Proceedings
of the Second Annual

Fertilizer Research and Education Program Conference

Sponsored By

California Department of Food and Agriculture
California Fertilizer Association

Public Service Research Program
University of California Davis

December 9, 1993
Davis, CA

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II. Introductory Addresses

Welcoming Remarks

Henry Voss
California Department of Food and Agriculture
Sacramento, CA

On behalf of the California Department of Food and Agriculture I would like to welcome you to the second Fertilizer Research and Education Program Annual Conference. I would like to acknowledge the foresight of the California Fertilizer Industry in supporting this very important program as well as the support of growers, commodity groups, the University of California, its researchers and many other participants and contributors. Their involvement has been critical to the early success of the Fertilizer Research and Education Program.

If anything has been constant in the last years it is **change**. Society's past goal for agriculture has been the production of abundant food at reasonable prices. The joint effort and creativity of California growers, researchers, government and support industries have delivered outstanding results. Now, however, society is placing new demands on growers: The production of abundant food and fiber while maintaining the integrity of natural resources and the environment. This new goal makes sense, because we have the responsibility to safeguard for future generations the renewable bounty that supports us all. From a practical standpoint it is much easier to prevent damage to our natural resources than to restore it.

This responsibility poses many challenges and opportunities for everybody. I am convinced we can enhance the environmental performance of our agricultural production and maintain its economic viability. As a matter of fact, I believe that improved stewardship of resources will become a requirement to remain viable in the competitive agricultural production sector.

Therefore we need to work with all parties to show that we can improve and enhance our land and water resources. If we fail, regulation will intensify. When and how I don't know, but it does not look encouraging from the experience of growers in other states such as Arizona and Nebraska. The way I see this situation is: Pay now or pay later, and the later it is usually much more expensive. We in agriculture are and should continue to be part of the solution. We recognize the complexity of the situation but would rather develop solutions that fit farming constraints than have somebody else tell us how to farm.

Growers care and have a vested interest in maintaining the viability of the resources that make farming possible and so successful here in California. We at the California Department of Food and Agriculture are part of that team effort. Research and education are key to improving our ability to maintain agriculture's viability. Today you will hear about our program activities and progress reports of the projects that we are helping support.

The Fertilizer Research and Education Program: An Update

Jacques Franco, Program Coordinator
Fertilizer Research and Education Program
California Department of Food and Agriculture
Sacramento, CA

Purpose

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

The program facilitates and coordinates the development of research and demonstration projects by: (a) providing technical assistance and funding to carry out research, demonstration and education projects; (b) improving access of local entities to resources needed to carry out these projects; and (c) by developing information and serving as a clearinghouse of information required to conduct these activities.

Program activities are directed to serving growers, public agencies, agricultural supply and service organizations, extension personnel, resource conservation and irrigation districts, consultants, the general public 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 first year activities concentrated on helping secure funding and technical expertise to start these research and demonstration projects. Initial projects were developed in the Salinas Valley and the Fall River Valley. The Salinas project is developing improved vegetable farming practices that 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 directed toward the environmentally safe and agronomically sound use and handling of fertilizer materials. The program is currently supporting twenty two projects. Details about them can be found in these proceedings.

The review, selection, and funding recommendations for projects is done by the Research Subcommittee of the Fertilizer Inspection Advisory Board. The subcommittee includes growers, members of the fertilizer industry, state government and university scientists.

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

These activities include participation in an inter-agency committee that coordinates efforts to reduce non point sources of contamination, participation in a University of California study team that is developing methods to assess the environmental and agronomic performance of various Best Management Practices, and membership in an advisory committee to the US Geological Service that is studying the extent and severity of nitrate contamination of groundwater in the San Joaquin Valley. Regulatory and legislative trends on nitrogen management across the country are also monitored.

FREP is also developing baseline information on fertilizer practices of target crops and exploring the use of Geographic Information Systems to pinpoint nitrate sensitive areas and help develop the most promising strategies for these areas. Additional activities include ongoing monitoring of scientific, technical, agricultural, industry, legal, government and policy developments and issues related to the program goals.

Outreach and Public Service
FREP makes available a number of publications, conference proceedings, project reports, videos and reprints of articles on fertilizer, water, crop and soil management topics. FREP also has information on sources of funding for nitrate management projects, and continuously provides expert referrals.

Program capabilities include a computerized system to store, process and produce resource materials and publications. The system, currently in its initial stages of implementation, is helping us provide clientele with timely and accurate responses to their requests for information and referrals.

Recent Accomplishments & Trends
We are very pleased to report that our list of information products recently exceeded fifty (please refer to section X). We have made available, in response to clientele requests, hundreds of copies of these materials and significantly improved our ability to promptly respond to these requests. We have noticed that a larger percentage of the individuals requesting materials from us are directly involved with production agriculture. This is an indication that our materials are of value. This year our first detailed progress report was released in February. It provides a thorough background on the nitrate in groundwater situation in California and FREP activities. Over two thousand copies have been made available. Please ask us for your copy.

This year's request for proposals is scheduled for release in January of 1994 and will be due by April 30th. Our advisory committee is in the process of extensively revising the priority research and education areas in response to what we have learned during the last four years. This year's request will be more focused and will be out for a longer period than in the past.

We are also pleased to report that in an effort to get the word out we have been working with the California Chapter of the American Society of Agronomy and will be holding a joint session at this year's meeting in San Luis Obispo. We have also been working with a group of University of California pomologists to improve fertilizer use efficiency in fruit and nut tree crops. Dr. Scott Johnson will be presenting an update on their activities today. We have also improved our coordination with the many commodity research boards to better serve the needs of growers.

One of our newest projects will be providing support to the Certified Crop Advisor program in California. This program is helping crop production professionals improve their abilities in the soil fertility area. Dr. Al Ludwick will provide more details about this promising program. This year FREP also made a commitment to support improved soil and tissue lab analysis. Dr. Bob Miller will be reporting on his project.

Next year we are planning to continue to expand FREP activities in new directions such as disease-fertility interactions, real time nitrate sensing technologies and heavy metals in fertilizer materials. We hope to continue to improve cooperative working relationships with parties that have common goals to ours and expand our outreach efforts. We will bring next year's annual conference to the San Joaquin Valley to make it available to our clientele there.

Conference Program Highlights
This year's conference program has benefited from the comments made by last year's participants. In addition to the project's progress reports scheduled for the afternoon, this year we have a poster session that will highlight early results of projects FREP is helping support. This format will allow for more interaction between the conference participants and project leaders.

The morning panel section has been set to increase interaction with the conference participants as requested by last year's participants. We have also added two new components to this year's program. First, the brief update section is intended to bring you "the big picture" and details of activities related to FREP's mission and help you improve your understanding of how these developments might affect you. In addition, we will feature what I hope will be the first of a series of "world premieres" highlighting information products that resulted from FREP-sponsored projects.

We are very proud to present this year an improved conference proceedings. We hope it will help you get the most out of your participation in the conference. You will notice that this year's proceedings, as requested by last year's participants, provides background information and addresses of each of this year's conference speakers. In addition to all the project updates, we have included an annotated "resource guide" (section X) to familiarize yourself with FREP project products and help you choose the ones you can use. You are welcome to browse through FREP products display table during the breaks and use the materials order form in the back of your proceedings. We'll be glad to send to you any material you may have an interest in.

I would like to encourage you to fill out the evaluation forms in your conference packet or call us any time with suggestions to help us improve FREP services and activities.

Acknowledgments
A great 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 Jill Auburn, Carl Bruice, Bob Dickens, Al Ludwick, Steve Purcell, Wynette Sills, Brock Taylor, Tom Beardsley and Charles Tyson, members of the Research Subcommittee and to all the members of the Fertilizer Inspection Advisory Board. Their dedication, insight and professionalism have been invaluable in helping us select quality projects.

Casey Walsh Cady is providing invaluable assistance and dedicated service in carrying out many of the activities required to keep the program going. Debbie Scott, Gwen Cristoni and the staff at CDFA's Feed, Fertilizer and Livestock Drugs Branch also provide ongoing assistance and support.

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 of the Agricultural Resources Branch and Steve Wong of the Feed, Fertilizer and Livestock Drug Branch. We would also like to acknowledge the efforts of Ezio Delfino, retired Assistant Director of Inspection Services, Bob Wynn, Assistant Director of Inspection Services, Henry Voss, Director and A.J Yates, Deputy Director, 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 reviewed project proposals.

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III. Brief Updates

The Coastal Zone Management Act and the Clean Water Act Reauthorization

John Norton
State Water Resources Control Board
Sacramento, CA

In 1990, when Congress reconsidered the Coastal Zone Management Act, it reviewed the results of a National Water Quality Inventory and found that coastal waters continue to be degraded by existing and expanding land uses and require protection if they are to be maintained for future benefit. With this in mind, Section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA) was passed which requires the State Water Board, in conjunction with the California Coastal Commission, to develop a coastal non point pollution control program. Congress directed the U.S. Environmental Protection Agency and the National Oceanic and Atmospheric Administration to specify management measures to prevent water quality impacts from urban development, agriculture, forestry and other land uses. Fifty-six management measures have been specified. These are to be the foundation of a program implemented along the entire coast. If these measures are not sufficient in a particular area, the State must develop additional measures. Failure to develop a coastal non point pollution control program will result in loss of federal funds which support the State Water Resources Control Board's non point source control program as well as funds which support the Coastal Zone Management Act Implementation.

The current draft amendments to the Clean Water Act, Senate Bill 1114 (Baucus/Chafee), propose to implement management measures similar to those developed for CZARA on a nationwide basis. This legislation would require the management measures to be implemented beyond coastal areas to include all lands. Another major theme of the current proposed legislation is the development of local Watershed Management Plans. These plans are intended to bring together local agencies and land users to develop appropriate solutions to water quality problems. This bill is receiving a great deal of attention and will likely be substantially amended or replaced over the next few months.

Certified Crop Advisor (CCA) Program in California

Al Ludwick
Potash & Phosphate Institute
Mill Valley, CA

The Certified Crop Advisor (CCA) program is a national effort being conducted under the direction of the American Society of Agronomy in cooperation with agribusiness and various government agencies. It was initiated in response to increasing concerns about the potential of fertilizer and associated management factors, such as irrigation, having a negative impact on the environment. Concerns about nitrate in the ground water and phosphates in lakes and streams have been the focus in recent years.

The purpose of the CCA program is to certify that individuals making fertilizer and crop management recommendations have the appropriate technical knowledge in the areas of soil fertility, soil and water management, pest control, and plant development. It is a voluntary program and is administered at the state or regional level. (The California State Board members are listed at the end of this paper). The goal of the program is to help agriculture as an industry meet its challenge to produce efficiently (high yields with low unit costs), while maintaining environmental quality for future generations.

The program is a first step towards raising and certifying the level of professionalism in our industry. It sets minimum acceptable standards and verifies that crop advisors have the basic knowledge to effectively address the agronomic needs of growers and the standards of the various environmental regulatory agencies.

Requirements include a B.S. in agriculture or a related field and two years experience in crop production; or an A.A. degree and three years experience; or four years of post high school experience. Participants must also take a competency examination, participate in 60 units of continuing education over a two-year period (this requirement is under review), and sign a professional code of ethics. The California PCA license is recognized as proof that an individual seeking to also become a CCA already meets the criteria for the pest control section of the examination

The examination, consisting of both national and state sections, is given twice a year (February and August) at several locations in California. The most recent was given to a total of 216 individuals on August 6, at California Polytechnic University, Pomona; Fresno State University, Fresno; and the University of California, Davis. The examination was preceded by a training seminar near each of these locations. The complete training package included a one-day seminar; a complete study-guide for the national portion of the exam, including practice questions and a copy of the Western Fertilizer handbook, 7th edition.

The California Fertilizer Association (CFA) and FREP are co-sponsoring the training programs and assisted in funding the previous training seminars. The CCA program recently received a grant from FREP to continue these seminars and develop continuing education activities. The next examination will be given February 4, 1994 at or near the above locations plus a fourth site in either the San Jose or Salinas area. Training prior to the examination will again be offered.

For more information contact Renee Pinel, California CCA Coordinator, or a State Board Member. The California State Board and Ex Officio Members for 1993 are:

State Board Member	**Representing**
Al Ludwick, Chair	California Fertilizer Association
Bob Dixon, Incoming Chair	ARCPACS/ASA*
Ed Murray	California Agricultural Production Consultants Association
Jack Hodges	California Environmental Protection Agency
Stuart Pettygrove	UC Cooperative Extension
Steve Wong	California Department of Food and Agriculture
Walt Bunter	Soil Conservation Service
Gary Rinkenberger	Retail Fertilizer Industry
George Tibbitts	California Farm Bureau
Jasper Hempel	Western Growers Association.
Steve Purcell	Fertilizer Manufacturer
Kimberly Crum, Ex Officio	California Agricultural Production Consultants Association
Steven Beckley, Ex Officio	California Fertilizer Association

* American Registry of Certified Professionals in Agronomy, Crops and Soils/ American Society of Agronomy

Pomology Nitrate Workgroup

R. Scott Johnson
Kearney Agricultural Center
Parlier, CA

At the Pomology Extension Continuing Conference in March 1992, it was decided that nitrate pollution of groundwater is a serious problem affecting all pomologists. Consequently, we formed a cross-commodity workgroup to address this concern. Over the past year and a half, we have met several times and are pursuing the following objectives:

1. Publishing a manual on nitrogen fertilizer management covering general principles of good fertilizer and irrigation management for all major fruit and nut crops.

