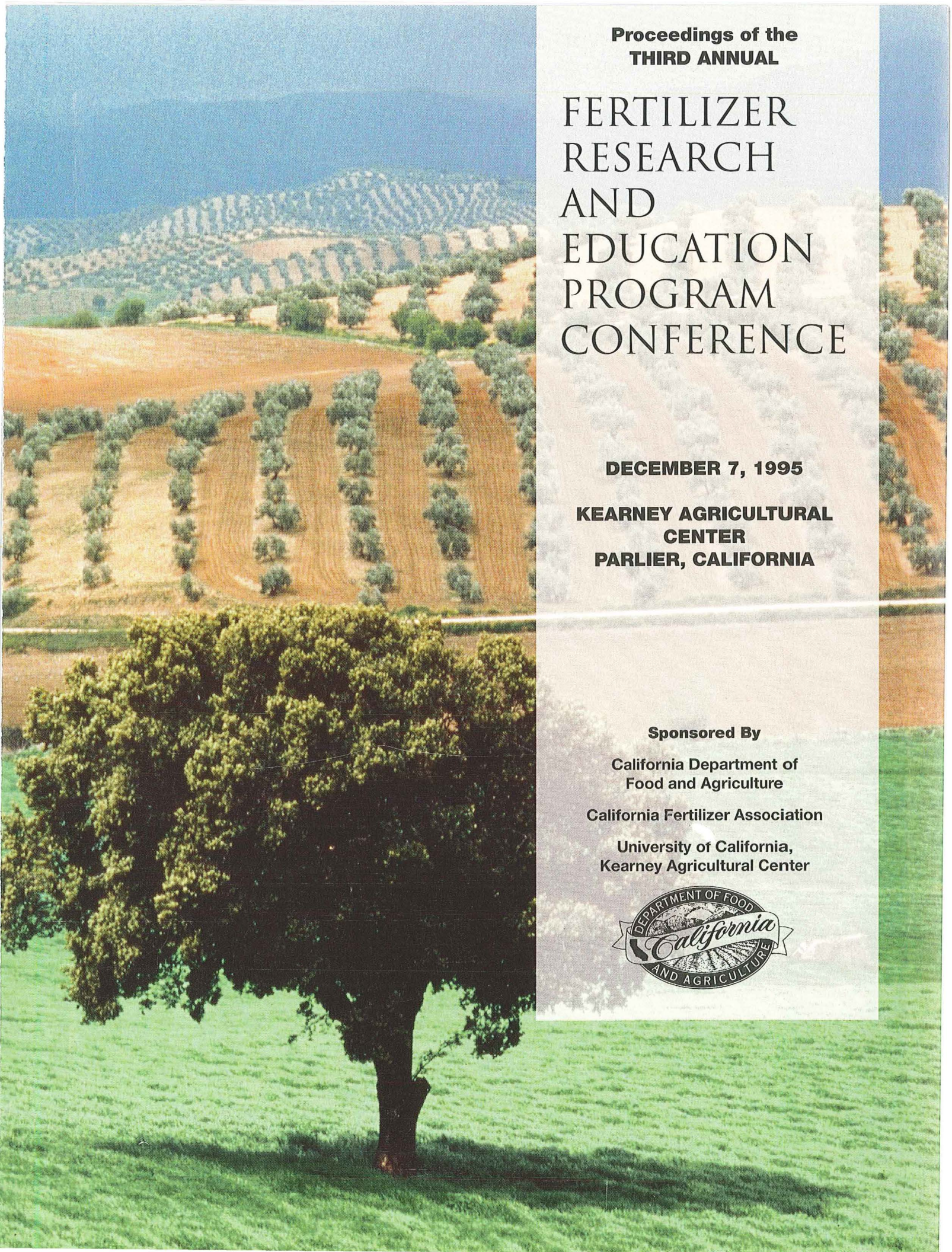

Proceedings of the
THIRD ANNUAL

FERTILIZER RESEARCH AND EDUCATION PROGRAM CONFERENCE

DECEMBER 7, 1995

KEARNEY AGRICULTURAL CENTER
PARLIER, CALIFORNIA

Sponsored By

California Department of Food and Agriculture

California Fertilizer Association

University of California, Kearney Agricultural Center

DEPARTMENT OF FOOD California AND AGRICULTURE

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CONFERENCE PROGRAM

7:30 **Registration**

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

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

8:20-8:50 **Fertilizer Research and Education Program: An Update**
Jacques Franco, Program Coordinator, Fertilizer Research and Education Program, California Department of Food and Agriculture

8:50-9:15 **Keynote - Agriculture and Nitrate in Ground Water: Conflict or Cooperation?**
Jack Pandol, Undersecretary, California Environmental Protection Agency

9:15-10:00 **Brief Updates**

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

Nonpoint Source Program Update
Jack Hodges, Water Resources Control Engineer, State Water Resources Control Board

Certified Crop Advisor Program
Steve Purcell, Agronomist, Unocal Corporation

10:00-10:40 **Break, Refreshments, & Poster Viewing**

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

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

Nitrogen Fertilizer Management to Reduce Ground Water Degradation
Steven Weinbaum, Professor, Dept. of Pomology, UC Davis

Nitrogen Management through Intensive On-Farm Monitoring
Tim Hartz, Extension Specialist, Dept. of Vegetable Crops, UC Davis

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

1:00-1:25 **Agriculture and Nitrate in Ground Water: An Overview of State Activities**
Roberta Parry, Ag Policy Analyst, U.S. Environmental Protection Agency

1:25-2:00 **Project Reports**

Diagnostic Tools For Nitrogen Management of Desert Vegetables
Charles Sanchez, Soil & Water Research Scientist, Yuma Valley Agricultural Center, U. Arizona

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

2:00-2:20 **Break, Refreshments & Poster Viewing**

2:20-3:30 **A Grower - Industry Panel: The Nuts and Bolts of Improved Orchard Nutrient Management**

Moderator: Scott Johnson, Extension Pomologist, Kearney Agricultural Center
Panel Participants: To Be Announced

POSTER SESSION

Western States Agricultural Laboratory Sample Exchange Program - Robert Miller

Establishing Updated Guidelines For Cotton Nutrition - Robert Travis and Bill Weir

Impact of Microbial Processes on Crop Use of Fertilizers - Kate M. Scow

Effects of Various Phosphorus Placements on No-Till Barley Production - Michael J. Smith

Avocado Growers Can Reduce Soil Nitrate Groundwater Pollution and Increase Yield - Carol Lovatt

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

Citrus Growers Can Reduce Nitrate Ground Water Pollution and Increase Profits - Carol J. Lovatt

Nitrogen Quick Tests for Determining N Fertilizer Needs of Vegetables - Kurt Schulbach and Richard Smith

II. BRIEF UPDATES

FERTILIZER RESEARCH AND EDUCATION PROGRAM: AN UPDATE

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

PURPOSE

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

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

BACKGROUND

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

FREP 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 developed improved vegetable farming practices to reduce nitrate contamination, while increasing the efficiency of fertilization and irrigation.

COMPETITIVE GRANTS PROGRAM

In 1990 the Department was authorized to increase the mill tax on fertilizers to conduct research and education projects to advance the environmentally safe and agronomically sound use and handling of fertilizer materials. The program is currently supporting forty-one projects at a projected cost of $1.7 million with $1.7 million in matching funds. Of these forty-one projects, seventeen have been completed. Details about these projects, and the information products generated can be found in these proceedings and the Resource Guide.

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

Recently eight new projects were approved for funding at a projected multi-year cost of close to $500,000 and matching funds at about $280,000. Section V of these proceedings describes these new projects.

MONITORING AND ASSESSMENT

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

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

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

RECENT ACCOMPLISHMENTS

FREP has made a significant impact developing quick diagnostic tools for cool season vegetable production. When I first went down to the Salinas Valley a few years ago, growers told me that soil and tissue tests were of very limited use to them because of the long turnaround time. Since then, about ten FREP-sponsored projects are tackling various aspects of this topic and have made significant progress. These projects are developing, testing and demonstrating under field conditions, the advantages of various diagnostic techniques such as quick soil tests, plant sap N analysis, etc. We will hear progress made by some of these projects today.

We recently released our new Resource Guide. This publication includes close to one hundred information products available through FREP, including educational videos and technical research reports. Topics covered include vegetable, orchard and field crops, and plant and soil testing and monitoring. A section of relevant publications available from other sources, and pertinent reprints from technical journals and agricultural media, is also included. We are currently working to make this information available through the Internet.

We also recently completed production of the *Compost Production and Utilization Grower Guide*. This publication will be periodically updated and also made available through the UC agricultural publications catalog. From early results we know the demand for this publication is very strong.

Another recent and very successful release is the *Drip Irrigation and Nitrogen Fertigation for Vegetables* video. The video, produced by Tim Hartz with contributions from FREP, was just awarded the American Society of Horticultural Science Education Aids Award.

Over the recent years, we have made available, in response to clientele requests, thousands of copies of these materials, and continue to improve our ability to promptly respond to these requests. A large percentage of the individuals requesting materials from us are directly involved with production agriculture. This is an indication that our materials are of value.

We are also pleased to report that we continue to work with the California Chapter of the American Society of Agronomy (CA-ASA) to disseminate new nutrient management information. At this year's CA-ASA annual conference, we will be holding a session highlighting results of FREP-sponsored research, for the third consecutive year. The conference is scheduled for January 17 and 18, 1996, in Modesto. The session will include out-of-state perspectives on nutrient management.

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

We continue to improve our coordination with the many commodity research boards to better serve the needs of growers. This year, FREP is entering into a partnership with the California Citrus Board to carry out a long term research study to improve citrus nutrient management.

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

FREP's commitment to support improved soil and tissue lab analysis is being enthusiastically embraced by industry. Dr. Bob Miller will be presenting a poster summarizing the progress of this project.

We are making progress in new areas of research announced in our last conference. Two new projects dealing with disease-fertility interactions have been started and a third project, in the area of precision farming will be initiated this fall. We hope to continue to improve cooperative working relationships with parties that have common goals to ours, and expand our outreach efforts.

CONFERENCE PROGRAM HIGHLIGHTS

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

The brief update section is intended to bring you "the big picture" and details of activities related to FREP's mission, to help you improve your understanding of how these developments might affect you. The afternoon grower panel session, facilitated by Dr. Scott Johnson, will provide practitioners perspectives on the nuts and bolts of improved orchard nutrient management. I also hope this session will generate good discussion on the topic. In addition, we will continue to feature "world premieres," highlighting information products that resulted from FREP-sponsored projects.

We are very proud to present this year a continually improving 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 has a new section covering about twenty nutrient-related projects being supported by parties other than FREP. I am convinced that this is information our clientele can use. Our previous proceedings included a "resource guide". The Resource Guide is now a stand alone publication that will be periodically updated. You are welcome to browse through FREP's information products display table during the breaks, and order any material you may need.

I urge you to fill out the evaluation forms in your conference packet or call us any time with suggestions to help us improve FREP 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 Carl Bruice, Al Ludwick, Steve Purcell, Wynette Sills, Brock Taylor, Tom Beardsley and Charles Tyson, members of the Technical Advisory Subcommittee (TASC) and to all the members of the Fertilizer Inspection Advisory Board. Recently, Dr. Jill Auburn resigned from the TASC due to her many obligations and was replaced by Jack Williams, Sutter/Yuba UC Cooperative Extension. I would like to acknowledge Dr. Auburn's contributions to FREP and welcome Jack Williams to the committee. TASC members' dedication, insight and professionalism have been invaluable in helping make FREP a success.

Casey Walsh Cady continues to provide invaluable assistance and dedicated service in carrying out many of the activities required to keep the program going. Debbie Scott 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 Drugs Branch. We would also like to acknowledge the efforts of Ezio Delfino, retired Assistant Director of Inspection Services; Bob Wynn, Director of Inspection Services; Henry Voss, former Secretary of CDFA and A.J Yates, Deputy

Secretary, for their ongoing support and assistance.

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

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

Project Leaders:

R. Scott Johnson
University of California
Kearney Agricultural Center
(209) 891-2500

Harry Andris
UC Cooperative Extension
Fresno County

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

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

OBJECTIVES

Our project is designed to refine this approach so it could be easily implemented by growers of early peaches and nectarines. Specifically, our objectives are:

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

For objectives 1 and 3, we are working in a block of Early Maycrest peach trees at Kearney Agricultural Center. Effectiveness of the treatments is being measured by assessing leaf N, stored N, tree growth, yield and fruit quality. Our education program will focus on growers of early season stone fruit and we will use a variety of approaches to reach as many growers as possible. To evaluate project success, we will obtain figures from urea producers and distributors to determine how extensively low biuret urea is being used in stone fruit orchards.

