0	8.0	31.6	37.8
250	43.2	22.0	8.0	31.4	35.9
125	40.0	16.0	6.0	31.6	40.0
0	58.0	23.2	10.0	33.4	40.1
	NS[z]	NS	NS	NS	NS

[x] Floral cups, incubated with each pathogen were attached to green fruit and fruit covered with plastic and paper bags for 24 h. Twenty fruit per replication.
[y] Means followed by the same letter do not differ significantly according to Duncan's multiple range test, P = 0.05.
[z] NS = not significant, P = 0.05.

SUMMARY

Brown rot blossom blight appears to be affected by nitrogen treatment: higher amounts of nitrogen result in more brown rot. Furthermore, the distinct change in disease levels that occurs between the 125 and 250 lbs nitrogen treatments suggests that nitrogen amounts below 250 are most likely to aid in reducing brown rot. Inoculations of young fruit or twigs did not show this relationship and it may be that other factors overrode those of nitrogen. Nitrogen content of young fruit and shoots may have varied in ways different than those in flower tissues.

A complete report on the project is available by calling FREP or ordering through FREP's Resource Guide.

NITROGEN MANAGEMENT THROUGH ON-FARM MONITORING

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OBJECTIVES

A series of trials were conducted in drip-irrigated commercial fields near Santa Maria, with these objectives:

1. Evaluate vegetable crop productivity at reduced N application rates.
2. Document soil and plant N dynamics in cool-season vegetable production under typical coastal conditions.
3. Evaluate the accuracy, labor requirement and cost of on-farm monitoring techniques for soil and plant N status.

DESCRIPTION

Eight drip-irrigated fields in long-term vegetable rotations, representing a range of soil texture, were monitored through typical crop rotations (including broccoli, cauliflower, celery and lettuce) from summer, 1994 through fall, 1995. At the beginning of each crop in each field, 4 replicate plots were fertilized by a banded preplant application of slow-release fertilizer at 100 lbs N/acre. These plots, which also received all N applications delivered through the drip irrigation system, served as a high N "reference" treatment against which the rest of the field (designated "field management" treatment) was compared with respect to crop performance and N status of crop and soil.

An intensive program of crop and soil monitoring was initiated at crop establishment, including soil NO_3-N determination (0-12 inch depth, by an on-farm "quick test" procedure and by conventional laboratory analysis), petiole NO_3-N (by on-farm sap analysis using the Cardy nitrate-selective electrode and by conventional laboratory technique) and relative chlorophyll content (by the Minolta SPAD leaf absorbance meter). The results of these on-farm monitoring techniques, together with the visual comparison of field management and reference plots, helped guide fertility decisions.

In nearly all fields monitored, seasonal N

applications considerably lower than industry norms were used without reducing marketable yield (compared to the high N reference plots). For example, average N application for cole crops was less than 200 lbs N/acre. In only one field (fall broccoli) was yield significantly affected, the effect being a slight delay in maturity. Total plant biomass was equivalent in both N treatments in all fields, as was total N uptake; the only consistent result of the increased N rate of the reference plots was to enlarge the pool of soil NO_3-N.

A consistent seasonal pattern of soil NO_3-N levels was observed. At the start of the 1994 summer/fall season, soil NO_3-N concentration was greater than 30 parts per million in all fields; these levels were maintained throughout the season, diminishing substantially only during heavy winter rains. Despite conservative fertilization, soil NO_3-N increased throughout the spring, 1995 season. By fall 1995, NO_3-N concentration was back to levels similar to the previous year.

The microbial conversion of N to plant-available forms (called mineralization) was a significant contributor to the development and maintenance of elevated soil NO_3-N. Net mineralization rates of 1.4 to 2.2 lbs N/acre/day were estimated by various incubation techniques, similar to rates measured in other recent studies of coastal soils in vegetable rotations. Such significant mineralization rates are not surprising, given the nature and amount of crop residue in typical vegetable rotations. An annual rotation of lettuce and broccoli would return to the soil approximately 150-200 lbs N/acre in the form of succulent, high N (>3.5%) residue.

On-farm monitoring techniques, although not as accurate as conventional laboratory analysis, provided useful information in a timely and cost efficient manner. Petiole NO_3-N analysis, whether by on-farm sap analysis or laboratory analysis of dry tissue, documented that adequate plant N nutrition was maintained, but could not reliably be used to infer soil N status. Soil NO_3-N testing was required to assess soil mineral N supply. A realistic monitoring program for conventionally-irrigated vegetables would be three soil nitrate tests (before each of two sidedressings, and one 3-4 weeks from harvest) and two petiole tests (done in conjunction with the last 2 soil analyses). This would require a total of about 4 hours for sample collection, preparation and analysis, with prorated analytical costs of about $10.50. This routine work is unlikely to be performed by farm management, but rather by lower level wage labor. At $15 per hour (wages, benefits and vehicle use) total seasonal monitoring cost would be approximately $70 per 20 acre field, or about $3.50 per acre. Per acre costs for smaller fields would be correspondingly higher, as would be the case if the program was conducted by an external consultant, or if traditional laboratory analysis was used in lieu of the on-farm techniques.

In summary, this study clarifies several important points regarding efficient N management in coastal vegetable production:

a) Typical N application rates are considerably higher than required for maximum yield. In general, the excess fertilizer N does not substantially increase plant N uptake but does increase soil NO_3-N, increasing the nitrate leaching hazard.

b) Efficient N management requires increased attention to soil NO_3-N levels; adjusting N rates field-by-field, based on preplant and/or in-season soil NO_3-N analysis, is appropriate.

c) Costs of intensive crop and soil monitoring are much less than the potential savings in N fertilizer expenses. The results of this study suggest that N rate reduction of 50-100 lbs N/acre are possible for growers currently using industry average application rates. At current N prices (an average of more than $.40/lb N for the commonly used fertilizer materials), per acre savings of $20-$40 are possible.

A complete report on the project is available by calling FREP or ordering through FREP's Resource Guide.

IMPACT OF MICROBIAL PROCESSES ON CROP USE OF FERTILIZERS FROM ORGANIC AND MINERAL SOURCES

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OBJECTIVES

The primary objectives are to determine relationships among: 1) microbial biomass and activity; 2) soil fertility parameters, particularly N pools; and 3) crop yield and quality at the end of the growing season. Studies were conducted in tomato and corn plots under three different N management systems: 1) N from mineral sources only; 2) N from covercrops and manure; and 3) N from covercrops supplemented with mineral sources.

DESCRIPTION

Soil biology has traditionally been treated as a black box, with limited understanding of how to translate knowledge of soil biological processes into specific farming practices. Certain phenomena that can be managed, such as irrigation, organic inputs, and excessive levels of mineral N, have been identified as possibly impacting microbial activity and nutrient cycling; however, more analyses of these relationships are needed to translate these factors into usable farming practices.

Our long-term goal is to understand the links between microbial communities, their predators, nutrient cycling and crop productivity, and how these interactions are reflected in the economics of various farming systems. The study was carried out at the Sustainable Agriculture Farming Systems (SAFS) project which is a comparison of two- or four-year rotations (tomatoes, safflower, corn, wheat/beans) managed by four farming systems

(conventional 2- and 4-year rotations, low input and organic). Major findings for the 3-year funding period are summarized below:

1. During the growing season, soil microbial populations were usually higher in size and activity in organic and low input than conventional farming systems. In the organic-amended systems, microbial populations rapidly responded to organic additions, steadily increased until the middle of the growing season, and then declined. The decline was greater in some years than others. With the increase in microbial populations, there was usually a small associated increase in soil inorganic nitrogen. Fluctuations in microbial biomass and activity were much less in conventional than the organic-amended systems. During the growing season, soil nitrate levels were usually significantly lower in organic than conventional tomato soils, yet often significantly higher in organic than conventional corn soils. Soil nitrate levels were positively correlated with microbial biomass levels in organic tomatoes and inversely correlated with microbial biomass in conventional tomatoes.