2. Holding meetings to update farm advisors and specialists on nitrogen related research and techniques available for reducing nitrate pollution of groundwater.

3. Establishing some type of cross-commodity demonstration and/or research plots which will help growers improve fertilizer management.

We have made good progress on these three objectives and will continue our efforts in this direction for at least the next year.

Western States Agricultural Laboratory Sample Exchange Program

Robert O. Miller
Department of Agriculture and Natural Resources Laboratory
UC Davis

During the past three years, there has been growing interest among government agencies, growers, laboratories and the commercial industry to standardize soil analytical methods and to initiate an agricultural laboratory performance evaluation program. This interest has been motivated by recent environmental legislation and the need for quality assurance in the industry. The initiation of a mandatory state or federal program, however, is met with resistance from the agricultural industry. A voluntary approach developed within the industry is more acceptable.

The objective of this project is to develop an industry based Agricultural Laboratory Sample Exchange Program modeled after existing programs in the midwest through merger and expansion of the Utah State University agricultural sample exchange program. The program involves a quarterly exchange of reference samples (soil and plant) with participating laboratories using standardized analytical methodologies for the purpose of: (1) assessing the analytical performance of the agricultural sample testing industry; (2) identifying those analytical procedures which have precision and/or accuracy problems; and (3) developing the framework for improving quality assurance of the industry. The program will be funded for three years by FREP with a staggered phase-in of participant support.

Interaction Between Pest Pressure and Nutrition in Fruit Trees

Themis J. Michailides and Brent A. Holtz
Kearney Agricultural Center, Parlier

Farmers can influence pests and pathogens by the type and amount of fertilizer they apply. Some non-parasitic diseases can result from nutrient deficiencies. Iron, zinc, boron, and manganese deficiencies may cause specific diseases such as chlorosis of fruit trees, rosette of apple, blossom blast of pear, little leaf of pistachio, and necrotic blossom-end of tomato. It has long been recognized that nitrogen fertilization can stimulate the production of juvenile growth, which may favor diseases such as powdery and downy mildews, and insect pests such as twig borers. The lack of nitrogen may lead to the formation of senescent tissue, which can favor such diseases as Alternaria, Botrytis, and Sclerotinia blights. Diseases affected by nitrogen fertilization include root and cortical rots, vascular wilts (Fusarium and Verticillium wilts), foliar diseases (powdery mildews, rusts, and smuts), canker diseases, and even virus diseases. Studies on the effects of nitrogen fertilizers on tree blossom and fruit diseases are limited. Excessive nitrogen application to apples can cause softer fruit, poorer fruit color, and more bitter pit, and in pears, a higher susceptibility to fire blight.

Nitrogen fertilization has long been recognized as being associated with changes in the levels of disease and yields of plants. In a recent study at the Kearney Ag Center of the University of California, we initiated a study to determine if and how nitrogen fertilization applied at different rates affects susceptibility of nectarines to brown rot.

Preliminary results show that excess nitrogen resulted in increased susceptibility of nectarine blossoms and fruits to brown rot fungus, *Monilinia fructicola*, and to peach twig borer infestations. Initial observations indicated that about 13% of the fruits had natural brown rot infections from trees fertilized with 325 lbs of N/acre, compared to only 3-4% of those from trees fertilized with 100-175 lbs N/acre. Fruits from the unfertilized control trees had the least amounts of brown rot infections. Similarly, after inoculation with spores (=conidia) of *M. fructicola*, up to 90% of Fantasia nectarines collected from the highly fertilized (250-325 lbs N/acre) trees rotted from brown rot while only up to 65% of fruit from trees fertilized with 100-175 lbs N/acre had brown rot

Although we do not have any explanation about the mechanism of this blossom resistance, differences observed in cuticle thickness of fruits from trees fertilized with different levels of nitrogen partially explain the differences in fruit susceptibility to the disease. We also studied differences in incubation (time required for the first symptoms of disease to appear) and latent periods (time required for sporulation) of the pathogen.

We believe that overfertilization in stone fruits can increase brown rot disease and deserves further study.

IV. Keynote

Prevention of Nitrate Contamination, A Voluntary Approach: The Iowa Experience

George R. Hallberg
Environmental Geology
Iowa Department of Natural Resources

Nitrogen is ubiquitous in the environment and is one of the most important plant nutrients. Its conversion to nitrate is part of the natural functioning of any ecosystem. Many activities of modern society contribute excessive nitrate into the environment, and nitrate has become perhaps the most widespread contaminant of water resources. While there are many sources, agriculture (and horticulture) is clearly the largest and most widespread contributor. Losses of nitrate into the environment can also be viewed as a matter of inefficiency and economic loss to producers. Ongoing efforts in Iowa, California, and many other states show that we can improve our environmental performance and profitability at the same time, through improved nitrogen management. While our crops are different, the management *principles* are the same. Iowa has had a substantial statewide program of on-farm demonstrations, public-farmer-dealer education, and information marketing, to promote the voluntary adoption of improved nitrogen management.

Since 1986, Iowa farmers have reduced their rate of fertilizer use on corn (nationally, the largest user of nitrogen fertilizer) by nearly 20%, reducing total loading from fertilizer-N by nearly 1.5 billion pounds. This has saved Iowa farmers $200-250 million in input costs, with program expenditures of about $10 million. Even with these reduced inputs, 1992 crop yields set a new record high!

In 1992, Iowa was awarded the EPA Administrator's Award for Pollution Prevention for these efforts. We can make a difference with aggressive voluntary education efforts, particularly if agencies and producer organizations work together. But it is also clear that such voluntary programs will not cause all producers to change and improve. Hence, we also must ask whether or not these differences will be enough. We also must realize that losses of nitrogen into the environment from agriculture are inevitable, because of the natural functioning of the nitrogen cycle and the vagaries of weather that crop producers must face.

IV. Ongoing Project Summaries

Nitrogen Fertilizer Management to Reduce Groundwater Degradation

Project Leaders:
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UC Cooperative Extension
Kearney Agricultural Center

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U.C. Cooperative Extension
Modesto

Cooperators:
Patrick H. Brown
UC Davis
Pomology

Dennis E. Rolston
UC Davis
Land, Air, Water Resources

Project Objectives:

This study is being conducted in two mature almond orchards in the nitrate-sensitive region of the Northern San Joaquin Valley in Stanislaus County. The objectives of this project include:

1. Determine the relationship between leaf N concentration and the rate of applied fertilizer N. This will include an assessment of the sensitivity of leaf N concentration to overfertilization and a reassessment of the validity of the currently accepted leaf N critical value.

2. Determine the relationship between leaf N concentration and tree productivity. (i.e., reassessment of the validity of the currently accepted critical value).

3. Assess the relationship between the rate of applied fertilizer N and the recovery efficiency of isotopically labeled (^{15}N-depleted) ammonium sulfate. This objective will be addressed following establishment of the N differentials as a result of yearly applications of 0, 125, 250, or 500 lbs N per acre per year.

4. Assessment of nitrate leaching below the root zone and its relationship to fertilizer N application rate, efficiency of fertilizer N recovery, and tree N status. This objective will be addressed following establishment of differential tree N status, determination of soil hydraulic conductivity, and measurement of soil nitrate concentrations.

5. Refinement of current management guidelines for N usage which will help to maintain productivity while reducing the amount of fertilizer N leached below the root zone.

Project Description

It appears axiomatic that the more fertilizer N applied to the soil, the greater is the potential for nitrate leaching, especially if the tree capacity for N uptake is exceeded. We anticipate a reduced recovery of fertilizer N at high application rates because (1) the capacity for N uptake is limited in trees at high N status and (2) recently applied fertilizer N may be diluted in the soil as a result of residual nitrate from previous fertilizations and the application of high nitrate irrigation water.

Two research plots have been established in nitrate-sensitive areas of Stanislaus County - one in Salida and one in Ceres. Both orchards, planted in 1980, are growing in Hanford sandy loam soils. After collecting baseline data on tree yields, midsummer leaf N concentrations, and soil nitrate concentrations, experimental treatments were initiated in October 1990. Differential rates of N fertilization have been applied as a 1/3 to 2/3 split in April and October, respectively. This fertilization regimen represents typical grower practice, although we suspect that fertilizer N recovery by the trees is reduced when applied as late as October. The presence of high residual levels of nitrate in the soil and the use of high nitrate irrigation water has delayed N deficiency and may preclude a decrease in leaf N concentration below 2.2%, especially in the Ceres orchard. Attainment of a broad range of leaf N concentrations in 1993 justifies postharvest (October) application of isotopically labeled fertilizer N in the Salida orchard. This differential in tree N status is less evident in the Ceres orchard, presumably because the nitrate concentration in the irrigation water is higher than that in the Salida orchard.

Four treatments, each with four two-tree replicates, were randomized within the orchard with adequate tree buffers between treatments. The four N treatments are 0,125, 250, 500 lb N/acre in a split application.

All treatments receive the N carried by the irrigation water. The N rates of 125, 250 and 500 lbs/acre do not include the N supplied in the irrigation water. To assess the N critical value, i.e., the leaf nitrogen concentration below which tree productivity is reduced, we must allow some trees to go deficient (0 lbs/acre).

Results and Conclusions

Since differential fertilizer N application rates did not influence tree yields statistically during the first three years of the project, it is apparent that annual fertilization is not necessarily required to maintain productivity. The lack of significant yield reduction in non-fertilized trees strongly suggests that current N management practices favor overfertilization and are likely to contribute to groundwater pollution, especially in coarse -textured soils. Overfertilization occurs when the availability of N in the orchard system exceeds the tree's capacity to absorb it. Excessively high leaf N concentrations (> 2.6% N), high residual levels of nitrate in the soil, high nitrate concentrations in wells used for irrigation, and high rates of annual fertilizer application were found in our test orchards. The amount of N applied (as nitrate) in the irrigation water in the Ceres orchard may be sufficient (even without supplemental fertilizer N) to maintain leaf N concentrations above 2.2%.

Leaf N concentrations decreased annually in all treatments and in both orchards between 1990 (pretreatment) and 1992. The greatest decrease in leaf N concentration occurred among trees receiving no fertilizer N. Less spectacular annual reductions in leaf N concentrations occurred with progressively higher fertilizer N application rates (125, 250, and 500 lbs N/A/year). In 1993 leaf N concentrations exhibited no further decline from the 1992 levels and, in fact, all the treatments in both orchards increased marginally relative to 1992 levels. Currently, almond trees are considered N deficient at leaf N concentrations below 2.0%, and leaf N concentrations between 2.2 and 2.5% are considered indicative of adequate N availability.

A trend toward increased yields with increasing leaf N concentration was noted in both orchards in 1993. In both orchards, trees receiving 500 lbs N/A/yr did not produce statistically greater yields than trees receiving 250 or 125 lbs N/A/yr, but (after 3 1/2 years) exhibited statistically greater yields than unfertilized trees. We suspect that yields would be maximized at lower fertilizer application rates in Stanislaus County if more efficient management practices were followed.

Leaf N concentrations (Ceres orchard) associated with statistically significant yield reductions averaged 2.37% N (range = 2.30-2.45%). Thus, a significant yield reduction was associated with leaf N concentrations currently considered to reflect adequate tree N status. A statistically significant yield reduction among unfertilized trees also occurred in the Salida orchard after 3 1/2 years. Those unfertilized trees averaged 2.28% N - also in the leaf N concentration range currently considered to be adequate. Although it would appear premature to draw definitive conclusions with respect to the relationship between tree N status and productivity, our data suggest that July leaf N concentrations should be greater than 2.3% to ensure that productivity is not N-limited. These data are unique because no previous studies have been conducted to determine the relationship between leaf N concentration and tree productivity in mature almond trees grown in coarse-textured soils.

In 1994, our study should generate additional data which may help clarify that relationship and minimize the economic risks associated with the use of publicized leaf N standards to guide fertilization practices. Data collected in 1994 should also provide information on the relationship between tree N status and tree recovery of (isotopically-labeled) fertilizer N.

A copy of the latest annual report titled "Nitrogen Fertilizer Management to Reduce Groundwater Degradation: Annual Report " is available from FREP. Please see Section X for ordering information.

Improvement of N Management in Vegetable Cropping Systems in the Salinas Valley and Adjacent Areas

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Project Objectives

1. Review literature on N and water management in production of lettuce, celery, broccoli, and cauliflower;

2. Demonstrate potential for reducing nitrate leaching by cover cropping;

3. Compare nitrate leaching, crop performance, and irrigation system performance under furrow and drip irrigation systems in a coarse-textured soil;

4. Develop the use of plant tissue analysis, soil sampling, and soil solution sampling for monitoring crop N status and nutrient supply.