NONPOINT SOURCE PROGRAM UPDATE

Jack Hodges
State Water Resources Control Board
Sacramento, CA

In April of 1994, the State Water Resources Control Board (SWRCB) initiated a review of nonpoint source pollution management using Technical Advisory Committees (TACs). TACs were established for ten different nonpoint sources. Over 150 people representing public and private stakeholders for irrigated agriculture, nutrient application, pesticide application, confined animal facilities, grazing, abandoned mines, urban runoff, hydromodification and wetlands, onsite sewage disposal systems, and boating and marinas participated in the TACs. Reports developed by each of the ten TACs contain recommendations for changing the NPS Program.

The TACs followed an interest-based problem solving process to develop a set of recommendations to the SWRCB on how it and other agencies can better prevent nonpoint source pollution. The TACs completed their work in November 1994 and presented their findings and recommendations to the SWRCB at a Workshop on January 24 and 25, 1995.

These common themes are found throughout the TAC reports:

First, voluntary cooperation is preferred over prescriptive measures, particularly for agricultural activities.

Second, there is a need for better public education so that individuals can take responsibility and make the cooperative approach work.

Third, the TACs almost universally extolled the benefits of managing nonpoint source pollution on a watershed scale, where local stewardship and specific, problem-responsive measures can be devised through a comprehensive watershed protection plan.

Fourth, there is a need to provide more comprehensive and directed technical assistance to local groups and individuals.

Finally, the activities of the various resource management agencies should be better coordinated.

The central theme of the recommendations of the Nonpoint Source Technical Advisory Committees was to manage nonpoint sources on a watershed basis. This call for a watershed approach is added to a chorus of advisors ranging from the Governor's External Review committees which completed their work in June, 1994 to the Inland Surface Waters Plan's Watershed Task Force which is currently underway.

In response to this groundwell of support for the watershed approach, the SWRCB adopted a "Strategic Plan" in June, 1995. The Strategic Plan endorsed watershed management and set out 5 goals:

- Provide water resources protection, enhancement and restoration while balancing economic and environmental impacts.
- Promote cooperative relationships and better assist the regulated community and public.
- Encourage balanced and efficient use of water through water transfers, recycling and conservation.
- Continuously improve our internal efficiency and effectiveness.
- Establish a stable, flexible funding source.

The watershed activities should provide for:

(1) information clearinghouse,

(2) technical assistance and evaluation,

(3) financial assistance,

(4) education and training,

(5) coordination of government and private sector watershed management efforts, and

(6) conduct of pilot watershed projects.

All recommendations of the TACs have merit and deserve attention and application. However, the SWRCB cannot implement all the recommendations such as a watershed salt balance, watershed wide riparian protection, the utilization of landowner/operator self assessments for nutrient and pesticide management, the development of small urban storm water management programs, and other specific recommendations. These pilot watersheds (within the NPS Program's target watersheds) will be designed to test the feasibility of a number of specific recommendations.

The new directions which are recommended would be implemented through the SWRCB's and Regional Water Quality Control Board's workplans. These workplans must take into consideration the availability and limitations of resources, State and Federal mandates and regional priorities. It is recommended that as many of the recommendations as possible be implemented within these constraints.

CERTIFIED CROP ADVISOR (CCA) PROGRAM IN CALIFORNIA

Project Leaders:

Steve Purcell
Unocal
West Sacramento

Renee Pinel
California Fertilizer Association
Sacramento, CA

The Certified Crop Advisor (CCA) program is a national effort 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 for 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 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 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 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.

Program requirements are 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 exam, 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 exam.

The exam, consisting of both national and state sections, is given twice a year (February and August) at several locations in California. Exams are preceded by a training seminar near each location. The complete training package includes: 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. The CFA has received a four-year grant in the amount of $35,000 from FREP to continue these seminars and develop continuing education activities.

For more information contact Renee Pinel, California CCA Coordinator, California Fertilizer Association.

AGRICULTURE AND NITRATE IN GROUND WATER: AN OVERVIEW OF STATE ACTIVITIES

Roberta Parry
Environmental Protection Agency
Office of Agricultural Policy Analysis
Washington DC

States are using a variety of mechanisms to protect ground and surface water from elevated nitrate levels due to agriculture—both fertilizers and animal manures.

Local Development and Local Implementation

Natural resource districts in Nebraska with water quality problems can be required to develop and implement an action plan to prevent further ground water contamination under the Special Protection Area (SPA) Program. The Central Platte Natural Resource District, the first SPA, has mandated the adoption of specific best management practices that vary according to the average nitrate levels in the groundwater. The practices include a ban on fall and sometimes winter application of nutrients, annual nitrogen soil tests, certification classes for operators using nitrogen fertilizer, and use of a nitrogen inhibitor for late fall and spring applications. The District has documented a decreasing trend in ground water nitrate.

State Development with Local Implementation

Pennsylvania's Department of Environmental Resources is set to propose regulations to implement the Nutrient Management Act. The Act requires farms with more than two animal equivalent units per acre to submit a nutrient management plan to the local conservation district for approval. Minimum criteria for the plans includes: realistic yield goal; application rates based on the nitrogen requirements of the crop; soil tests for potassium, phosphorus, and pH; minimum criteria for new and expanding manure storage facilities; and an excess manure utilization plan. The Department of Agriculture is developing a certification program to train, test, and certify nutrient management specialists to write the plans.

State Development with State Implementation

Idaho is not concentrating solely on nutrients, although nutrient management plans are already required in some circumstances. Instead state agencies and federal agencies are developing a program to coordinate all agriculture programs and regulatory requirements to make implementation more efficient for both the farmers and the government entities.

All farms in Arizona are operating under a general permit which requires compliance with best management practices. Fertilizer practices include the proper management of soil and water, appropriate timing of application, and appropriate application rates. If farmers do not comply with the general permit, they must apply for an individual permit.

In 1994, Vermont adopted a set of Accepted Agricultural Practices that all farmers must follow. All nutrients must be used in accordance with current University recommendations. No winter spreading of manure is permitted. Buffer zones must be established along all permanent water bodies.

III. ONGOING PROJECT SUMMARIES

WESTERN STATES AGRICULTURAL LABORATORY SAMPLE EXCHANGE PROGRAM

Project Leaders:

Robert O. Miller
University of California-Davis
Dept. of Land, Air & Water Resources
(916) 752-7448

Janice Kotuby-Amacher
Utah State University
USU Analytical Laboratories

OBJECTIVE

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

For the third quarter exchange (1994), 101 laboratories were enrolled and the exchange samples were shipped in September. Seventy-two laboratories completed the analyses. A high EC and SAR soil was included, which provided a challenge for the laboratory industry. Overall proficiency results for the third quarter were similar to those of the two previous quarters. For the fourth quarter exchange (1994), 102 laboratories were enrolled in the program and the samples were shipped in November. Eighty laboratories completed the analyses and results were used in the quarterly report mailed December 28, 1994. Results for the fourth quarter were comparable with earlier quarters. The number of labs exceeding warning limits decreased, compared to the previous quarter.

During 1994, approximately 50% of the soil labs reported more than 90% of their values within the established warning limits. For plant analyses, approximately 65 percent of the labs reported more than 90 percent of the values within established warning limits. Of the analytical procedures evaluated, the soil bicarbonate P and plant extractable nitrate procedures appear to have precision problems. We are currently developing a plan to identify and address these problems.

For 1995, we have revised the program name to "Western States Proficiency Testing Program" to more accurately reflect its scope. Additional soil analyses have been added: SMP buffer pH, ammonium nitrogen and soil cation exchange capacity. Soil saturated paste carbonate has been dropped from the program. Currently we have selected, prepared and packaged 12 soil and plant samples for the 1995 program and have developed 5 soil and plant samples for the 1996 program. Version 2.00 of the method manual, containing new methods, was printed. We are currently reviewing alternative statistical methods for assessing proficiency based on ACOC and EPA protocols to effectively define the true value and level of precision for each analysis.

For the first quarter exchange of 1995, 85 laboratories were enrolled in the program and the exchange samples were shipped the week of February 1. Samples ranged in pH from 5.9 to 7.8. Seventy-five laboratories completed the analyses and results were used in the final report mailed March 15, 1995.

For the second quarter exchange (1995), 92 laboratories were enrolled and the exchange

samples were shipped the week of May 1, 1995. Samples included a National Institute of Standards and Technology (NIST) certified reference solution which is being used to evaluate bias problems associated with the bicarbonate phosphorus method. Seventy-seven labs completed the analyses and results were included in the final report mailed June 20, 1995. Results indicated a high level of accuracy of the NIST sample by the lab industry for N, P, Ca, Mg, B, M, and Zn. Planning is underway for the third and fourth quarters exchanges of 1995. A laboratory survey on analytical methodology is being prepared for submission with the third quarterly exchange.

Two manuals describing the analytical methods used are available. *Plant, Soil and Water Reference Methods for the Western Region* is available from Ray Gavlak, Plamer Research Center, 533 E. Fireweed Ave., Palmer, AK 99645, (907) 746-9467. *Western States Agricultural Laboratory Exchange Program: Suggested Soil, and Plant Analytical Methods* is available from Janice Kotuby-Amacher, USUAL, Utah State University, Logan, UT (801) 797-0008.

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

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INTRODUCTION

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

OBJECTIVES

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

DESCRIPTION

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

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

In 1995, high humidity incubation chambers were prepared by lining the bottoms of plastic crispers with sterile river sand dampened with sterile deionized water. On 10 February, immediately before the trees were sprayed with a fungicide by the grower, 10 to 12 shoots bearing open flowers were collected from one Carmel and one Price tree in each plot and transported to the laboratory. Twenty fully-opened flowers per replication of each treatment from each cultivar were removed and placed, with stamens and pistils facing up, on the sand in the incubation chambers. Flowers were spray-inoculated with an aqueous suspension of 103 conidia per ml of *M. laxa* and incubated at room temperature for 3 days when the total number of stamens and the number infected stamens were counted. The experiment was repeated using Carmel flowers collected and inoculated, as above, on 15 February. Price flowers were not included in the second experiment because most were too mature to provide sufficient samples from all replications.

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

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

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

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

[y] Twenty-five flowers per replication, inoculated within 4 hours of collection. Number infected and total stamens counted three days after inoculation.
[z] Means followed by the same letter do not differ significantly according to Duncan's multiple range test, P = 0.05.

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

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

[y] Four 2-or-3-yr-old shoots per replication inoculated 10 May and lesion length measured 20 June 1994.
[z] Means followed by the same letter do not differ significantly according to Duncan's multiple range test, P = 0.05.

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

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

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

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

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

[x] Floral cups, incubated with each pathogen were attached to green fruit and fruit covered with plastic and paper bags for 24 h. Twenty fruit per replication.

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

[z] NS = not significant, P = 0.05.

SUMMARY

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

ESTABLISHING UPDATED GUIDELINES FOR COTTON NUTRITION

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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 vermicullitic clays exhibit K fixation. Current procedures will be compared to two new possible methods under development.

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.

DESCRIPTION

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 for the first year. 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 been completed. All plots were sampled for nitrate on the appropriate sample dates, and tissue analysis has been completed.

Growth and development data have been collected throughout the season. All in-season samples have been summarized. Growth the last half of June averaged 93 percent of the rate established for non-stress 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 variables 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

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

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 lbs/A of potassium was applied to large scale plots. Petiole and plant growth data were collected four times during the season. The first year's data has been summarized.

NITROGEN MANAGEMENT THROUGH INTENSIVE ON-FARM MONITORING

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OBJECTIVES

This project, conducted in commercial vegetable fields in the Santa Maria Valley, seeks to document the utility of intensive on-farm monitoring of soil and crop nitrogen status in fertility decision-making. The specific objectives are:

1. Document the accuracy, labor intensity and cost of on-farm monitoring techniques for soil and crop N status.
2. Develop baseline data on N uptake rates and tissue N sufficiency levels for the important cool season crops.
3. Demonstrate the effect of best management practices (drip irrigation and fertigation, intensive monitoring) on crop yield, and water and nitrogen use.

DESCRIPTION

It is generally acknowledged that intensive vegetable production as practiced along California's central coast is a significant contributor to the nitrate pollution of groundwater. The Salinas Valley, Santa Maria Valley and the Oxnard plain are all considered to be nitrate-sensitive areas. Typically, vegetable land in these areas is double-cropped, with per-crop N applications in excess of 200 lbs/acre common, particularly for broccoli, cauliflower and celery. Nitrogen removal with the harvested product usually accounts for only a small fraction of N applied. The cool-season vegetables produced in this area are shallowly rooted and intensively irrigated. These circumstances suggest substantial opportunity for nitrate leaching.