2. The low input system (combining covercrops and mineral fertilizer) supported crop yields in corn, and usually tomatoes, that were comparable to yields in the conventional 4-year system. The organic system (combining covercrops and composted poultry manure) on the other hand, usually had lower tomato and corn yields than did the other farming systems. The lower yields in the organic system are hypothesized to be due to the inability of the manure to provide sufficient fertility during periods of major crop demand. Differences between the organic and low input tomato systems with respect to microbial biomass were usually negligible, whereas the low input system had significantly higher microbial activity than did the organic during the period of high crop demand for nitrogen in 1995. The very high carbon to nitrogen ratio of organic inputs in 1993 and a viral disease in organic and low input tomatoes in 1994 made fertility relationships difficult to interpret in these years.

3. Some differences between farming systems in soil fertility and structure appear to be related to differences in soil biology. Microbial biomass was positively correlated with water stable aggregation; water stable aggregation increased from the conventional to low input to organic system. High microbial biomass and activity, and high numbers of bacterial-feeding nematodes, may have been responsible for adequate tomato yields during one year when the carbon to nitrogen (C/N) ratio of organic inputs was higher than normal. This finding has led to spin-off studies to determine the optimum C/N ratio of organic inputs in the companion research plots of SAFS. We hope to find a C/N ratio resulting in low soil nitrate levels due to microbial immobilization while providing sufficient fertility due to release of nitrogen from microbial biomass by nematode activity.

4. Though certain soil biological parameters are enhanced in organic compared to conventional systems, the conventional soil was nevertheless very active biologically. Under controlled conditions, added covercrop residues were found to decompose at the same rate in soils managed by conventional or organic farming practices. Using a test that estimates the metabolic diversity of the microbial community (Biolog), we found no differences between the conventional and organic tomato soils.

RESULTS

Table 1 summarizes the fertility management for the conventional, low input and organic tomatoes for the 1993-1995 growing seasons.

Table 1. Fertilizer rates in tomatoes

1993	
Conventional:	6-20-20 applied as starter at 100 lbs/acre in March; fertilizer sidedress with 34-0-0 at 120 lbs/acre in May
Low-input:	Purple vetch planted in October, incorporated in April; starter fertilizer 8-24-6-1 applied at 10 gal/acre to transplants in April
Organic:	Purple vetch planted in October, incorporated in April; starter fertilizer of fish powder (12-0.25-1 at 4 lbs/acre) and seaweed (3-0.25-0.15 at 1/2 gal/acre) applied to transplants in April; turkey manure (1% N) applied at 5 t/acre in April. Topdress of fish powder (12-0.25-1 at 4 lbs/acre) and seaweed (3-0.25-0.15 at 1/2 gal/acre) applied in July
1994	
Conventional:	8-24-6 applied as starter at 15 gal/acre in March; fertilizer sidedress with 46-0-0 at 304 lbs/acre in May
Low-input:	Purple vetch planted in November, incorporated in April; starter fertilizer 8-24-6 applied at 15 gal/acre to transplants in April and sidedress with 46-0-0 applied at 150 lbs/acre in May
Organic:	Purple vetch planted in November, incorporated in April; poultry manure of 3.4% N applied at 2.15 t/acre; starter fertilizer of fish powder (12-0.25-1 at 4 lbs/acre) and seaweed (3-0.25-0.15 at 1 gal/acre) applied to transplants in April. Topdress of fish powder (12-0.25-1 at 4 lbs/acre) and seaweed (3-0.25-0.15 at 1/2 gal/acre) applied in July
1995	
Conventional:	8-24-6-0.5 Zn applied as starter at 15 gal/acre at end of March; fertilizer sidedress with 11-52-0 at 100 lbs/acre and 46-0-0 at 302 lbs/acre in mid-May
Low-input:	Purple vetch planted in October, incorporated in April; starter fertilizer 8-24-6-0.5 Zn applied at 15 gals/ac to transplants in April and sidedress with 46-0-0 at 174 lbs/acre
Organic:	Purple vetch planted in October, incorporated in April; poultry manure of 2.8% N applied at 2.66 t/acre; starter fertilizer of fish powder (12-0.25-1 at 5 lbs/acre) and seaweed (3-0.25-0.15 at 1 gal/acre) applied to transplants in April

SOIL FERTILITY

In general, nitrate levels were lower in organic than conventional tomatoes, and higher in organic than conventional corn. As an example of fertility trends, in 1994, soil nitrate levels were originally higher in conventional (approximately 20 μg/g) than in the organic and low input tomatoes (2-3 μg/g). After covercrop incorporation, nitrate levels in organic and low input rose to almost 35 μg/g by early April and then declined and held steady at about 10 μg/g for the remainder of the growing season. Even though the organic system receives manure in addition to covercrop, the differences in nitrate between the organic and low input systems were minor. In the conventional system, nitrate rose to about 40 μg/g in early April following side-dress and declined more slowly than in the other systems. By the end of the growing season, there were no differences between the systems. In corn, levels of nitrate ranged between 10 and 20 μg/g over the entire growing season. In the organic and low input systems, however, levels ranged between 20 and 65 μg/g following covercrop incorporation. By the end of the growing season, levels in the organic soils were significantly higher than in the low input and conventional soils.

MICROBIAL PARAMETERS

During the growing season, soil microbial populations were usually higher in size and activity in organic and low input than conventional farming systems. There were significant differences, however, by year. Differences between conventional and organic or low input farming systems were greater in 1994 than 1995. In 1994, differences between the conventional and organic input systems were greater during the later part of the growing season. Fluctuations in microbial biomass and activity were much less in conventional systems. Both bacterial and fungal populations were higher in organic than conventional tomato soils as measured by direct counts; however, fungi constitute a minor portion of the total microbial community compared to what has been observed in cropping systems in other studies.

There were differences by crop in the relationship between microbial populations and soil mineral nitrogen levels. Small increases in soil

Table 2. Crop yields in different farming systems

1993	Organic	Low-Input	Conventional
Tomatoes (T/acre)	28.10	32.60	26.60
Corn (T/acre)	3.87b	5.72a	4.76ab
1994	**Organic**	**Low-Input**	**Conventional**
Tomatoes (T/acre)	24.39b	27.97b	41.49a
Corn (T/acre)	6.38a	6.55a	5.16b
1995	**Organic**	**Low-Input**	**Conventional**
Tomatoes (T/acre)	28.80b	35.83a	33.66a
Corn (T/acre)	4.00b	6.19a	5.66a

(Yields followed by different letters indicate significant differences among systems at p=0.05).

inorganic nitrogen in tomato plots were associated with increases in microbial populations and generally lower nitrate levels were present in organic than conventional soils. In contrast, soil nitrate levels in corn were often higher in organic than conventional soils, and differences in microbial parameters were not as large in corn as in tomato soils. The reasons for these differences among crop types are not yet understood and are under investigation.

CROP PARAMETERS

The information presented below was funded by the USDA SARE and UC SAREP research programs but is summarized because of its relationship to this CDFA project. Yields of tomatoes were usually significantly lower in organic than conventional systems, with the exception of 1993 when yields were low throughout the county (Table 2).