Project Description

Over the past two decades, nitrate levels in many Salinas Valley wells have increased and many samples exceed the federal/state drinking water standard. Research findings in similar environments suggest that irrigated vegetable fields are an important source of nitrate found in groundwater in the Salinas Valley as well as several other coastal areas of California. In the 1970s, UC researchers collected soil cores to a depth of 30 meters from nearly 60 agricultural fields in California. Results showed that in many cases, large amounts of nitrate had been leached to considerable depths.

Features of the crops, soils, and management practices of the Salinas Valley providing strong circumstantial evidence that vegetable fields are a likely significant source of nitrate in groundwater are:

1. Continuous vegetable rotations with two or more crops per year and frequent tillage are common;
2. Mild winters allow nearly year-round production;
3. Crops are shallow-rooted with 12 to 30 inch deep root zones;

4. Crops are high in value, and plentiful, continuous supplies of N and water right up to harvest are critical for yield and marketability;
5. Large amounts of high-N crop residue are often left in fields post-harvest; mild climate provides ideal conditions for rapid decomposition and N mineralization;
6. Water is relatively inexpensive in many areas;
7. In some areas, soils with low water-holding capacity overlie unconfined groundwater.

This is not to ignore the possibility that less diffuse sources of nitrate -- such as septic tanks and improperly sealed or abandoned wells -- are also contributing to the problem.

To reduce the quantity of nitrate leached from cropland, improvements must be sought in three areas:

1. Irrigation management. Decrease the volume of water leached below crop root zones through improvements in irrigation efficiency;

2. Fertilizer management. Decrease the proportion of added fertilizer nitrogen that is not used by the crop through improvements in fertilizer timing and placement and in choosing the appropriate application rate;

3. Fallow period management. Decrease the quantity of nitrogen leached by rain or pre-irrigation during fallow periods through cover cropping or by changes in crop rotation and soil management.

Several commonly advocated "Best Management Practices" are already in widespread use by Salinas Valley growers. Vegetable growers almost always split fertilizer N applications; application of N in the fall when bedding up is becoming less common. By San Joaquin Valley standards, fields are small, furrow runs are short, and such practices as blocked furrows, alternate sets of sprinklers, and nighttime irrigation are relatively common. Restricted water supplies and seawater intrusion as well as the nitrate problem have resulted in local ordinances requiring meters on all wells and backflow prevention devices. Several growers have installed drip irrigation systems on some of their acreage, and many more growers are experimenting with drip. The Department of Water Resources, Monterey County Water Resources Agency, the SCS, UC Cooperative Extension, and Cal Poly San Luis Obispo are promoting irrigation system evaluation and maintenance. Several weather stations have been added to the CIMIS network in the Salinas Valley, providing improved capability to estimate crop water requirements.

In 1991, our team decided to focus efforts to conduct a field scale comparison of drip and furrow irrigation methods, development of soil and plant monitoring methods, and on-farm demonstration of cover cropping that had been shown to reduce winter losses of nitrate. This work has been supported by the Monterey County Water Resources Agency and the CDFA Fertilizer Research and Education Program. Team members have also been supported in related activities by grants from the Iceberg Lettuce Advisory Board, the federal SARE/ACE program, and the UCD College of Agricultural and Environmental Sciences.

Results and Conclusions

A literature review was completed (Stivers et al., 1993) and is available from the Fertilizer Research and Education Program (Co-funded by FREP and the Monterey County Water Resources Agency).

A ten-page bulletin on best management practices (Pettygrove et al., 1993) was completed. It can be obtained from the Monterey County Cooperative Extension office in Salinas or from the Fertilizer Research and Education Program (Co-funded by FREP and the Monterey Co. Water Resources agency).

Winter cover crops were demonstrated in three grower fields in the northern Salinas Valley during the 1991-92 winter. Non-legume cover crops were planted on semi-permanent beds; one site was drip irrigated. At all three sites, the cover crops reduced soil nitrate levels at the time of incorporation and earlier compared to bare fallow plots. No problems were encountered with incorporation or with preparation of the seed bed for the following vegetable crops (Co-funded by the Monterey Co. Water Resources Agency and FREP). Research is continuing on some aspects of cover cropping. In one experiment, cover cropping with rye resulted in reduction in size of heads of the following lettuce crop, probably due to temporary N immobilization (Jackson, Iceberg Lettuce Advisory Board 1993 report). This has not been observed in other experiments with rye or with other cover crop species.

In a 1992 drip fertigation uniformity study (funded by FREP), soil solution nitrate, petiole nitrate, and irrigation emitter output and nitrate + ammonium concentration in irrigation water were monitored at the upper end, middle, and bottom of commercial bell pepper fields. Some non-uniformity in N fertilizer application was observed, but petiole nitrate levels and degree of uniformity were adequate in both fields.

In a study co-funded by Monterey County Water Resources Agency and FREP, irrigation system, crop, and soil nitrate data were collected over a two-year period covering four crops (lettuce-lettuce-lettuce-cauliflower) in an 860-ft long sandy loam field near Soledad (Major Farms). A 72-bed width of the field was divided into three 24-bed sections irrigated by furrow, surface drip, and buried drip systems. Results: Yields for the first crop were highest for the furrow-irrigated crop due to improper installation of a part of the drip system. (The furrow irrigated lettuce received six more inches of water than the drip-irrigated lettuce, likely resulting in significant deep percolation). In the second crop, a surge irrigation valve was installed that allowed the average water applied per irrigation in the furrow block to be reduced from 3.0 to 1.9 inches. The drip systems performed well and used even less water than the furrow block. In the third lettuce crop (summer 1992), the furrow block received about 13.2 inches of water versus 9.0 for the buried drip and 8.0 for the surface drip. Yields and head weights on the surface drip block were below those for the buried drip- and furrow-irrigated lettuce possibly due to mid-season water stress. The furrow-irrigated lettuce head weights averaged the same as the buried drip-irrigated but were more variable. Soil water content data again suggested significant deep percolation under furrow irrigation but not with drip irrigation. Soil nitrate content determinations in furrows between crops also indicated a much higher degree of leaching in the furrow irrigated areas of the field. However a somewhat lower clay content in the furrow irrigated block may have contributed to this leaching.

One conclusion reached from this research: Surface or shallow drip tape placement is not practical due to the large amount of damage inflicted on the tape during cultivations. Buried tape (6-8 inches below bed tops) has its own set of problems, but this appears to be the placement chosen by most growers.

A second conclusion from this study: Surge irrigation provided the capability to irrigate less and more frequently, but it is still necessary to apply enough water to "sub" past the seed line of the bed; if this is not done, the lettuce may be damaged by salts. The need to control salt damage may in some situations limit the gains that could be made with surge irrigation. The relationship of tape placement and other management variables to salt movement in beds is being investigated in a different grower's field under this FREP project.

We collected cores from furrows, measured nitrate, and estimated leaching losses of nitrate, defined as amount of nitrate increase in the 24 - 48 inch depth. During a period when 10 inches of rain was received (1991-92 winter) when the field was fallow, large amounts of nitrate were leached from both furrow and drip-irrigated blocks. This was in spite of relatively conservative fertilization practices by the grower. This points to the need for maintaining plant cover during rainy periods.

Development of plant sap analysis and soil solution sampling tools was also undertaken (funded by FREP). Richard Smith has used a portable nitrate meter to make weekly measurements of petiole sap and soil solution nitrate levels in two broccoli fields and a sweet corn field. The soil solution is obtained with a hand-held pump from ceramic-tipped soil solution access tubes placed at a 14-inch depth in the plant row. Weekly monitoring has provided enough data to detect rapid changes. It appears that the presence of a trend (e.g., a rapid decrease) is useful information even without knowledge of where exactly the "critical level" lies. For example, growers using this system can avoid applying any N fertilizer early in the season until levels appear to be headed strongly downward. So far, the combined use of petiole analysis and soil solution monitoring with a portable meter appears quite promising, especially for drip-irrigated crops where the grower can rapidly respond to the information. In a small project recently funded by the UCD College of Agricultural and Environmental Sciences, Louise Jackson and co-workers in collaboration with a local fertilizer company developed information on the cost of monitoring and trained personnel from several cooperating farms in the procedures to be used.

The following documents are part of this study and are available from FREP. Please see Section X for ordering information.

"Demonstration Program for Reducing Nitrate Leaching through Improvements to Irrigation Efficiency and Fertilizer/Cover Crop Management - Executive Summary "

"Use of Nitrogen by Lettuce, Celery, Broccoli and Cauliflower : A Literature Review"

"Best Management Practices for Irrigating and Fertilizing Cool-Season Vegetables"

"On-Farm Demonstration of Reduced Nitrate Leaching Using Cover Crops and Minimum Tillage"

Development Of Diagnostic Measures Of Tree Nitrogen Status To Optimize N Fertilizer Use

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Project Objectives

Our overall objectives are to develop improved plant N-monitoring techniques for perennial tree crops and to relate N application rates and soil N testing to tree N status. This will be done by:

1. Reassessing the sensitivity of currently accepted diagnostic criteria and developing more sensitive criteria of tree N status.

2. Developing plant sampling strategies to determine availability of applied N fertilizers.

3. Developing recommendations based on soil and/or plant testing to maximize fertilizer use-efficiency and reduce the contribution of orchard crops to nitrate contamination of groundwater.

Project Description

Orchard crops utilize large amounts of fertilizer N and are potentially major contributors to groundwater pollution in many areas of California. Large acreages of orchard crops are grown in areas designated as nitrate 'sensitive' in recent water quality assessments. Fertilizer management of orchard crops is, however, poorly regulated and the dynamics of N in orchard crops is the least well understood of any cropping system. In this research we aim to improve plant N-monitoring techniques so that fertilizer applications can be better managed. This will be achieved by monitoring the concentration, composition and distribution of a range of N-compounds in mature trees and relating this to plant yield, fertilizer N application and nitrate movement in the soil. Research of this type has been performed in annual crops but has not been adapted to perennial systems.

The experimental trial consists of four N treatments (O, 62, 125, 250 lb N/acre) replicated 4 times each in two crops: nectarine and almond. Each treatment block contains six trees, of which the central four are used for experimental purposes. Foliar samples were taken and analyzed for NH_4, NO_3, and amino acids. Soil samples were taken at 1,2, and 3 feet depth in each plot, and nitrate plus ammonium soluble in KCl (2N) were determined. The trunk diameter is measured at 2 month intervals and the growth rate calculated. Our aim is to identify a nitrogen compound in plant leaves that best reflects the N status of the plant. Optimal N status is determined by correlating plant N measurements with tree growth and productivity and relating that to N application rates and N leaching.

Results and Conclusions

In the first year of this experiment we found that the variables best correlated with nectarine growth rate were a) nitrogen (nitrate and ammonium) soluble in water and b) amino acids extracted in formic acid. In almond, the best correlation with growth was found with total nitrogen, ammonium nitrogen, nitrate and amino acids extracted in formic acid. In general, formic acid extracts were more consistent and easier to handle analytically than water extracts. In the second year we have reconfirmed the value of nitrate, ammonium and amino acids as indicators of N status. Work has commenced on determining diurnal and positional effects on N status so that an optimal sampling strategy can be developed. We are pursuing alternative methods of detecting nitrate, ammonium and amino acids that might be amenable to field use.

Though the determination of these N compounds correlates well with plant performance, several problems need to be addressed. These include 1) What is the optimal sampling protocol in terms of timing, number of leaves, position of leaves and number of replicates, 2) How are the levels of these N compounds affected by temporal changes in N availability and 3) Whether the test procedure can be adapted for in-field usage. To address these problems we have initiated a series of smaller experiments.

A copy of the latest annual report titled "Development Of Diagnostic Measures Of Tree Nitrogen Status To Optimize N Fertilizer Use: Annual Report " is available from FREP. Please see Section X for ordering information.

Citrus Growers Can Reduce Nitrate Groundwater Pollution And Increase Profits By Using Foliar Urea Fertilization

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Project Objectives

Our objective is to test the hypothesis that foliar urea applied April 1 to June 1 can do triple duty: 1) as a "non-pesticide" to control citrus thrips and reduce fruit scarring; 2) as a "growth regulator" to improve fruit set and increase yield without reducing fruit size or quality; and 3) as a nitrogen fertilizer by supplying a portion of the nitrogen to be applied in a given year thus reducing the amount applied to the soil. The goal of our research is to provide citrus growers with the optimal time and rate of foliar-urea application needed to successfully improve fruit set and yield and control citrus thrips to reduce fruit scarring. If our research is successful in improving yield and/or reducing the economic loss due to fruit scarring caused by citrus thrips, our research will provide an economic incentive for citrus growers to reduce their use of soil-applied nitrogen in favor of a spring foliar application of urea. Thus if successful, the results of our research will not only improve citrus productivity and grower profits, but will also reduce pollution to the groundwater from nitrate and reduce the amount of chemical pesticides currently used to control citrus thrips which results in less potential pesticide pollution of the soil and groundwater.