Past cropping history and the mild Mediterranean climate have resulted in the development of soils that are extremely active in nitrogen cycling. Large soil mineral N pools and rapid N mineralization have been reported by several researchers. Recently developed on-farm monitoring techniques for soil and plant N status are now available which can enable a grower to more fully exploit soil mineral N and limit additional fertilization. Furthermore, the increasing use of drip irrigation provides a vehicle for efficient water delivery (minimizing leaching losses) as well as delivery of fertilizer N independent of cultural constraints. This project is designed to demonstrate the advantages of drip irrigation and fertigation, and intensive N monitoring, on reducing water and N use while maintaining high productivity.

In cooperation with Betteravia Farms of Santa Maria, eight drip irrigated fields were selected for study in spring, 1994. They will be followed through normal crop rotations until fall, 1995. At the beginning of each cropping cycle, each field is divided into quadrants; in each quadrant a 4-row plot is fertilized with 100 lb N/acre in the form of a slow-release fertilizer. These plots, which also receive all N applications put on the whole field, serve as an N sufficiency reference against which the remainder of the field is evaluated with respect to crop yield and N status.

After the establishment of each crop, soil samples (0-12 inches) are collected and analyzed for mineral N (NH_4-N + NO_3-N) concentration. A subsample of that soil is incubated aerobically at 20°C (68°F) for 4 weeks, then retested for mineral N. The increase in mineral N during incubation estimates net N mineralization, the rate at which soil organic N is converted to plant-available forms.

Four times during the cropping season plant tissue and soil samples are collected by farm personnel and analyzed on-farm by the following methods:

a) Soil NO_3-N by a quick test technique which uses a volumetric extraction of moist soil, with nitrate measurement by colormetric test paper.

b) Petiole sap NO_3-N analysis with the Cardy portable nitrate selective electrode.

These tests, performed on-farm, provide information to guide N fertigation decisions. The accuracy of these methods is also monitored by comparison with standard laboratory analytical techniques. At each sampling date, whole plant samples are taken for determination of total plant biomass and biomass-N. At first commercial harvest, crop yield and quality is evaluated in the reference plots and matching sections of the field.

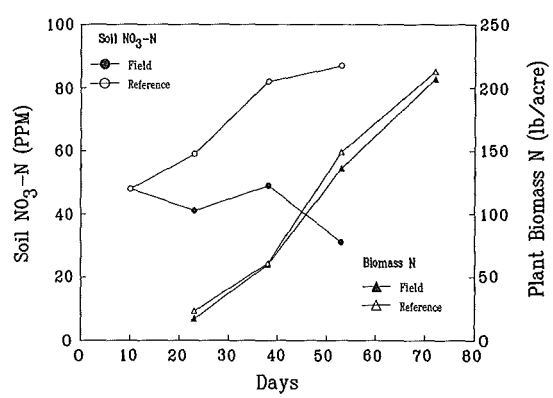
RESULTS AND CONCLUSIONS

The study is ongoing; this summary will focus on the four fields of cauliflower monitored in fall, 1994. All fields had high residual soil NO_3-N at crop establishment (Table 1), between approximately 190 and 270 lb N/acre in the top foot of soil. Such high values are not uncommon in coastal vegetable soils at the beginning of the summer/fall crop. In the absence of heavy, leaching irrigation, $_{NO3-N}$ builds up from fertilizer application on the spring crop and mineralization of organic residue. Aerobic incubation showed that these soils were capable of maintaining net N mineralization rates of 1-2 lb N/acre/day over extended periods.

Despite relatively conservative fertilization, high soil NO_3-N levels (generally >30 PPM) were maintained throughout the season. This was partly due to the continued mineralization of organic N, and partly to the low rates of water application from the buried drip system, which minimized leaching. Application of both fertilizer and water were about 1/3 less than under conventional management. The exception was field D, a very sandy soil that had historically been difficult to manage with conventional irrigation. Upon conversion to drip, the grower continued to apply high N rates. In-season soil sampling showed clearly that this was unnecessary; at harvest more than 200 lb NO_3-N/acre remained in the top foot of soil.

Crop yields showed that, in these nitrogen-rich soils, heavy N application was not necessary for maximum productivity (Table 1). In no case did the reference plots (which received an additional 100 lb N/acre in slow release form) significantly outyield the rest of the field. In fact, at no time during the season could the reference plots be visually distinguished in any field. It is instructive to look at the trend of soil NO_3-N and plant N uptake over the season (Fig. 1). As expected, the reference plots had higher soil NO_3-N levels, but this did not lead to greater plant N uptake. The only effect of the extra N was to enlarge the pool of NO_3-N susceptible to leaching.

Figure 1. Soil NO_3-N concentration and plant biomass N accumulation in field and reference plots, Field B.



The soil NO_3-N quick test and petiole sap NO_3-N analysis, although not as accurate as conventional laboratory analysis, proved to be valuable on-farm monitoring tools, consistently able to document high nitrate levels in both soil and plant tissue. On a commercial scale, monitoring as done in this study was an economically justifiable practice, with seasonal labor and equipment costs below $50 per 20 acre field. Reducing fertilizer application only 10 lb N/acre, based on the results of monitoring, would more than offset costs.

Judging by the results of this and other recent studies, N fertilizer input in coastal vegetable production can be reduced considerably without affecting crop productivity. In-season monitoring can help a grower effectively utilize residual and mineralized N, more effectively targeting fertilizer applications.

Table 1. Performance of drip-irrigated cauliflower under varying N management, summer/fall crop, 1994.

Field	Soil No_3-N at establishment[z] (PPM)	Seasonal irrigation applied (inches)	Seasonal N applied (lb/acre)	Relative crop yield (%)[y]
A	52	5.9	170	137*
B	48	5.8	175	96ns
C	67	6.7	173	119ns
D	61	9.8	295	103ns

[z] top 12 inches of soil, sampled after transplanting and initial irrigation; multiply by 4 for approximate 1b N/acre
[y] field productivity compared to reference plots receiving additional slow release N fertilizer; (field plots/reference plots) x 100
*, ns treatments significantly different or not different at p = .05

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

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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 groundwater as 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 to be truly predictive, and thus useful to growers. Also, 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: a) microbial biomass and activity; b) soil fertility parameters, particularly N pools; c) crop tissue levels over the growing season; and d) crop yield and quality at the end of the growing season. Studies are conducted in tomato and corn under three different N management systems: N from mineral sources only; N from cover crops and manure; and N from cover crops supplemented with mineral sources.

DESCRIPTION

The study site is the long-term Sustainable Agriculture Farming Systems Project, located at the Agronomy Farm at UC Davis, and now in its seventh year of study (funded by USDA, EPA and UC). 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, and a low-input 4-yr rotation. All 4-yr rotations follow the sequence: tomatoes, safflower, corn, and wheat or oats-vetch/ beans. The 2-yr rotation alternates between tomatoes and wheat/beans. Table 1 gives an example of typical production practices for tomatoes, in this case for 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

Measurements in soil have included: a) microbial biomass, both as C (MBC) and N (MBN), b) 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 c) nitrogen pools: nitrate, ammonium, potentially mineralizable N (PMN) which is an estimate of available nitrogen from organic matter. Emphasis in this project has been on organic and conventional tomatoes, with less frequent sampling of low input and conventional two-yr tomatoes and all systems of corn.

In 1994 (which was similar to 1993), nitrogen fertilizer application to tomatoes in the different farming systems was as follows:

Conventional: 8-24-6 applied as starter at 15 gal/ac in March; fertilizer side-dress with 46-0-0 at 304 lbs/ac in May.

Low-input: Purple vetch planted in November, incorporated in April; starter fertilizer 8-24-6 applied at 15 gals/ac to transplants in April.

Organic: Purple vetch planted in November, incorporated in April; poultry manure of 3.4% N applied at 2.15 t/ac; starter fertilizer of fish powder (12-0.25-1 at 4 lbs/ac) and seaweed (3-0.25-0.15 at 1 gal./ac) applied to transplants in April. Top-dress of fish powder (12-0.25-1 at 4 lbs/ac) and seaweed (3-0.25-0.15 at 1/2 gal./ac) applied in July.

Nitrogen fertilizer application to corn in the different farming systems was as follows:

Conventional: 6-20-20 applied as starter at 100 lbs /ac on April 2; fertilizer side-dress with 46-0-0 at 261 lbs/ac on April 22; fertilizer side-dress with 34-0-0 at 235 lbs/ac on May 12.

Low-input: Purple vetch planted in November, incorporated in April; starter fertilizer 6-20-20 appliedat 100 lb/ac in April; fertilizer sidedress with 34-0-0 at 235 lb/ac on May 12.

Organic: Purple vetch planted in November, incorporated in April; poultry manure (3.4% N)applied at 4.3 t/ac in late March.

RESULTS AND CONCLUSIONS

Differences in microbial parameters among farming systems. Fairly consistently, microbial biomass and activity show greater values (up to double) in organic than in conventional tomato plots. Figs. 1 and 2 show differences between organic and conventional tomatoes in five microbial parameters during 1993.

Figure 1. Changes in A. Extractable MBC and B. Extractable MBN in conv 4 yr and organic systems in 1993. Vertical bars = standard error (n=4).

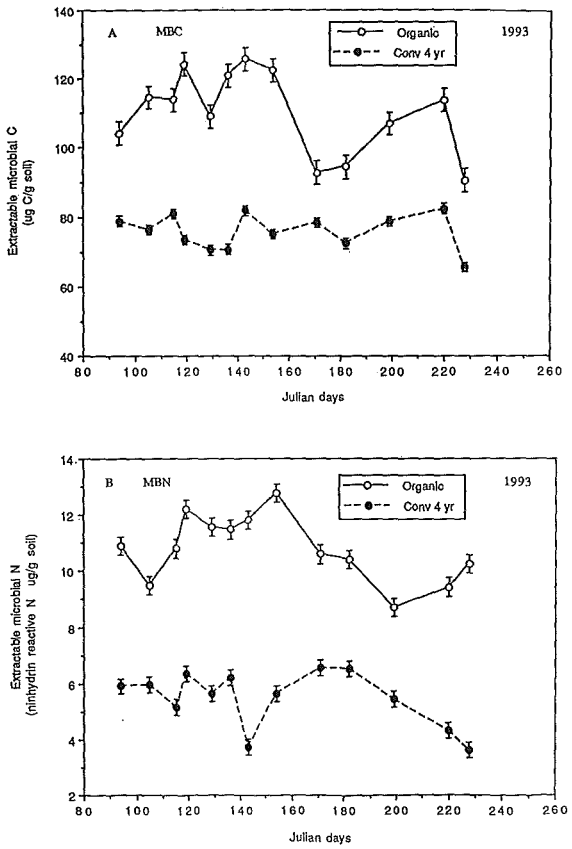
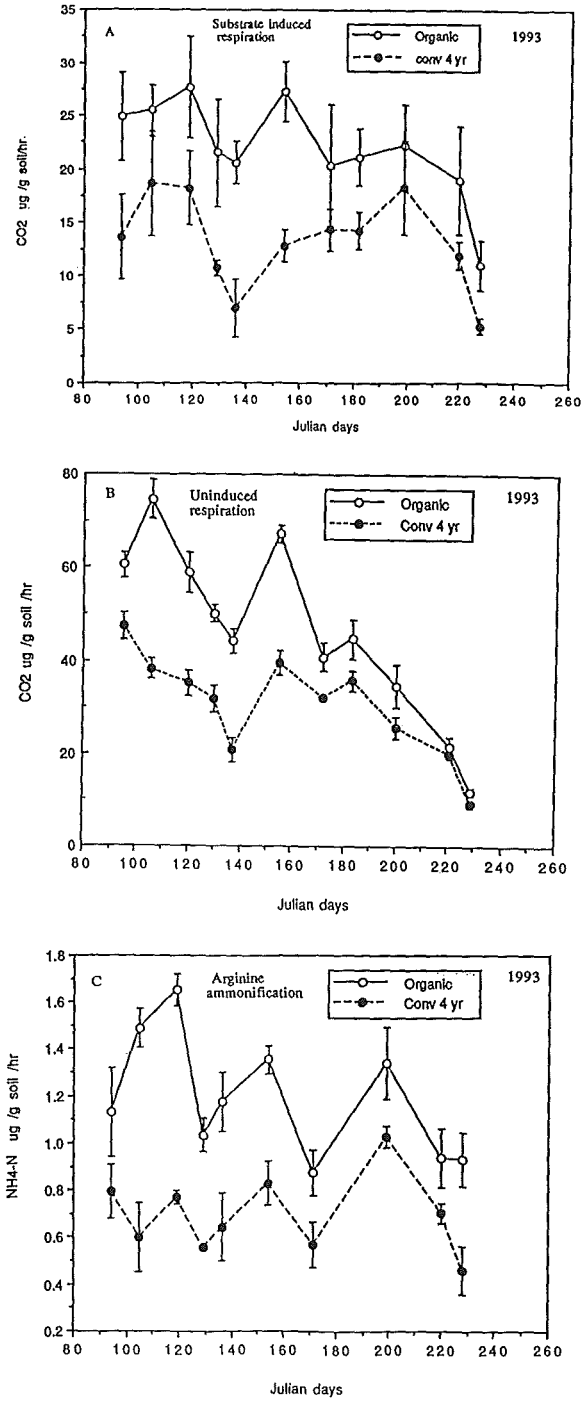
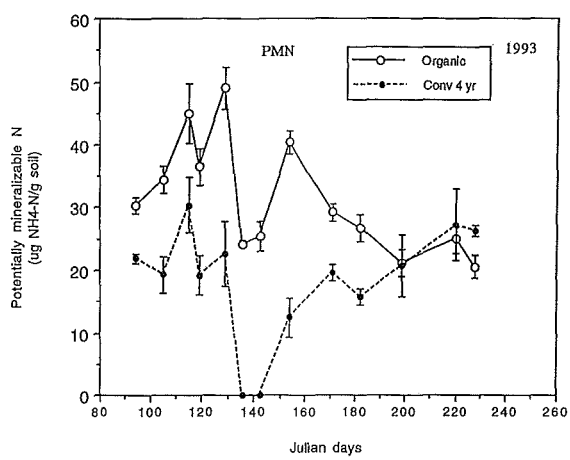


Figure 2. Changes in A. Substrate induced respiration, B. Uninduced respiration and C. Arginine ammonification in conv 4 yr and organic systems in 1993. Vertical bars = standard error (n=4).