Low input tomato yields usually compared favorably to conventional yields. An exception was in 1994 when transplants for the organic and low input systems contracted a whitefly vectored virus, which severely inhibited nitrogen uptake, decreasing vegetative growth and fruit yield. Organic tomato yields were usually lower than those of conventional tomatoes. For corn, low input yields were equivalent and sometimes higher than yields for conventional or organic systems. Yields of organic corn were usually lower than those of conventional corn.

Current work at the SAFS site suggests that low rates of decomposition of the composted manure used in the organic system may be partly responsible for the low yields in the organic system (Cavero et al., 1996). This observation is based on estimates of nitrogen mineralization and plant uptake of nitrogen which indicate little available nitrogen added by manure amendments. Supporting this observation is the lack of difference between organic and low input systems with respect to microbial parameters, thus indicating little additional benefit of the extra carbon associated with the manure inputs in the organic system. The hypothesis that manure is not readily decomposable is being pursued in future studies and in more detailed analysis of existing data relating microbial measurements to plant uptake of nitrogen.

RELATIONSHIP BETWEEN MICROBIAL PARAMETERS AND OTHER SOIL PROPERTIES

Soil moisture content is a significant environmental variable for soil populations. Moisture levels in the top 15 cm/6" of soil ranged between 12 and 30% in both organic and conventional systems; whereas levels in the top 5 cm/2" were consistently between 7 and 9%. Microbial populations in the conventional systems dropped considerably when irrigation was terminated late in the growing season. Correlation analyses performed on the relationships between microbial parameters and soil moisture combined from 1992 and 1993 indicated positive relationships ($p<0.0001$) between soil moisture and either MBC or MBN, but negative relationships ($p<0.0001$) with the C/N ratio of the microbial biomass, arginine ammonification, and the ratio of SIR to MBC. In both years, the soil temperature rose from approximately 15° C at the beginning of the growing season to the low 20's in organic and conventional systems. Soil temperature was inversely related ($p<0.0001$) to MBN, the ratio of SIR to MBC, and soil ammonium levels. Variations in both moisture and temperature were not as great in organic as in the conventional system.

Some of the differences between farming systems in soil fertility and soil structure appear to be related to differences in soil biology. Higher microbial biomasses are positively related to significantly higher water stable aggregation in organic compared to conventional soils. Seasonal changes in water stable aggregation corresponded directly to changes in microbial biomass (Amerkeza et al., 1996).

COMPARISON OF TECHNIQUES FOR MEASURING MICROBIAL POPULATIONS IN SOIL

A simple, yet representative, measurement of microbial populations could be useful to growers and farm advisors to help in assessment of soil fertility and changes in microbial populations due to management. Many of the methods used in this study require complex equipment and are not provided by commercial laboratories. A simple method is measurement of potentially mineralizable nitrogen (PMN). This method measures ammonium before and after incubation of soil for a 1-week period and these analyses can be performed by any soil analysis laboratory. The correlation between PMN and microbial biomass was significant at the 0.05 probability level. The relationship was stronger for the organic than conventional system, in part because there appeared to be interference by high levels of soil nitrate in some of the conventional soil samples. Nevertheless, PMN appeared to provide a meaningful and simple estimate of the size of the microbial biomass.

DIFFERENCE IN THE FUNCTIONAL CAPACITY OF ORGANIC AND CONVENTIONAL SOILS

Though certain soil biological parameters are enhanced in organic compared to conventional systems, the conventional soil was far from dead. Covercrops added to conventionally managed soil, collected at 5 different times of the year, usually decomposed at rates equivalent to those added to organic soils. Also, there was no difference in the ability of organic and conventionally managed soil to utilize a variety of carbon sources (based on Biolog analysis), thus suggesting no difference in the metabolic diversity (with respect to simple carbon sources) between the two farming systems. These findings suggest that conventionally managed soils maintain large, diverse, and active enough microbial populations to rapidly break down recently added organic material and may imply that the transition period for soil biota may be more rapid than previously thought. This hypothesis requires further testing by examining other measures of microbial process rates and diversity.

CONCLUSIONS AND RECOMMENDATIONS

We have been in consultation with the farm advisors associated with this project on the feasibility of utilizing different practices to promote microbial activity. Large variability among critical parameters (for example, high C/N ratios in organic and low input in 1993; poor tomato yields caused by a virus in organic and low input in 1994 makes it difficult to draw conclusions without additional years of field data or follow-up studies in controlled microcosms.

There is considerable interest on the part of growers and farm advisors in simple measurements that indicate microbial activity. We found a strong relationship between potentially mineralizable nitrogen by the anaerobic incubation method (the most simple-to-measure of the microbial parameters) and microbial biomass or activity. The relationship was stronger in organic than conventional system and high levels of mineral N sometimes interfered with the measurement.

There are substantial differences between tomatoes and corn in the behavior of soil fertility and microbial dynamics. It was somewhat surprising not to see the differences in microbial biomass and activity among the farming systems to be maintained across different crops.

In the rotational sequence, tomatoes follow the legumes in conventional, low input, and organic systems and these conditions may be especially favorable for microbial populations (particularly in the organic and low input system). Corn follows safflower (which follows tomatoes) and safflower does not return much to the soil in terms of organic residues. Thus, it is possible that microbial populations decline in all systems under safflower and that it takes a while for these

populations to recover. This is only speculation at this point and requires testing.

The differences in soil nitrate levels between corn and tomatoes suggests the need to rethink recommendations for optimum C/N ratios for organic inputs, at least for some crops. Differences between corn and tomatoes can be due to differences in root morphology and timing of nutrient demand. This topic warrants additional study because it implies that organic management practices need to be fine-tuned for the specific crop.

A complete report of this project is available by calling FREP or ordering through FREP's Resource Guide.

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NITROGEN FERTILIZER MANAGEMENT TO REDUCE GROUNDWATER DEGRADATION IN ALMONDS

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OBJECTIVES

1. Determination of the relationship between leaf N concentration and the rate of applied fertilizer. Assess the sensitivity of leaf N concentration to overfertilization and reassess the validity of the currently accepted leaf N critical value (i.e., the relationship between leaf N concentration and tree productivity).
2. Assess the relationship between the rate of applied fertilizer N and the recovery of isotopically–labeled N-depleted ammonium sulfate.
3. Assess the magnitude of nitrate leaching below the root zone and its relationship to fertilizer N–application rate, efficiency of fertilizer N recovery, and tree N status.
4. Estimate N usage by almond trees.
5. Refine current management guidelines for N usage which will help to maintain productivity while reducing the amount of fertilizer N leached below the root zone.

DESCRIPTION

Research plots were established in two mature almond orchards located in Salida and Ceres, both nitrate-sensitive areas of Stanislaus County.

The timeline of project activities included the following: (1990) Pretreatment collection of baseline data including soil nitrate levels, leaf N concentrations, tree yields, nitrate concentration of the irrigation water and the calculation of N application in the irrigation water; (1990-1993) Establish tree and soil N differentials as a result of differential rates of applied fertilizer N (0, 125, 250, and 500 lbs N/acre/year) and monitor tree yields, and leaf N concentrations; (1993) Apply labeled fertilizer to all treatments; (1993-1995), and monitor labeled N recovery in crop and perennial tree parts (following tree excavation) to calculate the effect of prior fertilizer N application rates on the efficiency of fertilizer N recovery.