Project Description

In early April, young, developing spring flush leaves averaged 150 ± 30 µg NH_3-NH_4^+ per g dry weight. These values were two times the concentration of NH_3-NH_4^+ in mature leaves from the previous year's spring flush. The level of NH_3-NH_4^+ in young and mature leaves decreased from April through May. By mid-May, both young and mature leaves had similar levels of NH_3-NH_4^+, approximately 35 µg per g dry weight. Foliar applications of low-biuret urea consistently raised the NH_3-NH_4^+ content of both the young and mature le aves by 100 to 150 µg per g dry weight leaf tissue, but this increase was only evident for the sampling dates 1 or 2 days after the foliar urea application. Eight days after the foliar application of urea, the levels of NH_3-NH_4^+in either young or mature leaves were not significantly different from the control leaves on the same date or the time-zero leaves collected the day before the foliar urea application.

Results and Conclusions

Total nitrogen content of the leaves increased from 2.5% in September 1991 to 2.9% in September 1992. Thus, a spring application of low-biuret urea appears to contribute to the annual nitrogen requirement of the tree.

In the first year of the study, spring foliar applications of low-biuret urea had no statistically significant effect on the population densities of *Scirtothrips cirti*. The high degree of variability in the number of thrips in each of the replicate samples made it impossible to detect statistically significant differences due to any of the treatments. In the first year of the study, spring foliar applications of low-biuret urea had no statistically significant effect on fruit scarring determined as either on-tree evaluations of fruit on the outside of the tree on September 2, 1992, or evaluation of total fruit per tree at harvest March-April 1993 (Table 1). While not significant at the 5% level, it is interesting to note that the May 20, 1992 foliar application resulted in the lowest degree of fruit scarring, especially severe scarring. This trend can be seen in both the on-tree and harvest evaluations. The correlation between the on-tree counts and whole tree harvest data are given in Table 1. Note that there is much variability in this correlation. For that reason, the data from all 48 data trees per treatment were subsequently analyzed as follows: whole tree harvest data were used as is, whereas the on-tree outside fruit data were transformed to a whole tree harvest evaluation using the correlation given in Table 1. The transformed data did not yield statistically significant separation between treatments, except in two cases. The May 20, application of low-biuret urea had significantly lower fruit scarring than the May 5 application of low-biuret urea, as determined by the on-tree counts and whole tree harvest data with transformed on-tree counts. Numerically, but not significantly, this trend was consistent. The May 20 application of urea resulted in slightly reduced scarring than the control trees.

Table 1. Effect of Foliar Applications of Low-Biuret Urea to 'Frost Nucellar' Navel Orange Trees in Ivanhoe, CA on Fruit Scarring by Citrus Thrips

	On-tree outside fruit September 2, 1992					Whole tree harvested fruit March-April 1993					Correlation between on-tree and harvest data			
			% scarred fruit					% scarred fruit						
Urea application date	# of trees	# of fruit	slight (a)	severe (b)	total (c)	# of trees	# of fruit	slight (d)	severe (e)	total (f)	(d)/(a)	(e)/(b)	(f)/(c)	
April 7	48	3284	23.3 a[z]	25.4 a	48.7 a	19	20,974	16.6 a	20.7 a	37.2 a	0.71	0.81	0.76	
April 21	48	3543	22.2 a	25.5 a	47.6 a	18	20,993	15.6 a	22.0 a	37.6 a	0.71	0.86	0.79	
May 5	48	3174	24.8 a	24.1 a	48.9 a	18	20,483	15.7 a	20.9 a	36.6 a	0.64	0.87	0.75	
May 20	48	3476	20.9 a	19.8 a	40.7 a	18	20,765	14.9 a	16.1 a	31.0 a	0.71	0.81	0.76	
Control	48	3147	23.5 a	22.2 a	45.7 a	18	19,491	14.7 a	18.9 a	33.7 a	0.63	0.85	0.74	
												Means		Grand Mean
											0.68	0.84	0.76	0.76

[z] Means in a vertical column followed by the same letter are not statistically different at the 5% level.

Table 2. Effect of Foliar-Applied Urea on the Predatory Mite, *Euseius tularensis* (hibisci)

		Cumulative # of mites/leaf[z]	
Urea application date	Mite release on March 19 (500 mites/tree)	through May 28	through July 9
April 7	Yes	0.92b	2.08a
April 21	Yes	1.23ab	2.21a
May 5	Yes	1.11ab	1.81a
May 20	Yes	1.59a	2.41a
Control	Yes	1.33ab	2.43a
Control	No	0.48c	1.06b

[z] Data are the mean of analyses of one tree per block x eight blocks; means in a vertical column followed by different letters are statistically different at the 5% level.

There were no statistically significant correlations at the 5% level between the degree of fruit scarring, *S. citri* population data, and maximum leaf NH_3-NH_4^+ concentrations. The results of the first year of the study provided clear evidence that a spring foliar application of low-biuret urea had no negative effect on the population densities of beneficial predatory mite, *Euseius tularensis* (hibisci). In Table 2, it can be seen that there was no significant difference in the number of *E. tularensis* mites per leaf for trees on which 500 mites had been released on March 19, whether or not these trees were left as controls or subsequently sprayed with low-biuret urea on the date indicated. The number of mites per leaf was not due to a natural increase in the population during the course of the study, since the control trees on which no mites were released had significantly lower numbers of mites per leaf on both sampling dates.

Table 3. Effect of Spring Foliar Application of Low-Biuret Urea on the Yields of 'Frost Nucellar" Navel Orange[z], 1992

Urea Application Date	Pounds of fruit/tree	P≤0.05	P≥0.10	# of fruit/tree of packinghouse carton size 56	P≤0.05	P≥0.10
April 7	570	b	b	135	b	b
April 21	601	ab	ab	148	ab	ab
May 5	572	b	b	136	b	b
May 20	639	a	a	166	a	a
Control	585	ab	ab	153	ab	b

[z] Data are the means of 48 data trees per treatment. Means in a vertical column followed by a different letter are statistically different at the P value indicated.

In the first year of the study, there were statistically significant differences at the 5% level between dates of urea application to the foliage in terms of total weight of fruit per tree and the number of fruit of packinghouse carton size 56 (fruit with diameters between 8.1 and 8.8 cm). The date of foliar urea application had no statistically significant effect on other sizes of fruit (Table 3). The May 20 application of low-biuret urea had the highest total fruit weight and the highest number of fruit of packinghouse carton size 56. In both cases, the May 20 application was statistically better at the 5% level than the April 7 and May 5 spray dates. However, the April 7, April 21, and May 5 treatments were not statistically different from the control at the 5% level. At the 10% level, the May 20 application resulted in significantly more total weight of fruit per tree and more fruit per tree of packinghouse carton size 56 than the control and all other treatments, ex cept the April 21 application.

It can be seen in Table 3 that the trees receiving the May 20 foliar application of low-biuret urea yielded 54 lbs more fruit than the control trees receiving soil-applied nitrogen. This represents an additional 1.35 40-lb carton of fruit per tree or a 9% increase in yield. At a typical planting density of 96 trees per acre, the May 20, 1992 foliar application of low-biuret urea would yield 130 additional cartons per acre. For the cost/benefit analysis, we used the following values: 1) The May 20 foliar application of urea increased the number of fruit per tree of packinghouse size 56 and had no effect on any other fruit size; thus, we used the price of $8.00 per 40-lb carton which was the low value in effect at the time of our harvest (March-April 1992), for 56's, 72's, and 88's and subtracted $2.29 per carton for packinghouse handling of the extra cartons (per Connelly Melling; Dole) to calculate profit; 2) 15 gallons low biuret urea per acre at $1.10 per gallon; and 3) spray rig at $25.00 per acre to calculate expenses with all other expenses being the same, although there really is the expense of a soil application of nitrogen to the control trees which we did not include. Despite this, the net return to the grower for the May 20, 1992 foliar application of low-biuret urea was $740 per acre.

The first year of the study was a very heavy thrips year. Our results suggest that urea will not have much impact in preventing thrips scarring of fruit when thrips pressure is great. The performance of urea in reducing the percentage of fruit scarred by thrips in a light thrips year or in combination with sabadilla treatments remains to be determined. The increase in yield without a reduction in fruit size observed for the May 20 foliar application of low-biuret urea is encouraging, but awaits confirmation by a second and third year field trial. No conclusions can be drawn until this field trial is replicated for at least a second year.

A copy of the latest annual report titled "Citrus Growers Can Reduce Nitrate Groundwater Pollution and Increase Profits: Annual Report " is available from FREP. Please see Section X for ordering information.

Potential Nitrate Movement Below the Root Zone in Drip Irrigated Almonds

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Project Objectives

This project was initiated to assist growers to better manage fertilizer nitrogen application through drip irrigation systems in order to achieve profitable almond production and reduce possible adverse affects on the environment. The study was designed with these objectives:

1. To assess the extent of nitrate movement under drip emitters from different nitrogen rates, each applied at two water levels.

2. To evaluate nitrate movement beneath drip emitters when different nitrogen sources are utilized.

3. To evaluate the effects of different nitrogen rates applied at two water levels on growth, nutrient concentrations in leaves and twigs, and nut yields of almonds.

4. To develop recommendations for nitrogen, irrigation and soil management for use in the establishment and early maturity stages of drip irrigated almond orchards.

5. To evaluate changes in soil acidity and nutrient (N, K, Ca, Mg) movement within the drip zone as a result of different applied nitrogen rates at two water levels and also different sources of nitrogen fertilizer.

6. To evaluate the effects of two rates of potassium on growth, nutrient concentrations in leaves and nut yields.

Project Description

Drip and other limited soil area irrigation is a unique method of providing water to trees which makes for a number of challenging management situations. Even though it is practiced on a relatively small percentage of the irrigated acreage in the state (perhaps <10%), drip irrigation has and will undoubtedly continue to increase because of the rising cost and reduced availability of water. Since water is applied to a more limited soil area, excessive amounts may move and also leach nutrients more rapidly than when other irrigation systems are used. The use of drip irrigation means that a relatively small volume of soil is used as the reservoir for water and nutrient uptake. Therefore, the soil is saturated a high percent of the time during the summer which provides a setting for several unusual chemical reactions in the soil. The use of an acidifying nitrogen fertilizer such as urea or any other ammonic form increases the solubility of potentially toxic elements like manganese and aluminum.

In an experiment which has been underway for several years, soil sampling of the high nitrogen-high water treated plots has indicated some nitrates have been leached below the root zone immediately below the drip emitter. The low nitrogen-low water treatment samples suggest little or no leaching of nitrates. A reevaluation of nitrate and other nutrient movement in the high and low nitrogen rate treatments as well as several of the three intermediate rates at the two water levels is being conducted. Soil sampling of another experiment having several different nitrogen sources is also being conducted. This project expands on an ongoing study that has been partially funded by the Almond Board wherein growth, nutrient concentrations in leaves and twigs, and nut yields of almonds are being measured.

This study is being conducted in an orchard that was planted at the Nickels Soil Laboratory near Arbuckle, CA in the spring of 1981 to three almond varieties--Butte, Carmel and Nonpareil-- on a 12' X 18' spacing (202 trees/A). In the spring of 1982, five 5-tree plots were selected from each of the four 28-tree rows of each variety to which the two replications of the ten treatments were assigned. The ten treatments included two water levels-0.6 and 1.0 of evapotranspiration (ET) each with five nitrogen rates-0, 0.5, 1.0, 1.5 and 2.0 oz/tree in 1982; 0, 0.8, 1.7, 3.5 and 7.0 oz/tree in 1983; 0, 2, 4, 8 and 16 oz/tree in 1984; 4, 8, 16, 24 and 32 oz/tree in 1985; 6, 12, 24, 36 and 48 oz/tree in 1986; 8, 16, 32, 48 and 64 oz/tree in 1987 and 1988; 6, 12, 24, 36 and 48 oz/tree in 1989; 4, 8, 16, 24 and 32 oz/tree in 1990, 1991 and 1992. Rates being applied in 1993 are 0, 4, 8, 16, and 32 oz/tree on two timing schedules; 1) one third each on 4/1, 5/1 and 7/1, and 2) one third each on 6/1, 8/1 and 9/1. Urea, the nitrogen fertilizer source, was applied on a monthly basis in five (6 in 1986-89) equal increments beginning April 1st prior to 1993. The 1.0 ET irrigation level is based on climatic data from CIMIS and the 0.6 ET treatments receive 60% of that amount. In a second experiment different nitrogen sources have been used for several years. They are urea, calcium nitrate, urea-calcium nitrate in alternating years, UN 32, N-phuric and 5 additional urea treatments to which different soil pH amendment materials will be added.