PMN levels are shown in Fig. 3. Similar differences were observed in 1994. Seasonal variations are considerable, with generally lower variability in conventional than organic plots. In addition, bacterial-feeding nematode populations are significantly higher in organic than conventional plots, which suggests their importance in the turnover of nitrogen contained in the microbial biomass. With regard to differences in microbial parameters among the other farming systems, levels of microbial biomass are sometimes, but not always, higher in organic than low input plots. Low input receives lower levels of carbon inputs (e.g., no manure) than the organic system. There is little difference in MBC between the conventional 2-and 4-year rotation systems.

Figure 3. Changes in PMN in conv 4 yr and organic systems in 1993. Vertical bars = standard error (n=4).

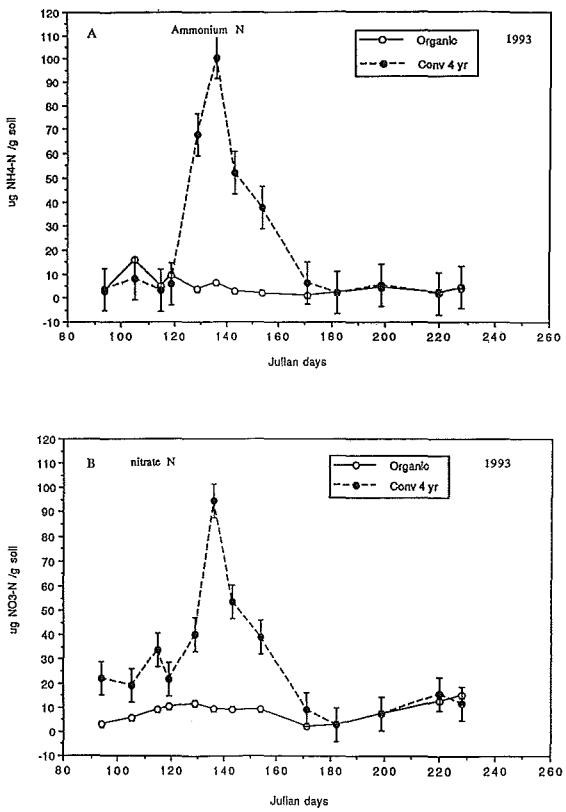


Microbial parameters are sensitive to both temperature and soil moisture. In 1993, soil temperature varied from approximately 15° C at the beginning to the low 20's throughout the remainder of the growing season. Frequent irrigation maintains soil moisture in organic and conventional plots at levels between 12 and 30% in the top 15 cm of soil. Irrigation is more frequent and soil moisture was usually higher in the organic than conventional system. Correlation analyses indicated positive relationships ($p<0.0001$) between soil moisture and either MBC or MBN, but negative relationships ($p<0.0001$) with the C/N ratio of the microbial biomass, arginine ammonification, and SIR/MBC. Soil temperature was inversely related ($p<0.0001$) to MBN, SIR/MBC, and soil ammonium levels. Severe declines in microbial parameters in the mid growing season were evident in all systems and appeared to be related to hot and dry periods between irrigation events.

Relationship of microbial parameters to soil fertility. An important objective for this project has been to evaluate whether the striking differences in microbial parameters correspond to differences in soil fertility among the different farming systems. In previous years we have shown that soil nitrate levels during the growing season differ among farming systems. The pattern changed from previously higher (1989, 1990) to now lower nitrate levels in organic compared to conventional tomatoes. In 1993, the inputs into the organic system had considerably higher carbon to nitrogen (C/N) ratios than in previous years because a large portion of the cover crop was oats (rather than vetch) and because the manure had large quantities of straw. Soil mineral N levels in the organic system were low over the 1993 season and were below what would be "acceptable" plant nutrition levels based on conventional agriculture criteria (Fig. 4). In the conventional 4-year system, however, mineral N levels increased dramatically following application of sidedress fertilizer, NH_4NO_3 and levels remained relatively high for three weeks. Regardless of these differences in soil N, crop yields in the two systems were comparable in 1993. We believe this was due to high activity of the very large microbial biomass in organic soil in mineralizing nitrogen which, in turn, was immediately taken up by the tomatoes. Availability of mineral N also may have been stimulated by predation of microorganisms by bacterial-feeding nematodes, whose populations increased substantially over the growing season. These results suggest that organic inputs with higher C/N ratios than typically recommended may supply sufficient fertility to crops while at the same

time potentially reducing nitrate leaching. The ability of organic inputs with different C/N ratios to supply fertility to tomatoes is being tested this year in sub-plots. Unfortunately, it was not possible in 1994 to confirm the 1993 field observations because the organic tomatoes, originally from transplants, had severely reduced yields due to a viral infection.

Figure 4. Changes in A. soil NH_4-N and B. soil NO_3-N in conv 4 yr and organic systems in 1993. Vertical bars=standard error (n=4)



Determining relationships among microbial parameters and soil nitrogen is complicated because of short-term fluctuations in both types of measurements. In general, when looking at correlations among parameters in all farming systems combined or in the conventional system alone, there is a significant ($p<0.05$) negative relationship between microbial biomass and either soil nitrate or ammonium. Analysis of data from the organic system alone, however, shows a positive relationship between MBC and soil nitrate and ammonium. In all systems, there is a strong correlation between most of the microbial parameters and PMN, the latter being an estimate of the pool of available organic nitrogen.

An important issue for farmers converting to farming systems using organic inputs is whether microbial populations in previously conventional soils are, during the first few years of transition, able to break down organic residues rapidly enough to serve as a nutrient source to crops. To test whether rates of cover crop decomposition were slower in conventional than organic managed plots, soils from both farming systems were collected in the field at five different times throughout the year and incubated in the laboratory with alfalfa residues. On all occasions, there was little or no difference between the soils in their rates of cover crop decomposition as measured by weight loss in litter bags and carbon dioxide evolution. Cover crop decomposition is only the first of several microbial processes that ultimately lead to release of mineral nitrogen from organic sources. Therefore the lack of significant difference in cover crop decomposition does not necessarily mean that organic and conventional managed soils are equivalent in their ability to supply crop nutrients from organic sources.

A commonly held, but largely untested, belief is that it is not possible to increase organic matter contents in California agricultural soils. After six years of farming, total organic mattercontents have increased significantly, by approximately 15-18%, in the organic system compared to the conventional systems. Organic matter decreases among farming systems in the following order: organic > low input > conventional 4-year > conventional 2-year. Total organic matter content is not as accurate representation of the nutrient pool available from organic matter as is microbial biomass (itself, part of organic matter). As discussed above, we have demonstrated the available organic matter pool (MBN) is now significantly higher in the organic than conventionally managed soil under tomatoes.

In 1994, tomatoes and corn plots showed marked differences in soil nitrate levels. In corn, levels ranged between 10 and 20 µg/g, whereas in organic and low input, levels ranged between 20 and 65 µg/g. By the end of the season, levels in organic were significantly higher than in low input and conventional soils. With respect to microbial parameters, MBC and MBN were often, but not always, significantly higher in organic than conventional soils. SIR was never significantly different and PMN was significantly different on only one date. Future work will be aimed at better understanding the differences in microbial and soil fertility dynamics in corn versus tomato plots.

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

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Because of the high values involved and the need for high quality products, vegetable growers cannot take the risk of under-fertilizing their crops. In order to reduce the amount of fertilizer applied with a minimum of risk of under-fertilization, a simple, quick, and inexpensive method of monitoring crop nitrogen status is needed. The Cardy nitrate meter is a compact, inexpensive (about $300) specific ion meter that can be used by growers for quick analysis of fresh sap from a variety of vegetable crops.

A recent economic study by Louise Jackson (unpublished) places the cost of weekly sampling of lettuce at about $15 per acre. In this case study, enough money was saved by reduced fertilizer and application costs to cover the cost of sampling. This shows that the use of sampling can reduce the potential for nitrogen leaching with little cost to the grower and that, in many cases, the testing will likely result in an economic benefit to the grower. We have been promoting the use of quick tests on the central coast for the last two years and growers are beginning to adopt the technology. As more growers begin to use quick testing, we need to make sure they have a good understanding of the accuracy and use of the nitrate quick tests.

OBJECTIVES

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

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

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

OBJECTIVES

This project is designed to evaluate several diagnostic approaches as tools to aid in the efficient N management of vegetables produced in the low desert. Approaches include the traditional dry midrib or petiole test, the sap midrib or petiole test using the Cardy Meter, absorbance using the chlorophyll meter, and various reflectance technologies including digital computer analysis of aerial photographs. Preliminary data collected by our group has shown reflectance technologies are sensitive to the N status of lettuce and have the potential to detect N differences in any portion of the field. This may be a useful tool for implementing variable placement technologies currently being developed. We are also evaluating a pre-sidedress N test near thinning since most plant testing technologies have proved insensitive during the earliest growth stages.

Specifically, our current objectives are to:

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

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

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SUMMARY

This two year project is studying various subsurface phosphorous placements and their effects on the growth and yield of cereal grains grown using a no-till farming system in San Luis Obispo County. Planting and fertilizing equipment designed specifically to apply seed and fertilizer at the same time is being used.

A randomized complete block design, with six replications is being used to study the effects of various possible combinations of phosphorous placement on nitrogen and phosphorous uptake. This is determined by measurement of actual uptake of N and P using a "difference" method—analyzing biomass production at various growth stages, yield components, *(number of headed tillers, number of kernels per spike, kernel weight, and grain: residue ratio)*, and grain yield measurements.

Determining optimum phosphorous placement, along with potential yield and economic advantages in no-till farming systems, will help bring grower adoption of this technology a step closer to fulfillment. This will help stop the unnecessary loss of thousands of tons of productive soil each year from often "HEL" (Highly Erodible Lands) sites, and significantly reduce soil pollution of surface water streams.

AVOCADO GROWERS CAN REDUCE NITRATE GROUNDWATER POLLUTION AND INCREASE YIELD AND PROFIT

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OBJECTIVES

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

The specific objectives are to:

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

DESCRIPTION

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

RESULTS AND CONCLUSIONS

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

No conclusions can be drawn at this time. The research needs to be replicated for several years and at a minimum during an "off" year. The potential of bloom and/or foliar applications of nitrogen to increase yield and/or size is promising but requires further investigation. At this point, only the increase in the number of larger-sized fruit (packinghouse sizes 40 and 36) with the bloom application of low-biuret urea approaches statistical significance (P=0.06).

EDUCATION THROUGH RADIO

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OBJECTIVES

To use radio as a means to educate growers on the safe and effective use of nitrogen fertilizers.

DESCRIPTION

A series of radio reports is being produced utilizing the latest findings by FREP-sponsored research projects. The reports are based on interviews with the researchers and others in the industry, especially growers who have had success with the latest findings. Nearly all the reports focus on the effective use of nitrogen fertilizers.

By using objective, UC studies, the information is legitimized and by using growers, the information is validated. Thus, growers hearing the reports may become more convinced of the need to focus on improved fertilizer practices.

In all, 12 five-part series will be produced for this project. The spots are aired on approximately 15 California radio stations reaching every major growing area of the state.

A toll-free number is set up and broadcast with each segment of the series to encourage listeners to call for more information on FREP or the topic discussed in the series.

RESULTS AND CONCLUSIONS

Currently, three five-part series are completed. While the level of phone calls requesting information has not been what was expected, this does not necessarily indicate lack of interest. When growers hear the information about other growers having success with improved fertilization practices, they may act on it on their own farms.