RESULTS AND DISCUSSION

Evidence for Overfertilization

Current fertilization practices in many almond orchards favor overfertilization: the application of fertilizer nitrogen in excess of tree capacity

to utilize it. Evidence consistent with that interpretation include: a) high residual levels of nitrate in the soil, b) lack of yield response to the fertilizer applied, and c) lack of response of leaf N concentration to high fertilizer N application rates.

a) The presence of high residual levels of nitrate in the soil. These may result from the combined use of high nitrate-containing irrigation water as well as excessive application rates of fertilizer N. High application rates of fertilizer nitrogen were associated with increased residual levels of nitrate in the soil going into the winter rainy period.

b) Lack of a yield response to the fertilizer. In the four years following establishment of the fertilizer rate trial, a significant yield reduction in unfertilized trees occurred only in 1993, which was three and one-half years after the last fertilization (Table 1). The lack of significant yield reduction in unfertilized trees in three out of four years (Table 1) indicates that fertilization was not required annually to maintain productivity under the given orchard conditions. We must conclude that sufficient N was available from other sources (e.g. high nitrate irrigation water, etc.) to maintain productivity without supplemental fertilization.

c) High leaf N concentrations. Pretreatment (1990) leaf N concentrations averaged above 2.6% in both orchards (Table 2). There is no evidence that almond yields respond to fertilizer N when leaf N concentrations exceed 2.5%. Leaf N concentration appears to be insensitive to overfertilization, thus, there is virtually no difference in leaf N concentrations between trees receiving 250 lbs N/acre/year and those receiving 500 lbs N/acre/year (Table 2). This probably means that at higher levels of available soil N, tree capacity for N uptake is saturated, and additional fertilizer N accumulates in the soil and becomes vulnerable to loss–probably leaching–in coarse textured, sandy soils.

Table 1. Differential N fertilization and almond yields in two Stanislaus County orchards

Orchard	Treatment[z] (lbs N/A/Yr)	Meat Pounds Per Acre[x]				
		1990[y]	1991	1992	1993	1994
Salida	0	3508	3587 a	1470 a	1938 c	*
	125	3508	3554 a	1538 a	2735 ab	*
	250	3508	3421 a	1606 a	3120 ab	*
	500	3508	3610 a	1789 a	3710 a	*
Ceres	0	4444	1633 a	2512 a	2421 b	3967 a
	125	4444	2309 a	2542 a	2956 ab	3837a
	250	4444	1807 a	2712 a	2913 ab	3786 a
	500	4444	1919 a	2879 a	3315 a	4008 a

[z] Treatments initiated post-harvest in 1990

[y] Pretreatment yields

[x] Values sharing a common letter within columns (years) in a given orchard do not vary statistically

* Plot treated with labeled N to assess effect of tree N status on fertilizer N recovery

Table 2. Changes in leaf N concentration with rates of applied fertilizer N in two Stanislaus County orchards

Orchard	Treatment[z]	Leaf N Concentration (% dry wt.)[x]				
	(lbs N/A/Yr)	1990[y]	1991	1992	1993	1994
Salida	0	2.61	2.27c	2.13c	2.28 c	*
	125	2.61	2.34 bc	2.18 c	2.40 bc	*
	250	2.61	2.36 bc	2.24 b	2.52b	*
	500	2.61	2.42 ab	2.37 a	2.68a	*
Ceres	0	2.69	2.49 a	2.29 b	2.37 c	2.51 a
	125	2.69	2.48 a	2.30 b	2.51 b	2.64 ab
	250	2.69	2.49 a	2.44 a	2.68 a	2.75 bc
	500	2.69	2.53 a	2.49 a	2.74 a	2.82 a

[z]Treatments initiated post-harvest in 1990.
[y]Pretreatment values.
[x]Values sharing the same letter within a column (same orchard) did not differ statistically at $P<0.05$.
*Plot fertilized with labeled N to asses effect of tree N status on fertilizer N recovery.

Preliminary analyses indicate not only that almond tree productivity is N-limited when mid-summer leaf N concentration is below 2.2%, but yield may even be reduced when leaf N concentrations are between 2.2 and 2.3%. This is a higher threshold than is currently accepted. A major determinant of yield is fruit number. As flower differentiation occurs in the summer soon after diagnostic leaf sampling in July, our data suggest that leaf analysis is more predictive of the subsequent year's crop than the current year's crop. Thus, a leaf N concentration below 2.3% in July 1993 may be predictive of a reduced crop in 1994. On the basis of our data, the ideal range of leaf N concentration to both maintain yield and minimize subsequent leaching appears to be between 2.3% and 2.5% N.

Tree N status and recovery of isotopically labeled fertilizer N

Following three years (1990-1993) of differential rates of N fertilization, we selected trees (Salida orchard) varying in leaf N concentration (Table 3). Labeled ammonium sulfate was applied post-harvest (October 2, 1993), at the rate of 166 lbs N/acre/year. Trees also received 84 lbs N/acre/year (non-labeled) in April, 1994, for a combined total of 250 lbs N/acre/year. We determined total recovery of labeled N in fruit at harvest (August, 1994). Four of the trees were also excavated in February, 1995, and analyzed for labeled N content to compute total recovery of the labeled N and the influence of N fertilization rate on the percentage recovery (recovery efficiency) of the labeled N. Between 65% and 79% of the labeled N absorbed by the trees was localized in the fruit with the remainder present in the perennial tree parts (branches, trunk, roots, etc., Table 3).

Trees that were fertilized at the rate of 500 lbs N/acre/year only recovered about 20.5% of the fertilizer N applied (Table 3). In contrast, trees that received 0, 125 or 250 lbs N/acre/year recovered 30% of the labeled N applied-about 50% more. Thus, the high rates of N fertilizer application between 1990 and 1993 reduced recovery of fertilizer N in 1993-1994. The four

Table 3. Effect of tree N status and previous fertilizer application rate on labeled N recovery following a uniform post-harvest application of isotopically-labeled ammonium sulfate[z]

Tree ID	1994 Yield meat lbs/tree	Fertilization (1990 - 1993) (lbs N/A/Yr)	1993 Leaf N (% dry wt.)	Soil Nitrate N[y](ppm)	Labeled N recovery (%)		
					Fruit 8/94	Tree 2/95	Total
10-19	50.1	0	2.06	1.95	24	—	—
14-19	48.1	125	2.28	0.81	26	7	33
18-12	43.7	0	2.37	0.81	19	8	27
10-8	45.9	125	2.46	0.37	22	—	—
10-9	54.8	125	2.65	—	22	—	—
6-10	54.6	250	2.59	15.5	27	—	—
10-11	54.1	500	2.70	193.6	14	7	21
10-13	58.6	500	2.92	48.1	15	5	20

[z] 872 g labeled N per tree was applied on 2 October, 1993.

[y] mg N-NO_3 per g of oven-dried soil. Analyses based on 4 soil cores per tree between 2 and 2.5 feet deep 10 days prior to application of labeled N.

trees which previously received labeled N (October, 1993) and were selected for detailed analysis of labeled N recovery satisfied two criteria: a) trees were similarly-yielding in 1994; and b) trees differed in tree N status as determined by leaf N concentration. We have found (in other studies) that N uptake is a function of tree N demand, and, in almond, fruit growth and nut fill are important determinants of tree N demand. Therefore, since tree N demand (yield) among the trees selected (Table 3) was similar, we believe that the reduced recovery of labeled N by trees previously fertilized at the high N application rate (500 lbs N/acre/year) was a consequence of greater dilution of the labeled N in the soil. Soil nitrate concentrations (measured 10 days before application of labeled N) averaged 3 to more than 50 times higher beneath trees fertilized 5 months earlier at the highest N application rate vs. trees fertilized at the rate of 250 lbs N/acre/year or less (Table 3).