Results and Conclusions

Tree trunk circumference measurements were taken in December and cross-sectional area was calculated to monitor tree growth for the 1992 growing season (299 trees). The data indicated there was a trend for the high water level to result in slightly greater increases in tree growth. There was no discernible effect of nitrogen rate on the tree trunk growth increases. These growth increases are somewhat different from earlier years when nitrogen rate was the more dominant factor in influencing trunk growth. A trend was observed for the Nonpareil variety to have a slightly larger increase in growth than the Butte variety which had only a marginally greater increase than the Carmel variety.

Twig samples from each of the 60 plots were taken twice- at early dormancy (December 17-18, 1992) and late dormancy (February 26, 1993). Significantly higher twig total nitrogen (N), calcium (Ca), sulfur (S), zinc (Zn), manganese (Mn) and boron (B) concentrations were associated with higher applied N rates for both sample dates. Water level had no effect on nutrient levels. At the early sampling date, significantly lower concentrations of potassium (K) were present at the higher N rates. No significant differences were observed in twig total phosphorus for the nitrogen rate-water level treatments. Higher concentrations in total N, P and K, slightly lower total Ca and nearly the same total S, Zn, Mn and B were observed in the late versus the early dormancy samples. It was also noted that at both sample dates the ranking for the three varieties from highest to lowest was Carmel > Butte > Nonpareil for the nutrients total P, S, Zn and B. The ranking was the same in the early sample date only for total N and K. For total Ca, the ranking was Butte > Nonpareil > Carmel on both sample dates. No differences between varieties was observed for either sample date for total Mn.

Leaf samples were taken in 1993 on April 2 and 5, May 3, June 2, July 6 and 7, and August 5. Only the results for total potassium (K) of the May and June sample date are available at this time. On both sample dates total K concentration was reduced with higher rates of applied nitrogen. No water level effect on leaf total K was observed and there was no difference in total K between the three varieties. The total leaf K concentration was increased significantly in the applied K treatments in the June sampling with a strong trend indicated in the May sampling.

Almond yield determinations for 1993 (Nonpareil variety) are currently being processed with the Butte variety harvest planned for September 24 and the Carmel approximately one week later. Hull, shell and kernel (meat) fractions will also be determined along with the total nitrogen of each fraction for calculating nitrogen removal by the harvested crop.

Soil samples were taken during the October through December period from several of the nitrogen rate-water level treatments. Samples were taken immediately under and at various distances from the emitters to various depths to assess nitrate and other nutrient movement. Very little nitrate or ammonium nitrogen was present in the samples from the two lowest N rate treatments with only small accumulations in the middle rate. At the two higher N rate treatments, both nitrate and ammonium nitrogen concentrations were higher, particularly with the lower water level treatment.

Plans are to take soil samples during October and November from plots where several different nitrogen fertilizer treatments have been applied. Samples will be collected from immediately under and at various distances from the emitters to a depth of about six feet or more to learn the degree of nitrate movement below the root zone. Earlier sampling has indicated a slightly greater acidification effect when the more acid forming materials were applied.

A copy of the latest annual report titled "Nitrogen Management in Drip Irrigated Almons - Orchard Establishment Years and Beyond: Annual Report " is available from FREP. Please see Section X for ordering information.

Nitrogen Efficiency in Drip Irrigated Almonds

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Project Objectives

This research is designed to determine the fate of fertilizer N applied to a drip irrigated almond orchard under acidified soil conditions. This information does not currently exist for finer textured soils nor for sandy soils. The use of stable isotopes will allow us to directly measure whole plant uptake (tops, roots and the crop). Knowing uptake, N efficiency in drip systems can then be calculated.

Project Description

Three replications of drip irrigated Nonpareil almonds on Lovell peach root were pretreated (fertilized) with ammonium sulfate or calcium nitrate to produce differences in soil acidity in the wetted soil volume. Fertilizer application rate for two years prior to treatment was 800 lbs per acre in split monthly or bimonthly applications for 1989 and 1990. Beginning in April 1991 ^{15}N-depleted ammonium sulfate was applied to the ammonium sulfate and calcium nitrate treatments. On January 21 and 22, 1992 six treated trees were extracted from the ground, chipped and weighed to determine the biomass in branches, stems, medium roots and coarse roots. Subsamples of these components were analyzed for total and isotopic N ratio in order to determine total N uptake and recovery of the applied lable. Soil cores from treated plots were obtained in March to determine root distribution and fine root mass as well as nitrogen distribution around the treated trees. Vacuum soil solution samplers and platinum electrodes have been installed to measure soil solution composition and aeration status in the drip zone.

Results And Conclusions

Before the ^{15}N-depleted ammonium sulfate was applied the ammonium sulfate treatments were distinctly more acid than the calcium nitrate plots. In the surface two feet, pH measured in 1:2.5 $CaCl_2$ averaged 5.59 for the calcium nitrate plots and 4.23 in the ammonium sulfate plots. In spite of the differences in pH, there were no differences in the total soil nitrogen after two years of heavy fertilization. However, extractable ammonium and nitrate distribution were different between the treatments. Nitrate extracted by KCl averaged 5.5 $mgkg^{-1}$ while extractable ammonium was 1.1 $mgkg^{-1}$ in the upper 36 inches of the calcium nitrate plots. In comparison the average nitrate level was 12.5 $mgkg^{-1}$ and extractable ammonium averaged 38.8 $mgkg^{-1}$ in ammonium sulfate plots. Thus prior to application of the ^{15}N-depeleted material, soils in the calcium nitrate plots were less acidic and lower in extractable nitrogen than soils of the ammonium sulfate pretreatments. In previous years foliage from the ammonium sulfate plots had been higher in total nitrogen than foliage from the calcium nitrate plots.

Examination of Table 1 shows that the majority of the biomass is associated with the tree stem and branches, which averaged 264 lbs per tree. None of the component biomasses were significantly different between the calcium nitrate and ammonium sulfate pretreatments. Likewise for the total nitrogen content there were no significant differences between pretreatments. The roots greater than 1/4 inch in diameter accounted for 16% of the total measured biomass but contained 36% of the nitrogen in these components (Table 2). This reflects the fact that the woody tissue such as stem and branch wood is generally low in nitrogen. Average above ground biomass combined with the coarse and medium roots was 336 lbs per tree. This calculates out to be 33.9 tons of dry material per acre. Another way to view this data is to consider that about 360 lbs of N are need to construct the above ground structures plus the coarse and medium roots in this orchard. Additional N is cycled into the foliage and fine roots. This additional N is retained in the orchard, while some N is removed in the crop. We are in the process of determining the amounts for these additional components.

Table 1. Dry weights of tops, coarse roots, medium roots and stumps of trees extracted in late January 1992. (Pounds of dry weight per tree)

Treatment	Tops	Coarse Roots	Medium Roots	Stump	Total
Ammonium sulfate					
AVERAGE	254	30	24	22	323
SDEV	25	8.5	4.2	4.0	23
Calcium Nitrate					
AVERAGE	273	24	31	20	348
SDEV	39	2.6	1.5	2.6	40

Table 2. Total nitrogen contained in the tree components (lbs/acre).

Treatment	Top	Coarse Roots	Medium Roots	Stump	Total
Ammonium sulfate					
AVERAGE	211	62	64	11	348
SDEV	4	23	17	1	39
Calcium nitrate					
AVERAGE	221	51	86	10	369
SDEV	16	7	13	3.5	17

Table 3 contains the data for nitrogen in the various tree and crop components which have been derived from the 15N-depleted source. In the calcium nitrate plots a greater fraction of the total N for all components was derived from the ^{15}N-depeleted fertilizer source. These differences were statistically significant for all of the components except the tops which is affected by one replication that is substantially lower than the other two in the calcium nitrate treatments. Using the crop values for 1991 and the 1992 biomass data, total uptake derived from the ^{15}N-depeleted material was 42 lbs per acre for the ammonium sulfate plots and 63 lbs per acre for the calcium nitrate plots. This accounts for 21 and 31% of the N applied (200 lbs per acre) during the 1991 season. The reason for this greater utilization in the calcium nitrate plots is not known. Since there was less available N in the calcium nitrate plots prior to ammonium sulfate addition, the fertilizer would have been a greater fraction of the available N pool in the calcium plots. However, further analysis is necessary to elucidate the reasons for this substantial difference between treatments in the total N labeling. Data for fine root biomass and nitrogen content as well as soil solution N and extractable N are currently being processed. With these data a more complete N budget can be constructed and the effects of soil acidity and nitrogen form on N use will be more apparent.

Table 3. Nitrogen (% of total N) derived from ^{15}N-Depleted fertilizer in 1991 and 1992. Component means with an *, or *** are significantly different at the 0.05, 0.01 and 0.001 level respectively between treatments.**

Treatment	Tops	Component Fine Roots	Coarse Roots	Stump	Kernal	Husk & Shell
Ammonium sulfate						
AVERAGE	9.09	14.24	10.79	12.50	5.34	4.16
SDEV	0.51	1.77	0.77	1.57	1.22	0.60
Calcium nitrate						
AVERAGE	12.85	20.87***	15.48**	17.91**	8.59**	6.91**
SDEV	3.23	0.84	1.72	1.64	0.95	0.98

A copy of the latest annual report titled "Nitrogen Efficiency in Drip Irrigated Almonds: Annual Report " is available from FREP. Please see Section X for ordering information.

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

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Background

Crop production in California typically utilizes significant inputs of relatively inexpensive, highly soluble inorganic N fertilizers. This applied N can move, as nitrate, out of the crop root zone and cause significant ground water contamination. Many factors contribute to this problem, including the relatively high rates of N fertilizer applied to many crops and the low levels of organic matter and microbial activity present in most of California's agricultural soils. Livestock operations involving large concentrations of animals, and the resulting manure, represent another major source of nitrate in California. Nitrate from manure can leach directly from livestock facilities if the manure is not handled properly. In addition, N from manures can also leach from crop fields when manure is applied at sufficiently high rates. Composting manure stabilizes the N present in the material so that it mineralizes more slowly and thus is less likely to leach as nitrate. .

Moreover, the use of such composted materials as soil amendments has many benefits. Adding compost to the soil is a desirable way to add relatively stable, but not nutrient (e.g., N) deficient, organic matter to the soil. It has been known for many years that soil organic matter is important for optimal crop performance. Not only does it enhance soil fertility by supplying nutrients to crop plants, but it also can improve soil chemical, physical and biological properties. Many problems associated with low organic matter levels (e.g., poor root growth, increases in soil borne diseases) can contribute to problems of inefficient fertilizer utilization and thus nitrate leaching.

Farmers also need to be familiar enough with soil N dynamics that they can understand and compare the potential benefits and risks of various practices (e.g., integrating the use of organic and inorganic sources of N vs. attempting to supply all of a crop's N needs with compost or manure). Interested farmers also need access to accurate information about the processes and technology of composting and how to evaluate the various composts and manures that may be available to them.

With the implementation of recent laws governing municipal wastes (e.g., AB 939), a variety of materials are becoming available. Some of these are very high quality materials, but others have questionable utility, and may even be harmful for use on crops. Such laws also will regulate certain aspects of agricultural "waste" management, including composting, and farmers and ranchers need to be educated about these and related laws and regulations that may directly affect them.

Objectives and Activities

The objectives of this two year program we are conducting are to educate farmers, livestock producers, industry, government and University representatives in the following areas:

1) Composts and manures - advantages, disadvantages, effects on soil properties, N dynamics, crop growth, how to evaluate and use them.

2) Composting -- biological processes and effects, management techniques, tools and equipment.
3) Legal aspects of agricultural waste management, fertilization and pollution.

These objectives are being met through public presentations/workshops and the production of a short, concise publication. The presentations are targeted to those areas and production systems of the state believed to be most critical in terms of agricultural nitrate pollution of ground water. These include Sutter, Yuba and Butte Cos. (deciduous trees); San Joaquin, Merced and Stanislaus Cos. (deciduous trees, dairy, poultry); Fresno Co. (deciduous trees, citrus); Tulare and Kern Cos. (deciduous trees, citrus, livestock); Monterey, San Benito and Santa Cruz Cos. (row crops). Presentations are made in coordination with other UC and non UC units. A number of these presentations are being made as a part of larger events, such as UC Cooperative Extension "grower meetings".

In March of 1993 a presentation was made in Monterey county to vegetable growers, consultants, farm advisors and industry representatives. During the same month, a presentation was made at the Organic Fertilizer and Amendments Conference at UC Davis. In April a third presentation was made at the UC SAREP Ecological Soil Management Symposium. At the time of this writing five or six presentations are being scheduled for the fall and winter months of 1993-1994. These will include a February presentation in Stanislaus county and a January presentation in San Luis Obispo. In addition, we will be involved in a field presentation of on-farm composting and municipal waste composting at the Farm Conference '94 in Ventura county.

The compost publication will cover topics outlined at the beginning of this section and will be available from FREP by June, 1994.