USE OF ION EXCHANGE RESIN BAGS TO MONITOR SOIL NITRATE IN TOMATO CROPPING SYSTEMS OF YOLO COUNTY

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DESCRIPTION

Monitoring soil nitrate is critical to evaluating crop nitrogen availability and assessing the potential for vadose zone nitrate losses. Recent work from a long term experiment on the U.C. Davis campus comparing conventional and cover crop managed systems showed reduced levels of surface soil nitrate in organically amended soils (Scow et al. 1994). While this suggests a decreased potential for leaching in these systems, samples below 30 cm were not taken due to the difficulty associated with taking deep profile samples, hence a full evaluation of soil profile nitrate is lacking. In order to have a more thorough measure of soil profile nitrate over time across cropping systems, better methodology is needed to quantify soil nitrate losses and, specifically, to evaluate the leaching potential of nitrate in cover crop and conventional tomato cropping systems.

Use of anion exchange resins bags provides an alternative. The anion resins have high affinity for nitrate and have been used to quantify nitrogen mineralization in situ (Rouppet et al. 1993). Recently, Li, Skogley and Ferguson (1993) have described a field method using anion exchange resins for monitoring soil nitrate movement which are installed attached to the bottom of PVC soil access tubes without crop destruction. Since the bags are left in the field, soil nitrate can be monitored throughout the growing season, rather than at one point in time as with deep core sampling. Resin bags can be easily removed and replaced, thus, permitting time course evaluations of nitrate movement.

This project is designed to improve the methodology of the anion exchange resin bag technique so that it may be used to monitor nitrate leaching in cover cropped and conventionally managed tomato systems in both experimental plots and growers' fields. Initial work is evaluating nitrate recovery efficiency of the exchange bags and determining spatial variability of a field cropped to tomatoes. Effectiveness of the technique will be based on correlation with a bromide tracer and traditional soil sample cores.

IV. COMPLETED PROJECTS

NITROGEN FERTILIZER MANAGEMENT TO REDUCE GROUNDWATER DEGRADATION

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OBJECTIVES

1. Assess the sensitivity of leaf nitrogen (N) concentration to overfertilization.
2. Determine the relationship between leaf N concentration and tree productivity. (i.e., reassess the validity of the currently-accepted leaf N diagnostic guidelines).
3. Assess the relationship between the rate of applied fertilizer N, tree N status and the percentage recovery of isotopically labeled (^{15}N-depleted) fertilizer N.
4. Assess nitrate leaching below the root zone and its relationship to fertilizer N application rate and tree N status.
5. Refine current management guidelines for N usage which will help maintain productivity while reducing the amount of fertilizer N leached below the root zone under conditions typical of the Northern San Joaquin Valley.

DESCRIPTION

Two research plots were 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.

The project was conducted in three phases. In 1990, pretreatment baseline data were obtained (on tree yields, leaf N, concentrations, and soil and irrigation water nitrate concentrations); and experimental plots were established. From 1990-1993, differences in tree N status and related effects were established (including yield differentials and soil nitrate levels) using 4 levels of applied fertilizer N (0, 125, 250, and 500 lbs N/acre/year) applied as a 1/3, 2/3 split in April and early October, respectively. From 1993-1995, a uniform amount of isotopically labeled ammonium sulfate was applied to selected trees differing in tree N status, and tree recovery of labeled fertilizer N and the likelihood of nitrate leaching below the rootzone was determined.

RESULTS

Current fertilization practices in many almond orchards favor overfertilization—the application of fertilizer nitrogen in excess of the tree's capacity to utilize it. The following evidence is consistent with that interpretation:

The presence of high residual levels of nitrate in the soil. These may result from the use of high nitrate-containing irrigation water (33 ppm nitrate in Salida and 44 ppm nitrate in Ceres) as well as excessive application rates of fertilizer N.

Lack of a yield response to the fertilizer. A significant yield reduction in unfertilized trees occurred only in 1993, which was 3 1/2 years

after the last fertilization (Table 1). The lack of significant yield reduction in unfertilized trees in 3 out of 4 years (Table 1) indicates that fertilization was not required annually to maintain productivity under the orchard conditions. We must conclude that sufficient N is available from other sources (e.g., high nitrate irrigation water, etc.) to maintain productivity without supplemental fertilization.

High leaf N concentrations. Pretreatment (1990) leaf N concentrations averaged above 2.6% in both orchards (Table 2). There is no evidence that almond yields increase above a leaf N concentration of 2.5%. Leaf N concentration appears to be insensitive to overfertilization, thus, there is virtually no difference in leaf N concentrations between trees receiving 250 lbs N/acre/year and those receiving 500 lbs N/Acre/Year (Table 2). This probably means that at higher levels of available soil N, tree capacity for N uptake is limited and additional fertilizer N accumulates in the soil and becomes vulnerable to loss—probably leaching—in coarse-textured, sandy soils. On the basis of our data, the ideal range of leaf N concentration to both maintain yield and minimize subsequent leaching appears to be between 2.3% and 2.5%N.

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

Tree N status and recovery of isotopically labeled fertilizer N. Following three years (1990-1993) of differential rates of N fertilization, we selected 18 trees (Salida orchard) varying in leaf N concentration (Table 3), and 1993 yield relative to pretreatment yields in 1990. Labeled ammonium sulfate was applied post-harvest (October 2, 1993) at the rate of 166 lbs N/Acre/Year. Trees also received 84 lbs N/Acre/Year (non-labeled) in April 1994. We then determined total recovery of labeled N in the fruit (1994). Four of the trees were also excavated completely in February, 1995, and analyzed for residual labeled N content.

Between 65% and 79% of the labeled N absorbed by the trees was in the fruit with the remainder present in the perennial tree parts (branches, trunk, roots, etc.), as shown in Table 3.

Trees that were fertilized at the rate of 500 lbs N/Acre/Year only recovered about 20.5% of the fertilizer N applied (Table 3). In contrast, trees that received 0, 125 or 250 lbs N/Acre recovered 30% of the labeled N applied—about 50% more. Thus, the high rates of N fertilizer application between 1990 and 1993 reduced recovery of fertilizer N in 1993-1994. Two factors may have limited uptake of fertilizer N by trees receiving 500 lbs N/A/Year between 1990 and 1993: a) dilution of labeled fertilizer N in the soil by high residual levels of nitrate (Table 3) and b) reduced tree N demand. As discussed below, leaching did not occur during the winter of 1993-1994.

We are finding (in other studies) that the N requirements of fruit growth, shoot growth and nut fill are important determinants of N uptake. During the post-harvest and dormant periods, growth nearly ceases, and dormant trees have a greatly limited capacity for N uptake. In years of heavy rainfall, significant leaching can occur between November and March. High residual levels of nitrate in the soil after harvest may be vulnerable to leaching within one to two months. Thus, a) low N uptake by trees during the post-harvest and dormant periods coupled with b) vulnerability of nitrate to leaching with the winter rains should discourage heavy post-harvest applications of fertilizer N. The winter of 1993-1994 was relatively dry, receiving only about 2/3 of the normal annual rainfall. Fertilizer recovery (Table 3) might have been even lower if we had conducted the study in 1994-1995 when rainfall was nearly double the long-term average. Our data do not allow us to determine how much of the labeled N recovery

occurred between October, 1993 and March 1994 (bloom) and how much between bloom and harvest (August, 1994).

Table 1. Differential N Fertilization and Almond Yields in 2 Stanislaus County Orchards

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

[z] Treatments initiated post-harvest in 1990
[y] Pretreatment yields
[x] Values sharing a common letter within columns (years) in a given orchard do not vary statistically
* Plot treated with labeled N to assess effect of tree N status on fertilizer N recovery

Table 2. Changes in Leaf N Concentration With Rates of Applied Fertilizer N in 2 Stanislaus County Orchards

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

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

Table 3. Effect of Previous Fertilizer Application Rate on Recovery of a Uniform Post-harvest Application of Isotopically-labelled Ammonium Sulfate[z]

Tree	Fertilization (1990 - 1993) (lbs N/A/Yr)	1993 Leaf N (% dry wt.)	Soil Nitrate -N[y] (ppm)	Labeled N recovery (%) Fruit Aug 1994	Tree Feb 1995	Total
10-19	0	2.06	1.95	24	--	--
14-19	125	2.28	0.81	26	7	33
18-12	0	2.37	0.81	19	8	27
10-8	125	2.46	0.37	22	--	--
10-9	125	2.65	--	22	--	--
6-10	250	2.59	15.5	27	--	--
10-11	500	2.70	193.6	14	7	21
10-13	500	2.92	48.1	15	5	20

[z] 872 g labeled N per tree was applied on 2 October, 1993.
[y] mg N-NO_3 per g of oven-dried soil. Analyses based on 4 soil cores per tree between 2 and 2.5 feet deep 10 days prior to application of labeled N.

DEVELOPMENT OF DIAGNOSTIC MEASURES OF TREE NITROGEN STATUS TO OPTIMIZE NITROGEN FERTILIZER USE

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OBJECTIVES

1. To develop a more sensitive measure of tree N status.
2. To develop 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.

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, not regulated and the dynamics of N in orchard crops is the least well understood of any cropping system.

In this project, we aim to improve plant N-monitoring techniques so that fertilizer applications can be better managed. This aim 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. Results will be used to develop fertilizer recommendations and monitoring procedures for orchard crops that will maintain profitability, optimize crop nutrient uptake and minimize nitrate leaching from the root zone.

Experimental design: A field experiment was initiated in young trees growing in Yolo county. Follow-up measurements were made in Stanislaus and Fresno counties. The trial consists of four N treatments replicated four times each in two crops: nectarine and almond. The rootstock for both crops is Nemaguard and the scions are Mission/Texas in almond and Fantasia in nectarine. All the trees were managed according to normal agricultural practices. The fertilizer was applied through a drip irrigation system to only the wetted zone where roots were presumed to be present. Leaf samples were collected in July and analyzed for NH_4NO_3 amino acids, ureides, total soluble N and total N. Trunk diameter in young trees and yield in mature trees was measured throughout the experimental period which has run three years.

RESULTS

Figure 1 shows that nitrate concentration in leaves is the best indicator of nitrogen status in almond.

The growth of young almond (trunk diameter) increased as nitrogen application increased from 0 to 79 g N/tree/year. There was no growth benefit from additional N and no increase in leaf total nitrogen (Kjeldahl N) or the amount of soluble N when N was increased

past 79 g N/tree/year. (79 g is roughly equivalent to 125 lbs/acre, assuming roots occupy 40% of the soil per acre). The concentration of nitrate in almond leaves, however, increased linearly with increasing N over the entire range of applications. Thus, when N is less than optimal there is a good relationship between total N, leaf nitrate and tree growth. However, when N is excessive, leaf total N did not increase, while leaf nitrate concentrations increased in direct proportion to N application.

N application in excess of 79 g N/tree/year was not beneficial to young tree growth. Leaf nitrate in young almond trees is a good indicator of tree N status and excess N application.

Figure 2 shows that ammonium is the best indicator of nitrogen status in nectarine. This response is similar to Figure 1. The growth of young nectarine trees increased as N increased from 0 to 79 g N/tree/year; higher N application did not increase growth. As in almonds, total N was a good indicator of tree growth only from 0 to 79 g N/tree/year and did not respond to additional N applications; hence it was a good indicator of excess N applications. In young nectarine trees, leaf ammonium is a good indicator of tree N status and excess N application.