During the post-harvest and dormant periods, growth nearly ceases, and dormant trees have a greatly limited capacity for N uptake. In years of heavy rainfall, significant leaching can occur between November and March. High residual levels of nitrate in the soil after harvest may be vulnerable to leaching as winter rainfall may be anticipated within several months. Thus, a) low N uptake by trees during the post-harvest and dormant periods coupled with b) vulnerability of nitrate to leaching with the winter rains should discourage heavy post-harvest applications of fertilizer N.

Relationship of nitrate leaching to fertilizer N application rate

Ponds were created at 6 different locations in the orchard during tree dormancy (when trees were leafless) to calculate soil hydraulic conductivity. Six additional sites throughout the orchard were equipped with tensiometers,

soil solution samplers (at depths of 2, 3, 4, 5 and 6 feet), and neutron probe access tubes. Our ultimate goal was to quantify N fluxes below the root zone as a function of N fertilization rate.

A summary of the principal findings are presented below:

1. Cumulative water flux between June 1993 and June 1994 declined with depth, i.e., 397 mm water passed the 2 foot depth, 133 mm passed the 3 foot depth, 42 mm passed the 4 foot depth and 7 and 8 mm of water passed the 5 and 6 foot depths, respectively.

2. The temporal patterns of water flux and nitrate flux appeared quite similar. This was anticipated because nitrate in the soil solution is known to move freely with the advancing water front.

3. In this specific orchard site and in this particular year of record, water and nitrate flux were consistently greater at the 3 foot vs. the 5 foot depth. The bulk of the almond root system is restricted to the top 3 feet of soil in this orchard, and nitrate leached beyond that depth may become inaccessible to the tree.

4. Nitrate flux was considerably greater during the irrigation season than during the winter (Nov.-Feb.). This pattern must be considered within the context of the below-average winter rainfall (8.9 inches) during the season of record. Thus, nitrate flux below the root zone in winter is likely to be greater during years of more typical rainfall. The rainfall during the winter of 1994-1995 exceeded the long-term average rainfall by more than 50%.

We question the rationale of typical grower practice in that area. Currently, two-thirds of the annual N application is applied post-harvest in late September -early October. The accumulation of high amounts of nitrate in the soil at a time when a) tree demand for N is low, and b) tree capacity for N uptake is decreasing places that nitrate in position to be leached beyond the root zone if significant winter rainfall occurs.

Although we were not able to make definitive comparisons of nitrate flux among the four fertilizer N application rates, we can reasonably anticipate a heightened potential for leaching at the highest N application rate (500 lbs N/acre/year), if we consider the higher levels of nitrate in the soil (Table 3) and assume that water flux remains constant across treatments.

Use of bromide as an indicator of soil nitrate leaching over the dormant season. In two of the eight soil cores taken, bromide was never detected in the soil profile (data not presented). It is not known whether the lack of resolution was due to deep percolation or whether sufficient dispersion occurred so that it was present in the soil profile at levels below the limits of chemical resolution. Bromide measurements from soil cores obtained after the winter (4 March) also indicated large site-to-site variability in bromide movement within the orchard. Where bromide was detected, however, it occurred at soil depths below 40 inches. The bulk of the almond root system occurs within the top 3 feet of soil. Thus, movement of bromide (or nitrate) to soil depths below 40 inches is likely to indicate that it has leached beyond the root zone.

Loss of extractable soil N over the dormant season. Typical examples of the relative concentrations of available N in the soil (i.e., nitrate and ammonium) profile as a function of the fertilizer N application rate and time of sampling were examined. Tree roots primarily occupy the surface 3 feet of soil. The following observations appear noteworthy:

1. The amount of available N in the root zone prior to the September 28 fertilizer application was higher in the fertilized plots than the control plot even though sampling occurred 5 months after the last (April) fertilization.

2. As anticipated, the available N in the top

2-3 feet of the soil profile increased dramatically within 6 weeks after fertilization. Differences in root zone soil N between the 125 and 250 lbs N/acre/year treatments were less noteworthy than the spectacular increases detected at the highest (500 lbs N/acre/year application rate.)

3. The levels of available N in the top 3 feet of soil decreased substantially over the winter dormant season. Both the amounts and percentage decreases in available root zone N were lowest in the unfertilized control. The magnitude and percentage decrease in available N was greatest at the highest fertilizer N application rate, i.e., 90% of the available N in the root zone disappeared over the dormant period.

Although some denitrification may have occurred, the most likely explanation for the disappearance is leaching deeper in the soil profile, i.e., beyond the root zone. It would appear desirable to minimize residual nitrate in the soil overwinter to limit nitrate leaching below the root zone–ultimately to reach the groundwater. Typical grower practice in this area involves a split application of fertilizer in April (1/3) and after harvest of the latest maturing cultivars in October (2/3). Our data indicates that high application rates of fertilizer N in October results in significant quantities of residual nitrate in the soil overwinter when tree capacity of N uptake is quite limited. This period (i.e., Nov.-March) is also coincident with the period of winter rainfall and the greatest likelihood of nitrate leaching.

Nitrogen usage by almond trees

Despite the importance and size of the almond industry in California, N usage by almond trees is poorly understood. Data accumulated a decade ago indicated that about 50% of almond tree N content was replaced annually via soil N uptake. Unfortunately, trees were not excavated at that time and, therefore, annual N uptake was not calculated. In the present study, we determined both crop N removal and the N content of dormant trees (data not shown). These data indicate that fruit N removal (including hull, shell and kernel) is equivalent to 40%-50% of tree N content (average equals 46%). Our data probably underestimates tree N content because N carried to the orchard floor at leaf fall was not determined and the N content of fine roots, was underestimated because 100% recovery was not achieved. Also, root senescence and turnover, blossom and immature fruit drop, prunings, etc., may increase tree N content by a value approaching 10%. Thus, fruit N removal represents an estimated 85-90% of annual N demand in almond trees. Limited data have indicated that N carried to the orchard floor in the leaf litter represents less than 10% of the amount of N removed in the crop. Crop N removal is often considered to be equivalent to N removal in the meats. Analyses of the various fruit components, however, indicates that N removal in the kernel (meat) underestimates fruit N removal by 25-27% .

CONCLUSION

Evidence consistent with overfertilization included the following: leaf N concentrations greater than 2.5%, lack of yield response to applied fertilizer N, lack of increase in leaf N concentration at high fertilizer N application rates and a 50% reduction in the recovery of labeled fertilizer N by trees fertilized previously at the highest (500 lbs N/acre/year) rate.

Several management parameters can be used to increase recovery of applied fertilizer N. Reduce application of fertilizer N to the extent that high nitrate irrigation water supplies significant amounts of N.

Leaf N concentrations of more than 2.5% are associated with high residual levels of nitrate in the soil and fertilization should either be omitted for a season or significantly reduced in these orchards. Apply fertilizer during periods of significant N utilization of trees. Currently, available data suggests that multiple or at least split applications should be made between April and the last preharvest irrigation in July

or August. Post-harvest applications rates of fertilizer N appear inconsistent with efficient recovery of fertilizer N and are likely to contribute to groundwater pollution.

Evidence was presented suggesting that overfertilization–the application of fertilizer N in excess of tree capacity to absorb it–occurred in our experimental orchards and, similarly, is likely to be widespread throughout the almond industry of California.

The question is how to reduce fertilizer N applications without sacrificing productivity. The answer is to focus in on strategies which 1) balance tree N utilization and availability; 2) withhold fertilizer N when tree N status exceeds 2.5% N (July standard leaf sampling); and 3) be aware of plant-available N other than currently applied fertilizer N. Residual nitrate in the soil and the N contribution of high nitrate irrigation water are typical sources of plant-available N in the Central Valley of California. This alternative N supports tree growth and productivity just as effectively as fertilizer N and should be taken into consideration when developing a N budget. Thus, if 80 lbs of N is removed in the fruit and your calculations indicate that 80 lbs of N is applied with irrigation water as a result of its high nitrate concentration, the amount of fertilizer N applied should be reduced by at least 80 lbs per acre.