Crop Management for Efficient Potassium and Optimum Winegrape Quality

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Project Objectives

Most of the research on mineral nutrition and irrigation of grapes in California has been conducted on one variety, Thompson Seedless, and on light soils in the Central Valley. Thus winegrape growers are largely adrift in terms of the fundamental knowledge necessary to establish prudent objectives for nutrient and soil management, especially on the heavier, potassium-fixing soils on hillsides and in the coastal valleys. This lack of understanding and the high cash value of premium winegrape production create an environment conducive to heavy fertilizer use. When in doubt, the grower of premium winegrapes is likely to apply fertilizer. This project is directed at removing the doubt about the role of potassium (K) in winegrape production and identifying alternative approaches to high rates of fertilizer application in correcting K deficiencies.

The information developed by this project will be important in establishing complete mineral nutrition programs that maximize fertilizer use efficiency. Our research program constitutes an initial foray into two potentially important controls in K use efficiency in winegrapes-- interaction with soil water content, and genetic differences in K uptake and utilization.

Experiments are underway to investigate several approaches to increasing the efficiency of potassium fertilizer use on clay soils, and to evaluate whether improved plant potassium status leads to improved efficiency of nitrogen fertilizer utilization. The problem of potassium deficiency on heavy soils creates a special need for efforts to improve efficiency because high rates of applications are often required to obtain plant responses. Our objectives are to test the potential of altered fertilizer placement, altered irrigation regimes, supplemental gypsum applications, and selection of rootstocks in winegrapes for decreasing the need for high rates of fertilizer applications. We also will re-evaluate the existing criteria for vine potassium requirements because these requirements may not be valid for some winegrape varieties and rootstocks. These objectives will be met by collecting data on vine potassium status, vine growth and productivity, and on soil water and potassium status from a series of field trials on sites predetermined to be problem soils for potassium nutrition. The project will culminate in a recommendation for improved potassium, and possibly nitrogen, fertilizer efficacy that will include rootstock selection, irrigation regime, and fertilizer placement.

Project Description

It is probable that winegrape varieties in California differ significantly in potassium requirements for productivity and quality. Christensen showed large differences among varieties in the concentrations of nitrogen and potassium in petioles for vines grown on the same soil. Genetic solutions to crop production problems are often best because they require less on-farm management and are generally stable. This would be true for potassium-efficient fruiting varieties or rootstocks. Preliminary results suggest that Pinot noir may require lower concentrations of K in the vines for maximum productivity than Chardonnay. We have observed no yield responses to potassium sulfate treatments in Pinot noir, whereas yield increased between 5% and 60% in the Chardonnay rootstock trial. This difference is not attributable to lower initial K status nor to a greater increase in K status in the Chardonnay compared to the Pinot noir. The range of yield responses among the rootstocks (0 to 60% increases in 1990) suggests that these rootstocks vary significantly in K uptake and in the responses in reproductive growth to K fertilizer applications on a low K soil. This suggests that among the alternatives for managing a soil with low available K are the choice of fruiting variety and rootstock.

Another alternative may be altered irrigation management. Winegrape production often involves the imposition of some degree of water deficit during fruit ripening. We hypothesize that some interaction between soil water content and K availability is leading to diminished K uptake during the fruit ripening. Symptoms of K deficiency usually occur after the onset of fruit ripening on these soils, perhaps due to the drying and contraction of the clay soils which commonly occur in the North Coast. On such soils, the supply of immobile nutrients may be depleted during the season, the availability may decline due to soil drying (dry fixation) in the upper soil profile, or K uptake may decline due to inhibited root activity under dry soil conditions. Both of the latter situations could give rise to late season deficiencies which were not detectable by petiole analysis at bloom time, an observation commonly made in regard to K. Again, preliminary results indicate that supplemental irrigation eliminated the decline in vine K status that occurs during the season under the standard irrigation regime.

Experimental sites were selected on the basis of: low petiole [K], low soil K analyses, late season K deficiency symptoms, lack of recent application of soil amendments, high soil clay content, (particularly vermiculite and smectite, which indicate potential for K fixation), presence of premium winegrape varieties that represent large acreage, relatively uniform soil and vine growth.

A field trial has been established to test the hypothesis that K uptake is limited by K availability and/or root activity in the upper soil profile. The site is a commercial Pinot noir vineyard on a clay loam soil that exhibits low petiole [K] by standard UCD criteria, and had not received fertilizer treatments for at least the previous five years. Treatments were imposed to increase K availability and uptake by fertilizer placement treatments and by altered soil water contents. Potassium sulfate fertilizer was applied to individual vines prior to budbreak by the standard method of incorporation into the soil beneath the drip emitter (at rates of 0, 4 and 8 lbs. per vine and via a 6" diameter auger hole approximately 2.5 ft. deep at 8 lbs. per vine). The auger hole is within 18" of the vine trunk and away from the vine row. In order to test whether irrigation can be used to improve K uptake, the above plots were split and some vines irrigated by the standard practice and others by rates that are two and four times higher.

A second field trial has been established in a commercial vineyard that contains Chardonnay scions on own roots and on St. George, AxR#1, 5C, 110R, 1202, and Freedom rootstocks in a randomized complete block design with whole row plots and three replications. The site is on a clay loam and the vines express significant K deficiency symptoms after veraison in each session. In each rootstock treatment, 8 lbs. of potassium sulfate per vine was applied to some vines and these plots were split to impose standard (no irrigation) and supplemental (weekly applications) irrigation treatments, creating 12-vine plots. Our initial results indicate large differences among rootstocks in vine K status (up to 100%) and in yield responses to applied K (from nil to 63% increases).

A third field trial was established near Healdsburg, CA, in a mature vineyard of Chardonnay vines where the vines generally express symptoms of K deficiency late in each season. Twelve-vine plots were established incorporating five treatments, including an untreated control; potassium sulfate; potassium sulfate+gypsum at similar rates; potassium nitrate; and calcium nitrate at a rate to produce similar nitrate as in the other N treatment. Treatments were applied in a randomized complete block design with five replications. Fertilizer was incorporated beneath the drip emitter as in other experiments and consistent with standard practices.

Results and Conclusions

When water was applied to the Pinot noir site at 3x the standard irrigation practice (which is less than that required to maintain high soil water contents) vine K status decreased less after bloom. For unfertilized vines, the K status at harvest was almost 2x greater in the supplemented treatment than with standard irrigation. This petiole K concentration, 0.51% d wt, was approximately the same as that attained by fertilized vines receiving standard irrigation. For fertilized vines with supplemented irrigation, K status increased between bloom and harvest, reaching 1.23% d wt. This is almost 500% greater than the untreated controls.

Initial soil analyses at the second site indicated low K and high Mg concentrations (exchangeable). K applications beneath the drip emitter were effective in moving K into the root zone to at least a depth of 75 cm. This method was also effective in decreasing the Mg concentrations by approximately 50% throughout the profile. We saw that the K status of Chardonnay vines varied significantly at this site. When supplemental irrigation of K fertilizer was applied, K status of most vines increased with a mean across all rootstocks of 0.23% K (irrigation) and 0.29% K (fertilizer). The effects of applied K and supplemental irrigation on vine K status response varied with rootstock. The change in vine K status due to fertilizer application varied from a negative 0.1% on 5C to an increase of 0.4% on St. George.

The rootstocks 110R, 5C, AxR#1, St. George, and 1202 were investigated to determine whether they caused differences in the K status, fruitfulness and yield of Chardonnay. Over two seasons the K in bloom petioles were more than two times greater in 5C than 110R. One year after K fertilizer was applied (8 lb. K_2SO/vine) , yield and clusters/vine increased (up to 60%) for all rootstocks except 5C. The high yield, high petiole K and lack of a yield response to applied K on vines on 5C suggest that 5C is more effective at absorbing K from this soil. The results show that there are significant differences among rootstocks in K uptake and in the productivity of the scion at a given petiole K status.

A copy of the latest annual report titled "Crop Management for Efficient Potassium and Optimum Winegrape Quality: Annual Report " is available from FREP. Please see Section X for ordering information.

Impact of Microbial Processes on Crop Use of Fertilizers from Organic and Mineral Sources

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Project Objectives

Efficient use of fertilizers resulting in maximum plant productivity and minimal environmental harm is desirable both to the agricultural community and members of the general public who rely on groundwateras a source of drinking water. The successful functioning of agricultural systems depends on the timely delivery to plants of nitrogen and other nutrients from mineral fertilizers and from decomposition of organic residues, both of which are strongly influenced by microbial activity in soils. Soil microorganisms are both a significant reservoir of plant nutrients and are responsible for the transformation of nutrients into forms available for crop uptake. The microbial community is typically treated as a "black box" and measurements of the consequences of its activities are made without an understanding of underlying mechanisms. Knowledge of the mechanisms involved, however, is essential if recommendations, such as for fertilizer inputs, are ever to be truly predictive, and thus useful, to growers. With an understanding of the synchrony between crops and microorganisms in nutrient cycling, it may be possible to increase fertilizer use efficiency by managing the microbial biomass through specific farming practices.

The primary objectives are to determine relationships among: 1) microbial biomass and activity, 2) soil fertility parameters, particularly N pools; 3) crop tissue levels over the growing season; and 4) crop yield and quality at the end of the growing season. Studies are conducted in tomato and corn under three different N management systems: 1) N from mineral sources only; 2) N from cover crops and manure; and) N from cover crops supplemented with mineral sources.

Project Description

The study site is the long-term Sustainable Agriculture Farming Systems Project, located at the Agronomy Farm at U.C. Davis, and now in its fifth year of study (funded by USDA SARE, USDA/EPA ACE, H.J. Heinz, UC SAREP, and CDFA/FREP) The project measures changes in soil fertility, crop, pest and economic parameters in four farming systems: conventional 2-yr rotation, conventional 4-yr rotation, organic 4-yr rotation (following CCOF guidelines), and a low-input 4-yr rotation. All rotations follow the sequence: tomatoes, safflower, corn, and wheat or oats-vetch/ beans. Table 1 summarizes the production practices for tomatoes (1992).

Table 1. Tomato Production Practices, 1992.

Operation	Organic	Low input	Conv. 4 yr	Conv. 2 yr
Planting	transplants	transplants	seeds	seeds
N Fertilizer				
Preplant & starter	cover crop manure	cover crop 8-24-6	6-20-20	6-20-20
Sidedress & topdress	fish powder seaweed	30 lb ammonium nitrate	120 lb ammonium nitrate	120 lb ammonium nitrate
Pesticides	--	--	Roundup Devrinol Asana XL	Roundup Devrinol Asana XL

For the CDFA FREP study, measurements in soil during the 1993 growing season included measurements of: 1) nutrient pools in the microbial biomass: microbial biomass C (MBC) and N (MBN), potentially mineralizable N (PMN), 2) microbial activity: arginine ammonification (ARG) indicating the potential for mineralization of organic N and substrate induced respiration (SIR) indicating the potential for respiration of carbon dioxide, and 3) mineral nutrient pools: nitrate, ammonium, sulfate. Plant tissue analyses included total nitrogen, phosphorus, and sulfur. Frequent (7-10 day intervals) soil samples were taken in the conventional 4-year and organic tomato plots. Monthly measurements were made in the other tomato farming systems and in the corn systems.

Results and Conclusions

Measurements of nitrate (Fig. 1) and ammonium throughout the growing season were lower in organic than conventional plots. Preliminary results from soil samples collected in tomato plots during the 1993 growing season are presented below. Not all analyses have been completed and data presented here are potentially subject to change. Graphs of changes in parameters over time are plotted as Julian days (JD) where JD1=January 1, JD32=February 1, etc.

Measurements of nutrient pools and activity levels in the microbial community completed so far were consistently higher in organic than conventional plots. Potentially mineralizable nitrogen (PMN)is an index of the amount of organic N available to crops over the growing season and is closely linked to the microbial population. PMN is an important soil fertility measurement because a significant portion of a crop's nitrogen comes from organic sources, even in mineral fertilized systems. Fig. 2 shows that PMN at the beginning of the cropping season (JD93) was larger in organic than conventional plots, suggesting the maintenance over winter of a higher microbial population under vetch than under bare fallow. PMN in the organic plots showed an increase after vetch incorporation, whereas there was little change in the conventional plots. Both systems had decreased PMN levels by JD 129 (mid-May); however, the drop was less extreme in the organic than conventional system. ARG levels, which measure the potential for microbial populations to mineralize organic N, also started out higher in organic than conventional, increased after vetch incorporation in the organic, and showed no change in the conventional plots. Other measurements showed similar trends. Based on these data it can be concluded that the level of nutrients in the microbial biomass and microbial activity are higher in organic than conventional tomato plots and these levels vary seasonally. These data will be compared to soil fertility measurements and tomato petiole N levels over the growing season once analyses have been completed. Also, measurements of crop growth, yield and quality will be compared for the different farming systems.

The results of this study will hopefully be of use in developing better methods for assessing soil fertility and ultimately improving fertilizer recommendations by taking into consideration the microbially-mediated interactions between inorganic and organic pools of N and other elements.