Figure 3 indicates that application of N in excess of tree requirements results in accumulation of potentially leachable nitrogen in the soil. The concentration of N in the soil with depth below almond and nectarine trees is shown. In both types of trees, the lowest N application (N1 = 79 g N/tree/year) resulted in

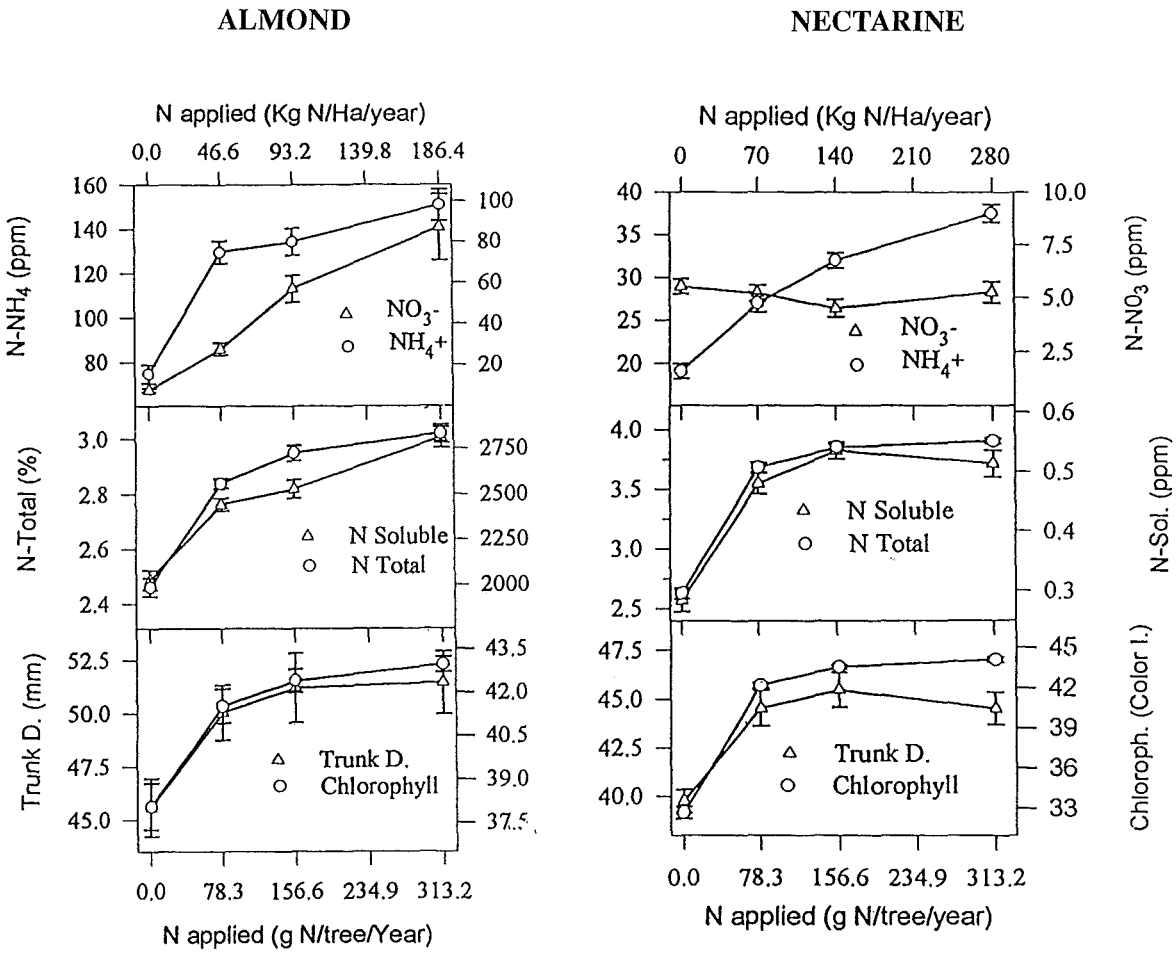

Figure 1 and 2. Effect of nitrogen application on nitrogen compounds, total nitrogen, chlorophyll and growth in Almond (left) and Nectarine (right).

maximal growth. Above this application rate (N2 and N3), soluble nitrogen accumulated in the soil where it may subsequently be leached to the groundwater.

These experiments were repeated in two mature almond orchards and one mature nectarine orchard. To determine which N compounds best represents tree N status we utilized a procedure similar to above. Trees were grown at four different N levels. Leaf N characteristics and yield were then determined over a three-year period. The sensitivity of an N compound to N application was determined as the percent increment in concentration with

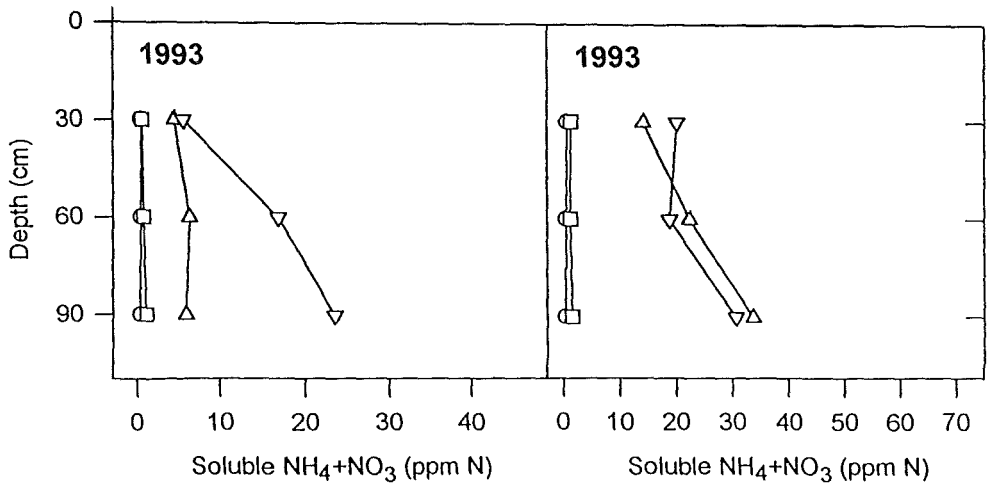

Figure 3. Effect of nitrogen application (NO=0, N1=79, N2=156, N3=235, N4=313 g N/tree/ year), on residual soluble nitrogen in the soil at various depths. Left Nectarine, right Almond.

Table 1. Nutrient concentrations in almond and nectarine and their relative change with N application. A high value indicates the N component measured is sensitive to changes in N application.

Species	Total N (% change)	Nitrate-N (% change)
Almond		
% Increment as N is increased from 0 - 560 lbs/acre/year	14	172
% Increment as N is increased above the critical value	12	83
Critical Value*	2.50%	180 ppm
	Total N (% change)	Ammonium-N (% change)
Nectarine		
% Increment as N is increased from 0 - 560 lbs/acre/year	32	49
% Increment as N is increased above the critical value	16	10
Critical Value*	2.70%	ND

* Critical value is the tissue nutrient concentration at which growth and yield are optimal.

the application of the fertilizer N. We also calculated the total increment in concentration with the application of the N fertilizer. In addition, the total increment in leaf N compounds that occurred at N rates above those required for maximal growth was calculated. These are shown in Table 1. We also calculated the tissue concentration of the various N coincided with maximal tree yield (CV in Table 1).

The results show that in almond, leaf nitrate responds dramatically to increasing N applications, increasing by 172% as N increased from 0-250 kg/ha/yr, whereas total N increased only 14%. The optimal N application rate was determined by measuring yield in all N treatments. Maximal yield occurred at different N applications in each year, and varied between orchards and species. Thus, there was no clear relation between N application rate and yield. Nevertheless, there was a consistent relationship between yield and tissue N concentrations and the critical value (CV) could be calculated.

In almond, maximal yield occurred when leaf nitrate was 180 ppm, or total leaf N was 2.5%.

In nectarine, maximal yield occurred when total leaf N was 2.7%. No other N compound was significantly correlated with yield. Thus, the concentration of N that corresponds to maximum yield (CV) is 2.5% N or 180 ppm nitrate in almond and 2.7% N in nectarine. When N is supplied in excess of that required for maximal yield, nitrate in almond increases by 83% while total N increases by 12%. (Table 1.)

In summary, nitrate is the best indicator of N excess in almond. In nectarine, the most reliable indicator of N status is total N which, unlike in almond, continues to increase as N availability increases.

Sampling Procedures: Experiments were conducted to determine the best sampling procedure for leaf nitrate and total leaf N. The key result is that leaf samples should be collected from June through August between 10 am and 5 pm, from the non-fruiting basal or spur leaves.

CONCLUSIONS

In almond, leaf nitrate is the best indicator of soil N levels and can be used to detect both deficient and excessive levels of tree N. Leaf nitrate levels in excess of 180 ppm were consistently found in trees supplied with greater than optimum soil N. Trees with total leaf N less than 2.5% may be deficient. The presence of excess N cannot be reliably determined using total leaf N. In nectarine, total leaf N is the best available index of tree N status and adequately reflects both N deficiency and toxicity. A total leaf N of 2.7% resulted in optimal yield; higher total leaf N indicated excess soil N application.

CITRUS GROWERS CAN REDUCE NITRATE GROUNDWATER POLLUTION AND INCREASE PROFITS BY USING FOLIAR UREA FERTILIZATION

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OBJECTIVES

The objective was to test the hypothesis that foliar urea applied within the period April 1 to June 1 can do triple duty as:

1. A "non-pesticide" to control citrus thrips and reduce fruit scarring,
2. A "growth regulator" to improve fruit set and increase yield without reducing fruit size or quality, and
3. 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 specific goal of our research was to determine whether there is an optimal time for cost-effective foliar application of urea that will successfully improve fruit set and yield and control citrus thrips to reduce fruit scarring. The results of our research will not only help improve citrus productivity and grower profits, but will also help reduce nitrate groundwater pollution and reduce the amount of chemical pesticides currently used to control citrus thrips.

DESCRIPTION

The research was conducted on 17-year-old 'Frost nucellar' navel orange trees on Trifoliate orange rootstock under commercial production by Paramount Citrus in the Ivanhoe area of the San Joaquin Valley. The research was replicated for three years due to alternate bearing.

There were five treatments each replicated as eight randomized blocks (six rows wide by 15 trees long). Data was collected from six individual trees per block for a total of 48 data trees per treatment. Foliar low-biuret urea was applied each year on approximately April 7, April 21, May 5, or May 20 for treatments 1 through 4, respectively. Treatment 5, the control, was Paramount Citrus' best management practice. Total nitrogen analyses were done annually in September on each of the 240 data trees in order to monitor the total nitrogen status of the tree (as is currently done commercially) and to determine the contribution to total N made by each treatment over the three years of the field trial.

Harvest was in March of each year. Fruit weight per tree, fruit number per tree, fruit size for all fruit on each of the 240 data trees, and degree of thrips scarring on all fruit on 120 data trees were determined.

RESULTS

The results of the study provided clear evidence that a spring foliar application of low-biuret urea had no negative effect on the population densities of the beneficial predatory mite, *Euseius tularensis* (hibisci). 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, 1992—regardless of whether 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 by immigration 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.

Spring foliar applications of low-biuret urea had no statistically significant effect on the population densities of *Scirtothrips citri*. 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.

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 in September or evaluation of total fruit per tree at harvest in March. While not significant at the 5% level, it is interesting to note that for both years of the study the late May (May 20, 1992 and May 25, 1993) foliar application of low-biuret urea resulted in the lowest degree of fruit scarring, especially severe scarring (Table 1). This trend was observed for both the on-tree and harvest evaluations for both years of the study. Although not significant at the 5% level, it is also worth noting that for both years of the study, the second date of foliar application of urea (April 21, 1992 and April 27, 1993) had the highest percent scarring, especially severe scarring. In year two, the mean percent of fruit severely scarred by citrus thrips biuret urea compared to trees receiving the late April application (Table 1). Neither value was significantly different from the control or from trees receiving urea to the foliage in early April or early May.

In the first year of the study, which was an "on" year, 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. The May 20, 1992 foliar 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, 1992 low-biuret urea 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, 1992 foliar application of urea 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, except the April 21, 1992 urea application.

In the second year of the study, which was an "off" year, there was no significant effect at the 5% level on the kg and number of fruit per

Table 1. Effect of Time of Application of Low-Biuret Urea to the Foliage of the 'Washington' Navel Orange on the Percent of Fruit at Harvest Severely Scarred by Citrus Thrips[z]

Date Urea Applied to the Foliage	% Severely Scarred Fruit Year 1		% Severely Scarred Fruit Year 2	
		P≤0.10		P≤0.10
Early April	20.65	a	11.93	ab
Late April	21.99	a	14.03	a
Early May	20.89	a	11.09	ab
Late May	16.09	a	9.67	b
Control: soil-applied N	18.94	a	11.08	ab

[z]Average yield for all treatments was 269±13 and 141±4 kg fruit per tree in years 1 and 2, respectively.

tree. There was, however, a statistically significant increase in the kg of fruit of packinghouse carton size greater than 56 (fruit with diameters greater than 8.8 cm) for trees receiving the May 25, 1993, foliar application of low-biuret urea compared to the control trees receiving soil-applied nitrogen. Trees receiving the May 25, 1993, foliar application of low-biuret urea had significantly more fruit of packinghouse carton size 56 than trees receiving the early April 13 foliar application of urea.

Repeated Measure Analysis was used to test the effect of the time of foliar-urea application on fruit yield, number and size over the two years of the study. The late May foliar application of low-biuret urea significantly (P 0.05) increased yield (kg) and both the kg and number of fruit of packinghouse carton size 56 per tree compared to trees receiving foliar applications of low-biuret urea in early April or early May, but was not significantly different from the control trees receiving soil-applied nitrogen or from trees receiving a foliar application of low-biuret urea in late April (Table 2). There was no significant effect on the kg or number of fruit in any other size category.