A complete report of this project is available by calling FREP or ordering through FREP's Resource Guide.

BEST MANAGEMENT PRACTICES FOR TREE FRUITS AND NUTS PRODUCTION: A VIDEO

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California tree fruit and nut production represents more than 90% of the total U.S. production of these crops, and brings more than $5 billion annually to the state's economy. Steadily improving yields are attributable in part to increased use of nitrogen fertilizers. Under irrigated conditions repeated application of excessive N to tree fruit and nut crops increases the danger of groundwater pollution by nitrates. Research has shown a growing number of nitrate "hot spots" in several of California's nitrate-sensitive areas, including portions of the San Joaquin and Sacramento Valleys, where vast acreage of tree fruit and nut crops are grown. Excessive N use can also have negative agro-economic impacts, including poor fruit quality, excessive vigor and shading, limb breakage, and reduced profits. The combination of potential negative agronomic, economic, and environmental impacts from excessive N use represents a compound problem for California's tree fruit and nut industry, as well as citizens of the state.

The goal of this project was to produce a 20-to-30 minute broadcast quality educational videotape, with an accompanying handbook, showing tree fruit and nut growers how to manage N to maximize yield, while minimizing the potential for ground water pollution by nitrates.

Expected release date for the video is December, 1996.
To order, contact FREP at (916) 653-5340.

V. NEW PROJECTS

EVALUATION OF PRE-SIDEDRESS SOIL NITRATE TESTING TO DETERMINE N REQUIREMENTS OF COOL-SEASON VEGETABLES

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OBJECTIVES

1. Evaluate the use of pre-sidedress soil nitrate testing (PSNT) to estimate sidedress N requirements in cool-season vegetables, and establish threshold values for soil NO_3-N.
2. Document the accuracy of an on-farm soil "quick test" for NO_3-N.
3. Survey commercial fields in the Salinas and Santa Maria Valleys to determine the range of soil NO_3-N concentrations common during lettuce production.
4. Conduct outreach efforts to disseminate the results.

DESCRIPTION

It is generally acknowledged that intensive vegetable production as practiced along California's central coast is a significant contribution to nitrate pollution of groundwater; the Salinas Valley, Santa Maria Valley and the Oxnard plain are all considered to be nitrate-sensitive areas. Past cropping history and the mild Mediterranean climate have resulted in the development of soils that are extremely active in nitrogen cycling. Large soil mineral N pools and rapid N mineralization have been reported by several researchers. In a recently completed study, the Project Leader showed that, in many fields, N application rates could be reduced as much as 30% below industry averages without reducing crop yield, quality, or crop N accumulation. Despite conservative fertilization, high soil NO_3-N concentrations (generally greater than 30 PPM) were maintained throughout the cropping season.

Early-season soil NO_3-N testing would help growers more accurately determine field-specific sidedress N requirements. This approach has been researched extensively in the Midwest for corn production. Called the pre-sidedress soil nitrate test (PSNT), it is now in widespread commercial use. This project proposes to adapt the PSNT technique to coastal vegetable production, and to refine a simple analytical technique for on-farm soil NO_3-N analysis.

In coastal vegetable production, the majority of seasonal N is applied in one to three sidedress applications. Evaluation of root zone soil NO_3-N immediately after crop establishment could provide an objective measure of sidedress N

requirement. Combined with several site-specific factors (soil texture and organic matter, previous crop, NO_3-N content of irrigation water), in-season soil NO_3-N analysis should allow growers to identify fields where sidedress N application could be scaled back without endangering crop productivity.

An initial test of this approach was conducted in a commercial, furrow-irrigated lettuce field in Guadalupe in the fall of 1995, by personnel from the Cachuma Resource Conservation District. On the strength of pre-sidedressing soil NO_3-N concentration of greater than 25 ppm, replicated plots were established in which sidedress N application was eliminated; the rest of the field received a total of 180 lbs N/acre (200 kg N/ha) in two sidedress applications, a typical usage rate. At harvest there were no differences in percent marketable plants or mean head weight between the N treatments.

METHODS

The first year of the project will be conducted on Betteravia Farms of Santa Maria. Working with the farm management, eight commercial vegetable fields will be identified, representing a range of soil types and crop rotations, to be planted into a common cool-season crop (broccoli, cauliflower, celery, lettuce). Planting dates will be staggered from late winter through August. All fields will be conventionally irrigated (sprinkler/furrow). Four 4-row plots (100 m long) will be selected to receive a reduced N regime, one plot in each quadrant of the field. These plots will not receive the first sidedress N application. At the second sidedress application, each reduced fertility plot will be split, with half receiving the sidedressing, half remaining unfertilized; thus, there will be replicated plots of 3 levels of N fertility.

To document soil N dynamics, composite soil samples (5-30 cm/1"-2" depth) will be collected prior to each sidedress N applications, at mid-season, and at harvest. These samples will be extracted in 2N KCI and analyzed for mineral N content (NO_3-N and NH_4-N) by conventional laboratory techniques. The samples will also be analyzed for NO_3-N concentration by the "quick test" technique by farm personnel. The technique will be modified, based on the experience gained in prior use. Those changes include: increasing the dilution ratio from 1:2 (soil:extractant) to 1:4, utilizing an inexpensive, hand-held meter to electronically read the color of the NO_3 test strips, and empirically adjusting results based on estimated soil moisture. The results will be compared with laboratory analysis of paired samples to document the accuracy of this procedure as an on-farm diagnostic.

At heading stage and at harvest plant sampling will be conducted to determine:

- petiole or midrib NO_3-N concentration
- total plant biomass
- whole plant total N content

At commercial harvest stage the plots will be harvested by a commercial crew and evaluated for percent marketable heads, mean head weight, and quality criteria suggested by the grower. Cost/benefit analysis will be calculated, evaluating the costs of crop and soil monitoring and the fertilizer cost savings achieved.

In the second year of the study similar field trials will be conducted in the Salinas Valley through cooperating commercial growers. In both years a survey of commercial vegetable fields (15 per year) will be conducted in both the Salinas and Santa Maria Valleys to document the typical concentration of mineral N present at plant establishment and at harvest. Sampling will be done by quadrants to determine the degree of field variability present. For all fields (including those used for the N rate studies) soil samples will also be analyzed for soil texture, organic matter content and total organic N. Additionally, potentially mineralizable N (PMN) will be assayed by anaerobic incubation. This information will aid in the development of a practical N management plan, and should help assess the degree to which N usage could be reduced industry-wide.

ON-FARM DEMONSTRATION AND EDUCATION TO IMPROVE FERTILIZER MANAGEMENT

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Nitrate levels in the ground water basin of the Salinas Valley have been increasing, and agricultural fertilizers have been identified as a primary source of this contamination. As part of its water quality planning program, the Monterey County Water Resources Agency (MCWRA) has led a coordinated research, pilot and demonstration, and outreach effort to reduce nitrate leaching through improvements to irrigation efficiency and fertilizer management.

This two-year project will demonstrate the use of soil and plant tissue "quick tests" which determine sufficiency of nitrogen fertilization. These tests have the ability to let growers more closely monitor the nitrogen status of their crops. Some growers have begun to use the quick tests, but so far there has not been widespread adoption due to 1) growers skepticism regarding their accuracy, reliability and credibility; 2) lack of time and training to supervise or perform such analyses; 3) uncertainty of costs and benefits of such fertility management programs; and 4) uncertainty about how to interpret and utilize their results.