A copy of the latest annual report titled "Impact of Microbial Processes on Crop Use of Fertilizers from Organic and Mineral Sources: Annual Report " will be available from FREP. Please see Section X for ordering information.

Figure 1. Changes in PMN over the Growing Season.

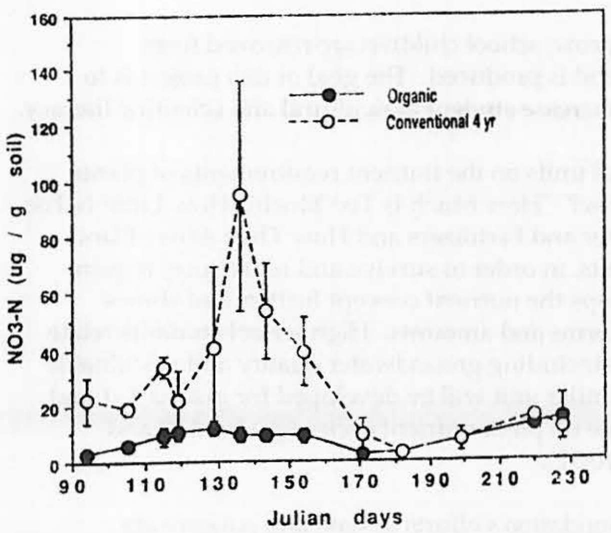
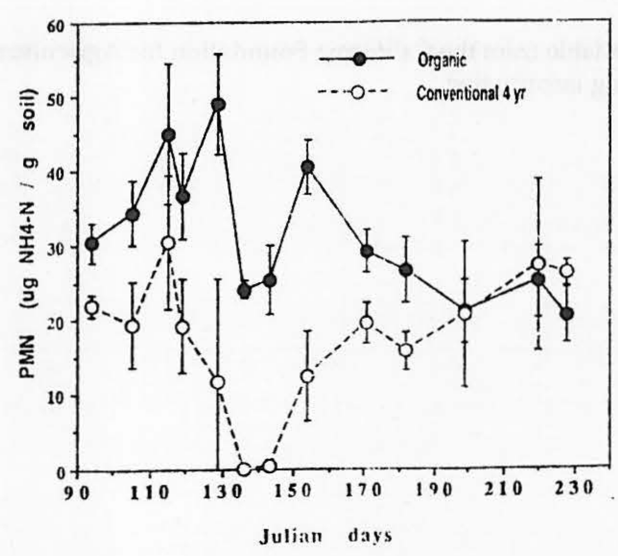


Figure 2. Changes in NO_3^- over the Growing Season



Integrating Agriculture and Fertilizer Education into California's Science Framework Curriculum Grades K-12

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Objectives

As California's urban population continues to grow, school children are removed from agriculture and lack knowledge of how their food is produced. The goal of this project is to provide educators with hands-on lessons that increase student agricultural and scientific literacy.

During the 1992-93 fiscal year, three educational units on the nutrient requirements of plants were developed: "What Do Plants Need To Grow?" "How Much Is Too Much? How Little Is Too Little?" and "The Interrelationships of Soil, Water and Fertilizers and How They Affect Plant Growth." Students in grades 2-4 learn that plants, in order to survive and reproduce, require certain nutrients. The 5th-8th grade unit develops the nutrient concept further and shows students that nutrients are required in proper forms and amounts. High school students relate classroom science to current agricultural issues including groundwater quality and sustainable agriculture. During the 1993-94 fiscal year, a similar unit will be developed for grades K-1 and two supplementary units will be developed--one on plant nutrient cycles (grades 4-8) and another on the chemistry of fertilizers (grades 10-12).

Other aims of the project are to promote the Foundation's efforts at state and nationwide workshops and conferences and to distribute the educational curriculum at low cost to teachers.

Distribution of the educational curriculum began in September, 1993. The Foundation is extremely pleased with the feedback it has received in the short time the units have been available. The Ag in the Classroom staff is looking forward to providing hands-on workshops throughout the year that promote the FREP lessons.

The curricula produced from this project is available from the California Foundation for Agriculture in the Classroom. Please see Section X for ordering information.

Establishing Updated Guidelines for Cotton Nutrition

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Kings Co.

Project Objectives:

1. Establish the relationship between tissue nitrate level and leaf function in cotton. About 50 percent of the nitrogen in a leaf blade is part of a protein RUDPase which through the process of photosynthesis incorporates carbon dioxide into sugars (carboxylation). 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, we must establish the critical level for optimum leaf function.

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 applications between preplant and side dress at the early square stage.

3. Improve the predictive ability of current soil K test procedures. Ammonium extractable K is the soil test currently used to identify potassium sufficiency. Soils with montmorillonitic or vermucillitic clays exhibit K fixation. The current extraction procedure does not adequately consider fixation. Current procedures will be compared to two new possible methods under development. These potentially new methods include water extractable K and a resin-K procedure.

4. Develop nitrogen and potassium 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.

Project Description:

This project brings together a cotton team with expertise in soil science, water management, physiology, agronomy, as well as individuals with educational expertise for proper extension of the project findings. This is the first year of this project. Field tests are still in progress.

Critical Nitrate Levels
Plots were established at the UC West Side 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. Leaves at three positions on the plant have been sampled when they were first fully expanded, the subtending boll was at bloom, bloom plus 21 days, and bloom plus 42 days. This detailed enzyme work to establish the effect of nitrogen rate and timing upon leaf function and longevity has not been completed. All plots were sampled for nitrate on the appropriate sample dates, but tissue analysis has also not been completed.

Growth and development data have been collected throughout the season. Only the first three of five in season samples has been summarized. Growth the last half of June averaged 93 percent of the rate established for non-stressed Acala SJ-2 and square retention was high (95 percent). At this early date all treatments had similar leaf size, leaf area, leaf density, plant height, number of nodes, and similar growth rates. No differences in any variable monitored were noted. On July 12, low nitrogen plots began to show a trend for decreased number of nodes and fewer nodes above white flower. Fruit retention remained high. At this stage of growth no differences were noted in leaf size, area, or density. By late July, low nitrogen plots had growth rates well below the highest nitrogen plots. Fruit retention remained high but differences in leaf size, area, or density were not apparent.

Preplant Versus In Season Nitrogen Application
Detectable nitrogen deficiency symptoms were detected in the water run nitrogen treatments (no preplant N) at the UC West Side Research and Extension Center. Tissue analysis are not yet available. Final plant mapping has been completed. Plots where 200 #/A nitrogen was 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 by 1.3, decreased fruit retention of 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.

Potassium Sufficiency Trials:
Approximately 50 field locations in all six SJV cotton growing counties were screened for soil potassium at two depths. Three locations in each of six counties were selected for study. These 18 field locations represented a difference in soil test level, ranged geographically in the SJV, and represented soils that have fixation characteristics as well as soils without K fixation. Prior to the first irrigation, 0 or 400 #/A of potassium was applied to large scale plots. Petiole and plant growth data were collected four times during the season. This data has not been summarized yet. Final plant map data are currently being collected.

A copy of the latest annual report "Establishing Updated Guidelines For Cotton Nutrition Annual Report" will be available from FREP during the first half of 1994. Please see Section X for ordering information.

VI. Completed Projects

Optimizing Drip Irrigation Management for Improved Water and Nitrogen Use Efficiency

T.K. Hartz
UC Davis
Vegetable Crops
(916) 752-1738

This project was completed in 1992. The Final Report is available from FREP. Please see Section X for ordering information.

Field Evaluation of Water and Nitrate Flux through the Root Zone in a Drip/Trickle Irrigated Vineyard

Donald W. Grimes
Kearney Agricultural Center
Parlier, CA

This project was completed in 1993. The final report is available from FREP. Please see the Section X for ordering information.

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

R. Scott Johnson
UC Kearney Agricultural Center
Parlier, CA

This project was completed in 1993. The final report is available from FREP. Please see Section X for ordering information.

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

Ronald Voss
UC Davis
Small Farm Center
Vegetable Crops

This project was completed in 1993. A copy of the curricula produced is available from the Small Farm Center. Please see Section X for ordering information.

Best Management Practices (BMPs) for Nitrogen and Water Use in Irrigated Agriculture: A Video

Larry Klaas
Agricultural Communications Video Group
Tucson, AZ

Thomas Doerge
University of Arizona Cooperative Extension
Soil and Water Conservation

A copy of the video is available from FREP. Please see Section X for ordering information.

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

Bonnie Fernandez
California Wheat Commission
Woodland, CA

This project was completed in 1992. Please see Section X for ordering information.

Production of a Drip Irrigation and Nitrogen Fertigation Management Videotape for California Vegetable Growers

Project Leader:

T.K. Hartz
UC Davis
Vegetable Crops
(916) 752-1738

Project Objectives:

Production of a videotape and accompanying reference guide which describe:

- Use of empirical drip irrigation scheduling techniques.
- Development of efficient nitrogen fertigation regimes.
- Uses and limitations of techniques to monitor soil moisture and nitrogen status of crop and soil.

Project Description:

The use of drip irrigation for vegetable production is expanding rapidly in California. Currently, more than 70,000 acres of vegetables are produced annually under drip, and thousands of acres are being converted each year. This has important implications for water conservation and nitrate pollution abatement efforts because of the degree of control of water and fertilizer inputs possible with drip.

Efficient management of drip irrigation requires cultural practices which are radically different from conventional furrow or sprinkler irrigation. Significant progress has been made in generating field-based information on drip management practices. Efficient irrigation scheduling programs based on reference evapotranspiration data have been validated for some major crops, and a range of useful soil moisture monitoring equipment is now available. Regarding nitrogen management, efficient fertigation programs have been developed and validated through replicated field trials. Additionally, "quick test" technology (soil solution access tubes, colormetric nitrate test strips, fresh sap analysis by nitrate selective electrode, and leaf reflectance measurement) are increasingly being used to augment traditional laboratory analysis of soil and plant tissue.

Unfortunately, there are no comprehensive reference materials designed for growers, consultants and other agribusiness professionals that summarize current knowledge on efficient management of water and nitrogen fertility with drip irrigation systems. This videotape and accompanying reference guide aim to fill that need. Contents include:

- Nitrogen cycling and crop nitrogen demands.
- Empirical irrigation scheduling techniques.
- Development of efficient nitrogen fertigation programs.
- Uses and limitations of fertility and soil moisture monitoring techniques.

The videotape, in VHS format, is approximately 25 minutes long. It demonstrates the application of this knowledge to the efficient management of water and nitrogen inputs for the vegetable crops which are commonly drip-irrigated. The reference guide provides in-depth coverage of the subject matter.

A copy of the video will be available from FREP in January, 1994 . Please see Section X for ordering information.

Determination of Soil Nitrogen Content In-Situ

Project Leaders:
Shrini K. Uphadyaya, Professor
UC Davis
Biological & Agricultural Engineering
(916) 752-8770

William J. Chancellor, Professor
UC Davis
Biological & Agricultural Engineering

Cooperators:
Gary Smith
UC Davis
Food Science & Technology

Thomas Cahill
UC Davis
Physics

David Slaughter
UC Davis
Biological & Agricultural Engineering

Carlos Castaneda
UC Davis
Crocker Nuclear Laboratory

Robert Zasoski
UC Davis
Land, Air and Water Resources

Project Description

"Site - Specific Crop Management (SSCM) " is becoming increasingly popular among agricultural scientists and engineers because of its potential to reduce production cost, increase productivity and protect the environment. This innovative and futuristic concept of SSCM is often referred by several other *buzz words* such as "Farming by Soil", "Prescription Farming", "Farming by the Foot", "Farming Soils, not Fields", and "Environmental Friendly Production".

Recent advances in computer technology making it possible to process tremendous amounts of information in a short period of time have made the concept of "Site - Specific Farming" almost a reality. A Geographic Information System (GIS) or a Field Information System (FIS) can be used to map the variablility within a field. This map along with a Global Positioning System (GPS) can be used to apply an appropriate amount of chemical or some other input in real-time. Most of this technology is already available. A differential GPS system with a precision of about an inch is currently available for about $9,000. This kind of accuracy is more than adequate for most site-specific applications. The technology in this field is advancing very rapidly and cost is expected to go down even further. Sensors to sense soil organic matter on-the-go have been successfully developed. Grain meters to map the yield have also been developed. The main bottlenecks are the lack of reliable sensors to determine various inputs such as soil fertility level, particularly soil nitrogen, and the form of empirical yield function for different crops in different soils.

This report presents a comprehensive review we conducted which deals with soil nitrogen and its implications on crop production, health and environment, SSCM, spatial variablility and GIS, GPS, sensing soil nutrients such as soil organic matter and nitrogen, grain flow meters and yield mapping, remote sensing, etc..

The complete report is available from FREP. Please see Section X for ordering information.

VI. New Projects

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

Project Leaders:
Carol Frate
Bill Peacock
Steve Sibbett
Neil O'Connell
Kevin Day
Michelle Le Strange
Steve Wright
All of UC Cooperative Extension
Tulare County

Project Objectives

The objectives of this project are to raise the awareness of growers and consultants regarding best management fertilization practices through a county-wide education program using Cooperative Extension newsletters and, ultimately, to improve current fertilization practices.