CONCLUSION

Our results suggest that urea will not have much impact in preventing 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 remains to be determined. The results provide evidence that a properly-timed spring (late May) foliar application of low-biuret urea significantly increased yield by increasing both the weight and number of large-sized fruit (packinghouse carton size 56) with some reduction in the degree of severe fruit scarring by citrus thrips. Trees receiving the late May foliar application of low-biuret urea averaged 11 kg more fruit than the control trees receiving soil-applied nitrogen over the two years of the study. This represents an additional 0.65 17-kg carton of fruit per tree. At a typical planting density of 96 trees per acre, the late May foliar application of low-biuret urea would yield 63 additional cartons per acre. For the cost/benefit analysis, we used the following values:

Profit was calculated at a price of $8.00 per 17-kg carton (despite the fact that the late May foliar application of urea increased the number of fruit per tree of packinghouse size 56 and had no effect on any other fruit size) minus $2.29 per carton for packinghouse handling of the extra cartons (per Connelly Melling; Dole).

Expenses were calculated at 56.8 liters (15 gallons) Unocal PLUS per acre ($16.50 per acre), and spray rig at $25.00 per acre, with all other expenses being the same, although there is the expense of a soil application of nitrogen to the control trees which we did not include. Net return to the grower for the late May foliar application of low-biuret urea was an average of $318 per acre per year.

A copy of the final report is available through FREP's Resource Guide.

Table 2. Effect of Time of Application of Low-Biuret Urea to the Foliage of the 'Washington' Navel Orange on Yield for the Two Years of the Study[z]

Date Urea Applied to the Foliage	Yield kg/tree		56s kg/tree	
Early April	197	b	53	b
Late April	210	ab	60	ab
Early May	201	b	56	b
Late May	215	a	65	a
Control: soil-applied N	204	ab	60	ab

[z]Yield data in Vertical columns followed by different letters are significantly different at P ≤0.05.

CROP MANAGEMENT FOR EFFICIENT POTASSIUM USE AND OPTIMUM WINEGRAPE QUALITY

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OBJECTIVES

The objectives were to evaluate approaches to improve vine potassium status on heavy, putatively K-fixing soils. The approaches included:

1. Method and placement of fertilizer
2. Manipulation of soil water content
3. Reducing K fixation by addition of gypsum
4. Screening rootstocks for improved K uptake efficiency

The study also examined:

1. The response of root growth to supplemental irrigation and potassium fertilizer applications.
2. The response of several aspects of fruit quality to these treatments and to the use of several rootstocks.
3. The impact of these practices on vine uptake of and soil movement of nitrate.
4. The utility of bloomtime petiole analysis for evaluating vine nutrient status.

Experimental sites were selected on the basis of low concentration of K in petioles (petiole [K]). low soil K analyses, late season K deficiency symptoms, lack of recent application of soil amendments, high soil clay content, presence of premium winegrape varieties that represent large acreage in the state, and relatively uniform soil and vine growth.

RESULTS AND CONCLUSIONS

Experiments were conducted at several sites to investigate different approaches to increasing the efficiency of potassium (K) 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 to improve efficiency because high application rates are often required to obtain plant responses.

High rates of potassium sulfate (8 lbs or greater of potassium sulfate per vine) and supplemental irrigation (2 to 4 times the standard rate) were utilized to decrease K fixation and increase the availability of K for root uptake. This successfully increased vine K status and maintained high K status beyond veraison. A slight increase in root growth in the upper 30 cm of soil due to both K and water applications may have contributed to increased K uptake. Augering holes next to vines (an expensive operation) did not increase vine K status above placement beneath drip emitters when evaluated at bloom, but the data suggest that augering maintains high K status during fruit ripening.

The genetic approach to managing these soils looks promising. For Chardonnay vines on low K soil, vine status was significantly greater on 5C and St. George rootstocks than on four other root systems. A wider range of genetic material that contains little or no *V. vinifera* should be evaluated. Applications of

K to these vines increased juice pH on some rootstocks and in some years there has been a significant correlation between vine K status and juice pH. Use of gypsum + potassium sulfate increased soluble K in the soil, vine K status, and yield above that of potash alone. The use of gypsum can be recommended when applying K on similar soils. At the Healdsburg Chardonnay site, treatments that combined nitrogen and potassium applications exhibited the greatest vine K status and yields.

A copy of the final report is available through FREP's Resource Guide.

POTENTIAL NITRATE MOVEMENT BELOW THE ROOT ZONE IN DRIP IRRIGATED ALMONDS

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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 to address 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 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.
5. To evaluate the effects of two rates of potassium on growth, nutrient concentrations in leaves and nut yields.
6. To develop recommendations for nitrogen, irrigation and soil management for use in the establishment and early maturity stages of drip-irrigated almond orchards.

DESCRIPTION

The study was 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, varying according to year. Urea, the nitrogen fertilizer source, was applied on a monthly basis in five equal increments beginning April 1st.

RESULTS AND CONCLUSIONS

The results of the nitrogen rate at two drip irrigation levels experiment and the nitrogen source experiment confirmed that the rates of nitrogen needed to produce optimum yields at the full water level (1.0 ET) do not result in large amounts of nitrate-nitrogen being leached below the root zone. The rates of applied nitrogen necessary to produce optimum yields and not have excess nitrate leaching can be achieved by monitoring early July leaf total nitrogen concentrations (desirable range is 2.3 to 2.5%) and applying water at the 1.0 ET level. Excess water or nitrogen may result in excess nitrate-nitrogen being leached below the root zone. Sustained high yields and vigorous tree growth require large amounts of nutrients, especially potassium. After observing the large differences in leaf potassium

concentrations during the early part of the growing season, followed by nearly the same levels on July 1st, it seems advisable for growers to take leaf samples twice a year, (about April 1 and July 1), from at least three areas within a field. The areas should represent low, medium and high producing portions of the field. Leaf analyses showing large differences in potassium or other nutrients in the early season samples may indicate a situation where a deficiency is approaching.

A copy of the final report is available through FREP's Resource Guide and the Almond Board of California 1994 Conference Proceedings. Please call 209-549-8262 for a copy.

FIELD EVALUATION OF WATER AND NITRATE FLUX THROUGH THE ROOT ZONE IN A DRIP/TRICKLE IRRIGATED VINEYARD

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The primary objective of the study was to determine the extent to which nitrate flux below the root zone occurs for a chemigated, drip/trickle irrigated Thompson Seedless vineyard when fertilization and added water amounts are at optimum levels. Tasks included 1) establishing normal and usual conditions for a 1.2 ha Thompson seedless vineyard by means of a uniformity study, 2) installing neutron probes, tensiometers and solution suction probes to characterize soil water retention transmission properties, 3) installing drip irrigation laterals and imposing irrigation and chemigation treatments, and 4) measuring water and nitrogen flux below the effective root zone.

Season-long water flux below the root zone was only 23 mm. With the measured nitrogen concentration in this quantity of water, only 1.5 kg N per ha (1.3 lbs N per acre) was moved below the effective root zone of the crop. This study clearly showed that nitrogen fertilization and irrigation to fully meet water and nutrient requirements of grape vineyards can be done without contaminating groundwater.

A copy of the final report is available through FREP's Resource Guide.

INFLUENCE OF IRRIGATION MANAGEMENT ON NITROGEN USE EFFICIENCY, NITRATE MOVEMENT AND GROUNDWATER QUALITY IN A PEACH ORCHARD

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This comprehensive project, completed in 1993, covers a wide range of issues in irrigation and nutrient management for stone fruit orchards. Two literature reviews were written and made available to UCCE stone fruit farm advisors and CDFA. They are titled "The Effects of Various Cultural and Environmental Factors on Nitrogen Use Efficiency" and "Techniques for Sampling Soil Nitrates: Ceramic Cup Extractors".

A plot study of fertilization and irrigation regimes was also carried out. Multiple applications of N fertilizer applied through a low-volume system were compared to one-time applications within three different irrigation regimes (a high frequency 100% ET, low frequency 100% ET and high frequency 100% ET except for 150% ET during the final fruit growth stage). Single fertilizer applications were compared to multiple ones.

Project results show that there were no significant effects of fertilization treatments on any measured yield or growth parameters. Yield and number of fruit per tree were significantly reduced in the 150% ET treatment.

A copy of the complete report and the two literature reviews are available through FREP's Resource Guide.

NITROGEN EFFICIENCY IN DRIP-IRRIGATED ALMONDS

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OBJECTIVES

This research was 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 or for sandy soils. The use of stable isotopes allowed for directly measurement of whole plant uptake (tops, roots and the crop). Knowing uptake, N efficiency in drip systems can then be calculated.

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. Fertilizer application rate for two years prior to treatment was 800 lbs per acre in split monthly or bimonthly applications (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. 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 were installed to measure soil solution composition and aeration status in the drip zone.

RESULTS AND CONCLUSIONS

Analysis of the data for fine root biomass and nitrogen content as well as soil solution N and extractable N show that extractable N decreases as distance from the tree and N source increases. The ratio of ammonium to nitrate also decreases with distance and is strongly correlated with soil pH. In all cases, the soil pH is greater in the calcium nitrate treatments compared to the ammonium sulfate treatments. In both treatments pH increases with distance from the tree. Fine root biomass was greater in the ammonium treatments in spite of lower pH levels. It appears that the higher N rate is more influential than the low pH in determining fine root growth.

Results from the experiment show that ammonium sulfate is strongly acidifying when concentrated in the small area utilized by drip systems. This can happen in a few years with high N rates and pH values as low as 3.6 have been found in the soil and in solution. However, ammonium sulfate does appear to supply more N to the plant and maintain a higher extractable and soluble soil N level. Fine root biomass is greater in the ammonium sulfate treatments than in the calcium nitrate treatments. A greater N supply is the most probable reason, but other interactions with pH can

not be ruled out. Soil N and soil acidity are dynamic. Between monthly fertilizations, pH may vary as much as 3 units and levels of soluble N fluctuate several hundred mg/l. The strong acidification associated with ammonium sulfate may have significant long-term consequences and needs to be monitored.

A copy of the final report is available through FREP's Resource Guide.

OPTIMIZING DRIP IRRIGATION MANAGEMENT FOR IMPROVED WATER AND NITROGEN USE EFFICIENCY

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The objectives of this research project were to improve nitrogen and irrigation management practices of commercial vegetable growers. Specific objectives were to 1) document the importance of drip irrigation and fertigation on nitrate leaching losses, 2) investigate techniques to rapidly measure soil moisture and soil and plant tissue N levels and 3) disseminate information to growers.

Irrigation scheduling techniques were studied to optimize yield and water use efficiency. This study along with previous work of the project leader showed that the use of reference evapotranspiration (ETo) for California Irrigation Management and Information Systems (CIMIS) adjusted for crop growth stage accurately predicts crop water needs. Studies of the effect of N fertigation levels on pepper and tomato resulted in the development of nitrogen sufficiency guidelines at various growth stages.

The effects of drip irrigation and fertigation management on nitrate leaching were evaluated by the use of buried anion exchange resin bags. Results showed that these traps were at least partially successful in distinguishing differences in seasonal nitrate losses among treatments.

The study also investigated the use of suction lysimeters, portable nitrate selective electrodes and a leaf reflective meter for field N monitoring. The investigation showed that suction lysimeters are best used to determine rootzone nitrate sufficiency rather than deficiency.

Correlations between fresh sap and dry tissue nitrate-nitrogen concentration were also developed for tomato, pepper and lettuce.

A copy of the final report detailing experimental design and more complete results is available from FREP.

IMPROVEMENT OF N MANAGEMENT IN VEGETABLE CROPPING SYSTEMS IN THE SALINAS VALLEY AND ADJACENT AREAS

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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.

DESCRIPTION

During 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 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 provide strong circumstantial evidence that vegetable fields are a likely significant source of nitrate in groundwater:

* Continuous vegetable rotations with two or more crops per year and frequent tillage are common; mild winters allow nearly year-round production;
* Crops are shallow-rooted with 12 to 30 inch deep root zones;
* Crops are high in value, and plentiful, continuous supplies of N and water right up to harvest are critical for yield and marketability;
* 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;
* Water is relatively inexpensive in many areas;
* 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 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, and 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 NRCS, 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 focused efforts on conducting 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 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 was 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 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 available from FREP's Resource Guide.

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

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

Best Management Practices for Irrigating and Fertilizing Cool-Season Vegetables

INTEGRATING AGRICULTURE AND FERTILIZER EDUCATION INTO CALIFORNIA'S SCIENCE FRAMEWORK CURRICULUM: GRADES K-12.

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Cooperators:

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California Farm Bureau Federation

OBJECTIVES AND RESULTS

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 was to provide educators with hands-on lessons that increase student agricultural and scientific literacy.

During 1992-93 fiscal year, three educational units on the nutrient requirements of plants were developed: 1) What Do Plants Need to Grow?; 2) How Much Is Too Much? How Little Is Too Little?; and 3) The Interrelationships of Soil, Water and Fertilizers and How They Affect Plant Growth. Spanish student worksheets were developed for What do Plants Need to Grow? Students in Grades 2-4 learn that plants, in order to survive and reproduce, require certain nutrients. The 5th-8th grade unit developed 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 was developed for grades K-1, The Mysterious Plant Caper, which has Spanish student worksheets. Two supplementary units were developed on plant nutrient cycles, Starting All Over Again (grades 4-8) and The Chemistry of Fertilizers (grades 10-12).