The project will be conducted in two growers' fields per year (one conventionally irrigated, one drip irrigated). Four field days will also be held each year.

PRACTICAL IRRIGATION MANAGEMENT AND EQUIPMENT MAINTENANCE WORKSHOPS

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The objective of this two-year project is to develop and conduct a series of irrigation and fertigation workshops throughout the Salinas Valley. The two-three hour workshops will address technical issues geared towards growers and other agricultural professionals, as well as less technical issues geared towards the irrigators and irrigation foremen. At least nine workshops will be held per year (six on practical sprinkler irrigation management, two on fertigation, and one on drip irrigation filter maintenance). The workshops will include a professional evaluation.

The goal of the workshops is to further the understanding of factors that limit irrigation system performance, so that irrigation systems and fertilizer use is improved, and nitrate leaching is decreased.

FERTILIZER USE EFFICIENCY AND INFLUENCE OF ROOTSTOCKS ON UPTAKE AND ACCUMULATION OF NUTRIENTS IN WINE GRAPES GROWN IN THE COASTAL VALLEYS OF CALIFORNIA

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There are approximately 702,000 acres of grapevines grown in California, with 42% of that acreage devoted to wine grape production. Presently, the most rapidly growing segment of the wine industry is the sale of premium wine. The majority of grapes used to produce premium wine are grown in the coastal valleys of California. Unfortunately, a large portion of the vineyards in those areas are having to be replanted on rootstocks resistant to *Phylloxera*, a root feeding louse. Most of the fertilization recommendations for grapevines in California were developed for vines growing in the San Joaquin Valley on their own roots. Thus, there is an urgent need to develop fertilization recommendations for premium wine grape cultivars grown on different rootstocks in the coastal areas of California.

The goal of this three-year project is to determine fertilizer use efficiency of premium winegrapes using ^{15}N labeled fertilizer in four different vineyards (two Chardonnay and two Cabernet Sauvignon vineyards) growing on different rootstocks. In addition, nitrogen and potassium budgets will be determined on these vines and compared to more conventional means (petiole analysis at bloom time) to determine vine nutritional status. Project sites will be located in Napa, Monterey and San Luis Obispo Counties. Data obtained from this study will be passed onto county Farm Advisors and utilized by those in the grape industry.

DEVELOPMENT OF A NITROGEN FERTILIZER RECOMMENDATION MODEL FOR CALIFORNIA ALMOND ORCHARDS

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Nitrate pollution of groundwater can often be traced back to excessive N fertilizer applications in agriculture. Overfertilization in almond orchards is attributed to the lack of reliable tools for measuring tree N status, tree N demand and soil N availability.

The purpose of this three–year project is to provide better tools for distinguishing between fertilizer applications that are essential and those that are excessive. The project will provide guidance to growers on when and how much N fertilizer should be applied to obtain optimum yield, while minimizing the potential pollution to the environment. The specific objectives of this proposal are 1) to conduct field validation of leaf nitrate analysis in almonds; 2) to develop an "on-site" testing protocol; 3) to determine seasonal and total N demand in almonds; and 4) to develop a grower used PC-based site-specific N management program.

This project will provide field validation of nutrient testing in almonds in Stanislaus, Fresno and Merced Counties and will address the problem of on-site NO_3 analysis. These will provide a more precise method of N determination throughout the year. Incorporating results of this project into a simple program or worksheet will allow the precision management of N in almonds. This should allow optimum yield to be attained while ensuring minimum N overfertilization.

IMPROVING THE FERTILIZATION PRACTICES OF SOUTHEAST ASIANS IN FRESNO AND TULARE COUNTIES

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In the last two decades, the Southern San Joaquin Valley has seen an increase in the number of small farmers from Southeast Asia, with the greatest representation from Hmong and Laotian peoples. These farmers in Fresno and Tulare Counties grow a multitude of specialty vegetable crops but have only a limited understanding of fertilizer basics. They often lack understanding of plant nutritional requirements, fertilizer analysis, nitrogen types, fertilizer movement in soils, or timing of applications. Additionally, most speak limited English, and require translation of agricultural terms.

The goal of this two-year project is to provide culturally appropriate field trainings and demonstrations, in an appropriate way, to educate Hmong and Lao farmers in plant nutrition and fertilizer practices. A survey of the participants understanding and application of fertilization practices will be administered prior to the workshops and at project completion. Success of the field trainings will be determined by any improvement or differences in pre/post test survey responses, and observed changes by the investigators.

SURVEY OF CHANGES IN IRRIGATION METHODS AND FERTILIZER MANAGEMENT PRACTICES IN CALIFORNIA

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Quantitative, current, and geographically extensive data describing transitions in irrigation and associated fertilization practices being used in California agriculture are not available. The specific objectives of this project are to:

1) conduct a survey of farmers; 2) identify the crops and geographic regions where most change in irrigation and fertilization methods have occurred; and 3) make resulting information and analyses available to survey participants, resource management agencies, and the general public. The California Farm Bureau will cooperate in administering the survey.

The results of this survey may prompt farmers to consider whether to adopt certain irrigation technologies to optimize water use, fertilizer application methods, and crop production methods. Results will confirm trends towards different irrigation and fertilization methods within commodity groups and geographic regions. This project will test a new protocol for gathering agricultural information, to be refined and potentially repeated at regular intervals.

MINIMIZING FERTILIZER AND IRRIGATION INPUT DURING PRODUCTION OF CONTAINERIZED WOODY ORNAMENTALS

Project Leader:
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California's nursery industry is the largest in the nation and accounted for $1.8 billion in cash receipts for nursery products in 1994. The majority of nursery production occurs in the coastal counties between San Diego and San Francisco. In many of these areas, nitrate concentrations in wells for drinking water were reported to exceed the federal standards. All agricultural businesses are urged to use nitrogen judiciously in order to prevent further deterioration of groundwater quality. Much variability in N use in the production of containerized woody ornamental plants and leaching losses through runoff are reported in the literature. Many factors such as the type and rate of fertilizer applied, the amount of irrigation, frequency, and method of irrigation application affect N leaching and plant growth.

The overall objective of this three-year research effort is to establish guidelines for minimum fertilizer and irrigation input during nursery production of containerized woody ornamentals. Three woody ornamental plant species, a light, medium, and a heavy feeder, will be grown under five fertilizer regimes in Riverside County. Fertilizer will be applied either as controlled-release (CRF), liquid (LF), or a combination of both. Results of this research will be disseminated through publications, lectures, workshops, and demonstrations. Nursery growers, the fertilizer industry, educators, consultants, and students are the primary target for this information.

MANAGEMENT OF NITROGEN FERTILIZATION IN SUDANGRASS FOR OPTIMUM PRODUCTION, FORAGE QUALITY, AND ENVIRONMENTAL PROTECTION

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Sudangrass hay contributes over 50 million dollars annually to the export balance of California, and its importance has increased in recent years. Large quantities of N fertilizers are used annually in the production of sudangrass hay, at rates varying from 150 to over 800 lbs N/acre. However, there is virtually no research data to guide growers in the determination of optimum N fertility management for sudangrass in California. Insufficient N has been identified as a common yield-limiting factor in the Low Desert Region, often resulting in a 1-3 ton dry matter loss/acre loss in yield (priced at approximately $120/ton). Excessive application rates applied to Sudangrass may exacerbate groundwater nitrate problems or nitrate toxicity in cattle feed. Improved knowledge of the N fertility needs of sudangrass would enable greater efficiency and profitability of crop production, and help protect the Salton Sea from nitrate contamination.