Project Description

The advantage of most, if not all, best management practices is that they not only protect the environment but they are usually the most profitable practices for growers. A farmer who overfertilizes with nitrogen, or other nutrients may get very high yields but his/her actual profits are less than those of a person who fertilizes to obtain the most profit.

Tulare County Farm Advisors currently produce 10 commodity-based newsletters. A mailing will be sent to all subscribers. Four mailings will be sent out in a year covering basic fertilizer information with an emphasis on nitrogen. More advanced information will be tailored to specific crops and situations in follow-up commodity newsletters.

Certified Crop Advisor Program

Project Leaders:

Al Ludwick
Potash and Phosphate Institute
Mill Valley, CA

Renee Pinel
California Fertilizer Association
Sacramento, CA

For a complete description of this project, please see page 12.

Laboratory Quality Assurance Program

Project Leaders:

Robert Miller
UC Analytical Laboratory
UC Davis

For a complete description of this project, please see page 15.

VIII. Biographies of Speakers and Presenters

Jill Auburn is the information systems manager for the University of California Sustainable Agriculture Research and Education Program. She has also chaired the national Sustainable Agriculture Network coordinating committee and has participated in international sustainable networking projects. In addition, she chairs the Research and Education Committee for the Organic Farming Research Foundation. Her B.A. and M.S. are from Miami Univeristy in Ohio and her PhD. is from the University of California -Davis.

Steve Bassi is Vice President of Farming Operations and Production Services at Tanimura & Antle, Inc., a premier grower/shipper of fresh vegetables in California, Arizona and Mexico. He was previously Celery Product Manager at the same company. Prior to his employment at Tanimura & Antle, Inc., he worked as Pest Control Advisor for 10 years. His current interests include drip irrigation and soil tissue testing for maximum fertilizer utilization. He is a member of the Iceberg Lettuce Research Advisory Board and served on the Technical Advisory Committee for establishing BMP's to reduce nitrate leaching in Monterey County. Mr. Bassi is a licensed Pest Control Advisor and a graduate of California State University at Fresno.

John Brown is a member of the State Water Resources Control Board. John fills the position designated for a registered civil engineer with experinece in the fields of water resources, water rights and water quality related to irrigated agriculture. Prior to his appointment, Mr. Brown was the manager for the Sacramento and Central Valley area office of Camp Dresser and McKee, Inc. He has also worked for the Irvine Co. in southern California for 13 years and served most of those as chief engineer of the Engineering and Water Department, designing and maintaining vast irrigation systems. Mr. Brown is licensed both in civil and agricultural engineering. He served for 15 years as a director for the Orange County Resource Conservation District, eight years on the Board of Governors for the Council of California Growers, and is a graduate of the California Agricultural Leadership Program.

Patrick Brown is an Assistant Professor with 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.

Pamela Emery is the curriculum coordinator for the California Foundation for Agriculture in the Classroom and a middle school science teacher for the Fairfield-Suisun Unified School District. Ms. Emery is responsible for curricula development projects that incorporate agriculture into grades K-12 curriculum and is the lead author of several Fertilizer Research and Education Program curriculum on the nutrient requirements of plants.

John France is the owner-operator of the France Ranch in Porterville. He grows citrus, olives, walnuts, prunes, peaches, nectarines, table grapes, and raisin grapes. He owns and operates France Spreading which applies over 40,000 tons of bulk soil amendments to growers up and down the San Joaquin Valley. He is a certified organic grower on 114 of his 146 planted acres.

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. During that period he managed and consulted on ag technology transfer programs for professionals from European and Latin American countries. He is a graduate of the University of California, Davis Graduate School of Management, and has an M.S. in Agro-Ecology and a B.S. in Agriculture. He has authored over thirty technical papers and publications.

George Hallberg is the Supervisor of Environmental Geology for the Iowa Department of Natural Resources. He has been with the State of Iowa since 1972. He directs a variety of environmental and natural resources research and demonstration programs in Iowa related to agriculture, soils environmental monitoring and exposure assessment, nonpoint source pollution, hydrogeology, and groundwater contamination. He has published more than 150 technical papers on these subjects.

He is the project director of the Big Spring Basin Demonstration Project, the Model Farms Demonstration Project, project coordinator for the Integrated Farm Management Demonstration Project, and other projects dealing with agriculture and environmental quality in Iowa. He also directs other projects such as Iowa's Statewide Rural Well-Water Survey, the Aquitard Hydrology Study, the Groundwater Vulnerability Mapping Project, and the Nonpoint Source Monitoring Program. He is the program manager for Iowa's Agricultural-Energy-Environmental Initiative which recently won USEPA Administrator, William K. Reilly's 1992 Administrator's Award for excellence in pollution prevention. He was awarded the 1992 Division of Soil Conservation Award, for outstanding service in soil and water conservation, by the Iowa State Soil Conservation Committee and Iowa Department of Agriculture and Land Stewardship. Dr. Hallberg is also an Adjunct Professor at both Iowa State University and the University of Iowa. He received his Ph. D. in geology from the University of Iowa in 1975. His B.A. is also in geology from Augustana College. Dr. Hallberg also serves on numerous academic and professional committees.

Timothy K. Hartz is an Extension Vegetable Specialist with the Department of Vegetable Crops at the University of California, Davis. His primary interests include commercial vegetable crop management, irrigation, fertility and groundwater pollution. Dr. Hartz earned his B.S. in Biology and Chemistry at Bowling Green State University, his M.S. in Horticulture at Colorado State University and he received his Ph.D. in Horticulture from Virginia Polytechnic Institute and State University in 1980.

Carol Hillhouse is on the staff at the UC Davis Student Experimental Farm where she teaches sustainable gardening and farming practices and manages the demonstration and market garden areas. She has participated in research projects at UC Davis covering various aspects of sustainable crop production. She also serves as a farm inspector for California Certified Organic Farmers.

Kent D. Johnson is the president and manager of Ag Production Co. located in Turlock, Calif. Agpro is a retail supplier of agricultural chemicals, fertilizers, and their 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. Kent received his B.S. in Plant Science and M.S. in Integrated Pest Management from the University of California, Davis.

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. Scott received his B. A. from the University of Utah and Ph.D. from Cornell University.

Mark Linder is executive director of the California Foundation for Agriculture in the Classroom. He is responsible for directing the Foundation's education programs and fundraising activities. The Foundation's programs are designed to incorporate the study of agriculture into existing K-12 curricula. Mark is president of Linder Family Farms and currently serves on the National Steering Committee for Project Food, Land and People. He is a Class XII graduate of California's Agricultural Leadership Program.

Carol Lovatt is an Associate Professor of Plant Physiology in the Department of Botany and Plant Sciences at the University of California, Riverside. Her research encompasses regulation of basal metabolism, especially nitrogen metabolism, stress physiology, and regulation of flowering, fruit set and fruit development of citrus and avocado. She has a special interest in use of foliar-applied fertilizers to regulate physiological processes. Dr. Lovatt received her

B.S. from the University of Massachusetts and her Master's and Ph. D. from the University of Rhode Island.

Al Ludwick is the western director of the Potash and Phosphate Institute where he coordinates research and conducts educational programs in seven western states and Mexico with the overall objective of market development of phosphorus and potassium fertilizers. He was the coordinator for Latin American programs for the Institute and a professor of Agronomy at Colorado State University for 10 years.

Mark Matthews is an Associate Professor of Plant Physiology in the Department of Viticulture and Enology at the University of California-Davis. His research interests include plant-water relations, physiological control of photosynthesis and leaf growth during water deficits, acclimation to dry conditions, fruit growth and ripening in grapes, and irrigation and mineral nutrition of grapes. Mark received both his B. S. and M. S. from the University of Arizona and his Ph. D. from the University of Illinois.

Roland D. Meyer is an Extension Soils Specialist with the University of California Cooperative Extension, LAWR Dept., Davis. For the past 20 years he has been actively involved in research and extension concerning the efficiency, economics and environmental impacts of fertilizer application to California crops. Areas of research include the rate, timing, placement and frequency of application of nitrogen, phosphorus, potassium, sulfur, calcium, magnesium, zinc, manganese, iron, copper, molybdenum, boron, cobalt and selenium. The soil fertility-plant nutrition relationships have involved forage-alfalfa, irrigated pasture and range legumes and grasses, field and vegetable, fruit and nut crops as well as timber, Christmas tree and other forestry species.

Themis J. Michailides is an Associate Plant Pathologist at the Department of Plant Pathology, University of California, Davis, located at the Kearney Agricultural Center in Parlier. Dr. Michailides was initially with the University of California, Berkeley and transferred to Davis in 1992. He is involved in intensive research on the etiology, ecology, epidemiology, and control of diseases of fruit and nut trees in the San Joaquin Valley, including post-harvest diseases of these crops. He is interested in seeking ways to control diseases by proper tree nutrition, cultural practices, and biological means. He is also studying preharvest aflatoxin and other mycotoxin contamination in nut tree crops and figs. He is a graduate of the University of California, Davis.

Robert O. Miller is the Director of the Department of Agriculture and Natural Resources Analytical Laboratory and a Soil Extensions Specialist in the Department of Land, Air and Water Resources. Bob has been employed by UCD 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.

John Norton is the Chief of the Nonpoint Source Unit in the Division of Water Quality with the State Water Resources Control Board. Major areas of responsibility include the development of a plan to meet the requirements of the Coastal Zone Act Reauthorization Amendments, the development of a statewide strategy for remediation of abandoned mines, the development of a watershed approach to solving water quality problems and the administration of federal grants to local agencies for implementing nonpoint source controls.

Stuart Pettygrove is a Cooperative Extension Specialist in the Department of Land, Air and Water Resources at UC Davis. His work has focused on crop nitrogen management and land application of wastes and wastewaters. He has co-authored a bulletin on organic amendments and fertilizers and a guidance manual on wastewater irrigation. Current projects include preparation of a manual on water and nitrogen management for vegetable growers and research on cover cropping and straw management in rice production. He holds degrees from UC Berkeley, Cal Poly San Luis Obispo, and Oregon State University.

Kate Scow is an assistant professor of soil microbial ecology in the Dept. of Land, Air and Water Resources at the University of California, Davis. Her research interests include understanding the relationship between microbial population dynamics and soil fertility in agroecosystems, as well as biodegradation of pesticides and toxic chemicals by microorganisms. Her B.S. is from Antioch College in Ohio and her M.S. and Ph. D. are from Cornell University.

Tim Taylor is Vice-President and co-owner of the John Taylor Fertilizers Company. He has worked there since 1972 after receiving his B.S from the University of Oregon. His responsibilities include personnel, production management and commodity fertilizer purchasing. He has served on the Board of Directors of the California Fertilizer Association and is the 1993/94 President.

Shrinivasa K. Upadhyaya is a Professor with the Biological and Agricultural Engineering Dept. at the University of California, Davis. His research interests include traction, soil compaction, farm machinery design, site-specific farming and agricultural sustainability. He received his Ph. D. in Agricultural Engineering from Cornell University, Ithaca, New York, in 1979. He was given the 1982 Paper Award by the American Society of Agricultural Engineers [ASAE] for the paper "Dynamics of Fruit Tree Trunk Impact." He also received a 1990 Honorable Mention for the paper "Hydro-Pneumatic Singulation of Gel-Encapsulated Propagules." [ASAE]. Professor Upadhyaya also has a patent for Hydro-Pneumatic Seed Singulation for Plant Propagules.

Mark Van Horn is Director of the UC Davis Student Experimental Farm, where he teaches courses in sustainable agriculture and crop production. He has conducted research in several areas including composting, cover cropping and pest management.

Henry J. Voss is the Director of the California Department of Food and Agriculture. Mr. Voss was first appointed Director in 1989 after serving the California Farm Bureau Federation for 23 years, including 8 years as president. He also served on the American Farm Bureau Federation Board of Directors. Mr. Voss was born in San Jose and earned a B.S. in horticulture from the University of California at Davis. His 500 acre family farm in Ceres, Stanislaus County, produces peaches, prunes, walnuts, and almonds.

Steve Weinbaum is a professor in the Pomology Department at U.C. Davis. His primary area of research deals with nitrogen usage by deciduous fruit and nut trees and the environmental impact of fertilization practices in deciduous orchards. His use of stable isotopes of N has permitted direct measurement of tree recovery of fertilization nitrogen as well as characterization of the pool of storage nitrogen which the tree accumulates in the late summer/autumn and utilizes to support the spring flush of growth.

Bill Weir is field crop, soils and irrigation Farm Advisor in Merced County for the University of California. He holds a Ph. D. from the University of California, Davis. Bill has active research efforts in several crops, but he is most recognized for his cotton work with plant growth regulators, development of the 30-inch row spacing management system, utilization of harvest aid chemicals, and cotton nutrition.

IX. Addresses of Conference Speakers, Project Leaders and Cooperators