This two-year research project will determine the yield and forage quality (particularly nitrate concentration) response of sudangrass to N fertilizers in the Low Desert environment, quantify the effects of N application rates on the potential for groundwater contamination, and develop rapid diagnostic tests (using Cardy meters and near infrared spectrophotometry) to monitor N content in the forage. These techniques would aid the in-season management of N fertilization of sudangrass to prevent deficiencies or excessive applications. Nitrogen rate studies are proposed for Blythe and El Centro, California, with extensive plant and soil water monitoring to determine crop response and the potential for soil water contamination. We will communicate the results of this research during and after the two-year study through field days, newsletters, DANR publication, and workshops.

VI. BIOGRAPHIES OF CONFERENCE SPEAKERS AND POSTER PRESENTERS

Ashok Alva is an Associate Professor in Soil Chemistry and Mineral Nutrition for citrus at the University of Florida's Citrus Research and Education Center. His current area of research is developing best management practices for irrigation and N fertilization of citrus trees to improve N use efficiency and minimize nitrate leaching to groundwater. Other areas of interest include the fractionation of metals in agricultural soils, improving iron nutrition on high pH soils, the beneficial effects of industrial by-products as agricultural amendments, and the diagnosing nutritional disorders in citrus by leaf analysis. He received his Ph. D. in soil chemistry and fertility from Pennsylvania State University in 1983.

Patrick Brown is an Assistant Professor in the Department of Pomology at UC Davis. His major research interests include the investigation of the factors controlling the availability of nutrients in soils, the role of plant exudates and microbial populations in nutrient acquisition, nutritional requirements of fruit and nut trees, fertilizer application practices and the environmental impact of fertilizer use. Dr. Brown received his B.S. and his M.A. in Agronomy from the University of Adelaide, Australia. He earned his Ph. D. in Agronomy from Cornell University in 1988.

Bob Dixon grew up on a cherry and walnut ranch in the Santa Clara Valley. After graduating from the University of California, Davis, with a bachelors degree in agronomy, he spent 26 years in marketing and technical services for a major manufacturer of fertilizers and agricultural chemicals. He founded his own private consulting firm, Agro Environmental Services, in 1984. He is a certified professional agronomist and currently serves on the board of the California Chapter of the American Society of Agronomy and the California State Certified Crop Advisors (CCA) program.

Jacques Franco has been Program Coordinator for the California Department of Food and Agriculture's Fertilizer Research and Education Program since its inception. He lived on a 600 acre diversified farm and worked as an extension advisor from 1973 to 1980. He has also worked as an agriculture technology transfer consultant and for Netafim Drip Irrigation from 1980 to 1985. He is a graduate of the UC Davis Graduate School of Management, and has an M.S. in Agro-Ecology and a B.S. in Agriculture.

Thomas Harter is an Extension Groundwater Specialist at the University of California Kearney Agricultural Center. Among other projects, he is currently investigating groundwater quality, particularly nitrate levels, under central California dairies. He is also conducting a comprehensive study on the conjunctive use of surface and groundwater in southern Tulare County. He has ten years of field experience in groundwater management. He received his M.S. from the University of Freiburg, (Germany), and his Ph. D. from the University of Arizona.

Kent D. Johnson is the president and manager of Ag Production Co. located in Turlock, California. Agpro is a retail supplier of agricultural chemicals, fertilizers, and related services. Kent was recognized as the "Industry Man of the Year" in 1984 by the California Fertilizer Association for his work on the environmental committee. He currently serves as a director of the CFA. Johnson received his B.S. in Plant Science and M.S. in Integrated Pest Management from the University of California, Davis.

R. Scott Johnson is a Pomology Extension Specialist at the University of California, Kearney Agricultural Center. He has responsibilities for fresh market peaches, plums, nectarines and kiwifruit. Much of his research has focused on nutrition and irrigation management. He currently serves as the chair of the Pomology Nitrate Workgroup. Johnson received his B. A. from the University of Utah and Ph.D. from Cornell University.

Phil Osterli is County Director of the University of California's Cooperative Extension Service in Stanislaus County, where he is responsible for coordinating and administrating support for programs conducted by a team of ten advisors in agriculture, natural resources, home economics and 4-H. Mr. Osterli

has also served as a farm advisor in vegetable crops, dry beans and sugar beets in Stanislaus County. He received his B.S. and M.S. in Agronomy from UC Davis.

Robert O. Miller is an Extension Soil Specialist in the Department of Land, Air and Water Resources. He has been with the University of California-Davis for the past five years and was responsible for the restructuring and modernization of the Analytical Laboratory. His research interests center on crop nutrient bioavailability and accumulation.

Peter Rooney was appointed Undersecretary of the California Environmental Protection Agency in June of 1996. Mr. Rooney holds a B.S. in Political Science from the University of Santa Clara and a J.D. from Stanford University Law School. He also participated in an early class of the Agricultural Leadership Program. Mr. Rooney has also had over thirty years of experience in production agriculture in Sacramento County.

Mr. Rooney has also served as chair of various industry and civic organizations, including a Federal Marketing Order, the California Wheat Commission, and an advisory committee at the California Department of Conservation. He has also served on various water agencies and commissions, as well as being a past president of the Sacramento County Farm Bureau.

Charles A. Sanchez is a Research Scientist with the Soil, Water, and Environmental Sciences Department at the University of Arizona. He is located at the Yuma Agricultural Center. His research focuses on the efficient fertilization and irrigation of vegetables in the low desert. Dr. Sanchez received his B.S. and M.S. from New Mexico State University and his Ph.D. from Iowa State University. Before joining the faculty at Arizona, he was associate professor of vegetable crops at the University of Florida.

Richard Smith is a Vegetable, Berries and Small Farms Advisor with the University of California Cooperative Extension in San Benito County. He is involved in research and education programs in peppers, onions, garlic, cole crops and strawberries. Current research efforts are working on managing fertility of drip irrigated vegetables, the use of quick tests, and disease control research using resistant varieties. Richard received his B.A. in Biology from Sonoma State University, and his M.S. in Agronomy from UC Davis. In 1996, Richard was awarded the Pedro Ilic Agricultural Award for Farm Advisors.

Beth Teviotdale is an Extension Specialist in the Department of Plant Pathology, University of California, Davis, and is located at the Kearney Agricultural Center in Parlier. She has responsibilities for fungal and bacterial diseases of deciduous fruit and nut crops, and olives. Her research interests include cultural and chemical methods for disease control. She received her B.A. in Botany from Pomona College in Claremont, CA, and her M.S. and Ph.D degrees from the University of California, Davis.

Ann Veneman is the Secretary of the California Department of Food and Agriculture, a position which she has held since June, 1995. From 1991-1993, Ms. Veneman served as Deputy Secretary of the U.S. Department of Agriculture where she directed and oversaw the activities and policies of the USDA and its 42 agencies. From 1989 to 1991, she served as Deputy Under Secretary of Agriculture for International Affairs and Commodity Programs.

Currently, Ms. Veneman serves as the president of the Western Association of State Departments of Agriculture, and serves on the Board of Directors of the Farm Foundation and the Close-Up Foundation, and is a member of the USDA's Advisory Committee on Emerging Markets.

Ms. Veneman has also worked as an attorney in Washington D.C. and Modesto, California. She was raised on a peach farm in Modesto, and earned a B.S. in political science from the UC Davis, an M.S. in public policy from UC Berkeley and a J. D. from UC Hastings College of Law.

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