During the 1994-95 fiscal year, the FREP units were promoted at educator conferences and workshops in order to increase the awareness and use of the curricula. Attendance and participation in educator conferences and workshops is the most effective way to promote and distribute curricula. Educators attending these conferences look for materials to enhance their personal teaching and to gather material to share with colleagues. These conferences and workshops allowed the Foundation staff to present the curricula and allowed the educators to experience the FREP curricula firsthand. The conferences included: the California Science Teachers Association in Palm Springs, the California School Boards Association Annual Education Conference in San Diego, and the California Farm Bureau Federation Annual Meeting in Anaheim.

In the 1994-95 fiscal year, 200 copies of each of the FREP units and 100 copies of each of the two Spanish student worksheets were printed. The FREP units were included in the Foundation's Lesson Plan Catalog and the Teacher Resource Guide which is distributed to educators throughout the state. The FREP units were promoted via advertisements in the California Science Teacher Association newspaper four times, and in the California Foundation for Agriculture in the Classrooms *Cream of the Crop* newsletter.

The curricula can be ordered from AITC at (916) 924-4380.

NUTRIENT RECOMMENDATION TRAINING: URBAN MARKETS

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It is of great concern to the fertilizer industry that the garden supply salespersons in California have a less that rudimentary knowledge of basic fertilizer use, disposal and environmental impact. The overall goal of the program is to educate garden supply salespersons on all aspects of fertilizer use so that they can in turn educate consumers on the use of fertilizer in the most environmentally and agronomically sound manner possible.

A comprehensive video will consolidate current information pertaining to home fertilizer use and Best Management Practices from previously FREP-funded projects and private organizations. An accompanying study guide will include detailed questions and answers regarding home fertilizer and plant nutrient recommendations, and the role of urban markets on the impact of non-point source pollution. An informational poster on how to read fertilizer labels will be included. The poster will be displayed in the garden section of home centers for consumer quick-reference on managing fertilizer use and reading fertilizer labels.

The video and manual will be released in 1996.

THE USE OF COMPOSTS TO INCREASE NUTRIENT UTILIZATION EFFICIENCY IN AGRICULTURAL SYSTEMS AND REDUCE POLLUTION FROM AGRICULTURAL ACTIVITIES

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The production and utilization of composts has the potential to contribute to the productivity of California agriculture while simultaneously helping reduce nitrate water pollution associated with some agricultural practices. The most significant agricultural sources of nitrates in groundwater are nitrogen fertilizers applied to crops and the nitrogen contained in animal manures. The proper production and use of composts can help reduce nitrate leaching from both animal and crop systems. However, many in the agricultural sector are unfamiliar with the production, utilization, advantages and disadvantages of composts. In addition, recently enacted laws and currently evolving regulations will affect both the quantity of commercially available composts on the market, as well as on-farm composting in the near future. Therefore, an educational effort is needed to address both the technical and regulatory aspects of composts in agriculture. The production of composts from agricultural wastes in California is increasing and many composts from non-agricultural or mixed agriculture/non-agricultural sources are projected to be on the market as compliance with AB 939 is achieved. Without the appropriate information to evaluate various management options, it will be difficult for farmers to use composts and other resources wisely to optimize production and reduce environmental degradation.

The objectives of this program were to educate farmers, livestock producers, and representatives of industry, government and the University in the following areas:

1. Composts: What they are, advantages, disadvantages; their effects on soil properties, N dynamics, plant nutrients and crop growth; comparisons of composts, manures and inorganic materials and inorganic fertilizers; how to evaluate and use them.
2. Composting : Biological processes and effects, management techniques, tools and equipment.
3. Legal aspects of agricultural "waste" management, composting operations, and pollution, with emphasis on the management and utilization of composts, other organic materials and inorganic fertilizers to maximize efficient nutrient use and minimize environmental pollution, particularly nitrate pollution of groundwater.

This project provided the agricultural sector with the best available information to make intelligent decisions about the production and use of composts. The new impact of this effort should be enhanced crop productivity and a reduction in nitrate leaching from both crop and livestock systems. The objectives were met in three ways. Eighteen presentations were made at events sponsored by various groups and organizations throughout the Central Valley, Central Coast and South Coast regions reaching more than 1,000 people.

Three in-field demonstrations of compost production and utilization were conducted in the same regions. These were highly successful as attendance figures far surpassed initial goals. A concise guide to on-farm compost production was produced and distributed to all interested parties. A draft version of the document was distributed to more than 1,000 people.

The document *Compost Production and Utilization* is available through FREP's Resource Guide and the University of California Division of Agriculture and Natural Resources (DANR) Communication Services.

BEST MANAGEMENT PRACTICES (BMPS) FOR NITROGEN AND WATER USE IN IRRIGATED AGRICULTURE: A VIDEO

Project Leaders:

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Thomas Doerge
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Soil and Water Conservation

The result of this project was a 30 minute educational video which defines and illustrates technologies and handling practices for best management of nitrogen in California agricultural systems. It discusses the role of N and its behavior in vegetable and orchard systems. Two case studies are presented and nitrate-sensitive areas in California are discussed. A study guide is included.

The video is available through FREP's Resource Guide.

NITROGEN MANAGEMENT FOR IMPROVED WHEAT YIELDS, GRAIN PROTEIN AND THE REDUCTION OF EXCESS NITROGEN

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The objective of this project was to prepare and distribute educational material to extend previously conducted research results directly to wheat growers and encourage them to use the results.

A descriptive brochure (explaining the research results and recommendations for the use of these results) was published, printed, and distributed to growers, suppliers and advisors. The brochure was prepared from research results reported by Ken Cassman to the California Wheat Commission. The brochure explains that late season nitrogen (applied after heading and with an irrigation) provides growers with a powerful management tool to optimize yields and achieve higher wheat protein levels while reducing total applied N. Late season N is more effectively taken up by wheat plants than preplant N and is more efficiently partitioned to grain. This management technique results in higher farmgate value, lower production costs, and the reduction of excess (unused) nitrogen lost in the soil.

10,000 brochures were printed and mailed to wheat producers, fertilizer suppliers, and others throughout the state. The brochures will help growers change N fertilizer management plans to maintain yields, improve protein scores, and reduce excess (leachable) N.

The brochure is available through FREP's Resource Guide.

DRIP IRRIGATION AND NITROGEN FERTIGATION MANAGEMENT FOR CALIFORNIA VEGETABLE GROWERS

Project Leader:

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This educational video describes the use of drip irrigation in California vegetable systems. It discusses scheduling techniques, the development of efficient nitrogen fertigation regimes and the uses and limitations of fertility and soil monitoring techniques. The video was awarded the best educational tool of 1995 by the American Horticultural Society. A detailed study guide is included.

The video is available through FREP's Resource Guide.

DETERMINATION OF SOIL NITROGEN CONTENT IN-SITU: A LITERATURE REVIEW

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The result of this project is a comprehensive literature review of site-specific crop management. The report covers spatial variability, geographic information systems (GIS) position detection and global positioning systems (GPS), sensing soil nutrients, texture and grain flow meters and yield mapping. Techniques for determining soil mineral nitrogen are also detailed.

A copy of the complete report is available through FREP's Resource Guide.

EXTENDING INFORMATION ON FERTILIZER BEST MANAGEMENT PRACTICES AND RECENT RESEARCH FINDINGS FOR CROPS IN TULARE COUNTY

Project Leader:

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This project, completed in March 1995, provided funding for the University of California Cooperative Extension-Tulare County Office to publish a year-long series of newsletters focusing on fertilizer nitrogen use efficiency. Four issues of a special document "Nitrogen Digest" were published, covering such issues as the effects of N on crop quality, foliar fertilization, nitrogen fixation and cover cropping. These were distributed to all those receiving any of the Tulare County commodity newsletters. Sixteen articles pertaining to N or nitrate management in various commodities were also published in individual commodity newsletters.

A telephone survey was used to evaluate the effectiveness of the project. Two hundred and one people participated. In general, survey results indicated that the information was understandable, useful and had some influence on management practices. Seventy-eight percent of the survey respondents recalled receiving the Nitrogen Digest, and thirty-three percent of them changed, modified or adapted their fertilization practices.

EDUCATING CALIFORNIA'S SMALL AND ETHNIC MINORITY FARMERS: WAYS TO IMPROVE FERTILIZER USE EFFICIENCY THROUGH USE OF BEST MANAGEMENT PRACTICES (BMPS)

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This project, conducted under the auspices of the Small Farm Center, conducted an outreach program for small farmers and farmers of Hispanic and Southeast Asian heritage. Growers were taught regionally-specific techniques for efficiently managing nitrogen in their cropping systems. Three field days were held in San Diego, Fresno and Monterey Counties, reaching a target audience of approximately 100 people.

A basic written curriculum with slides was produced in Laotian, Spanish and English.

V. NEW PROJECTS

BEST MANAGEMENT PRACTICES FOR TREE FRUIT AND NUT PRODUCTION: A VIDEO

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

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

IRRIGATION AND NUTRIENT MANAGEMENT CONFERENCE AND TRADE FAIR

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Nitrate levels in the ground water basin of the Salinas Valley have been increasing and agricultural fertilizers have been identified as a primary source of this nitrate contamination. As part of its water quality planning program, the Monterey County Water Resources Agency has led a coordinated research and outreach effort to reduce nitrate leaching through improvements in irrigation efficiency and fertilizer management. As part of the effort, an Irrigation and Nutrient Management Conference has been held in Salinas three times since 1992.

The goal of this project is to hold an annual conference in Salinas to transfer practical knowledge to area growers about the issues and practices of irrigation and fertility management. The conferences will focus on delivering practical information and new technologies designed to efficiently manage water and fertilizer inputs. Experienced growers and other key industry personnel will play a significant part in the conference.

The conferences are targeted towards all growers in the Salinas Valley and nearby regions who are interested in improving their on-farm irrigation and fertility management. In the past several years, approximately half the attendees have come from areas outside the Salinas Valley such as the Pajaro, San Juan, Santa Maria and San Joaquin Valleys. There has also been significant attendance from agricultural support industries such as local and regional irrigation and fertilizer companies, as well as crop consulting firms.

DEVELOPING SITE-SPECIFIC FARMING INFORMATION FOR CROPPING SYSTEMS IN CALIFORNIA

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The wheat-tomato rotation is the primary cropping system used by tomato producers in the Sacramento Valley, comprising approximately 400,000 acres annually. Typically, growers manage individual fields based on unit areas ranging from 20 to 120 acres, but there could be significant economic and environmental benefits from smaller management units, i.e., "site-specific management". In many instances soil variations across the field landscape significantly impact irrigated wheat and tomato yields as a result of changes in soil texture, fertility or other factors. Field spatial information is critical to improving productivity and the efficient use of production resources.

In the last five years, grain producers in the upper Midwest have developed site-specific farming information systems which provide intensive data on field variability, based on nutrients and yield. This management information has resulted in identification of nonproductive field areas, improvement in nutrient application efficiencies and improved productivity. Information management tools used for site-specific farming (e.g., grain yield monitors, geographical position systems (GPS), etc.) have been sufficiently developed so that they are used by the top producers in the Midwest.

The main objective of this two-year effort will be to explore and demonstrate the potential for relating in-field variation in wheat and tomato yields to variations in soil, vegetation index (based on aerial infrared photos), leaf chlorophyll and plant nutrient sampling. The results will help establish which method(s) of obtaining data on field-level spatial variability would be most useful and cost-effective for site-specific crop management for this rotation. A secondary objective is to relate variations in wheat grain protein in high protein varieties such as Express to flag leaf N content near the time of heading. The final product will be a farmer-oriented bulletin on site-specific farming technology and potential use of this information in wheat-tomato rotations. A demonstration of this technology will be presented at the LTRAS 1996 field day, the Yolo County wheat grower meeting, and the winter tomato conference in January 1997.

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

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The objectives of this research project are (1) to evaluate the effectiveness of conventional and alternative sprinkler irrigation systems on water and fertilizer use efficiency in three commercial carrot production seasons in the Southern SJV, and (2) to adapt an existing computer simulation model to carrot production to assess environmental and economic consequences of irrigation water and nitrogen fertilizer management under conventional and alternative sprinkler irrigation systems.

A three-season on-farm experiment conducted in conjunction with southeast Kern County carrot grower cooperators is proposed to evaluate the effects of 45 X 30, 40 X 30 and 35 X 30 ft sprinkler irrigation spacing on 1) applied water use efficiency: 2) nitrate-leaching losses: and 3) carrot yields and quality. The information generated by this study will be timely and useful to growers, irrigation and water district managers and researchers in the Southern SJV and may contribute substantially to resource conservation and environmental preservation efforts in this vitally important agricultural region.

RELATIONSHIP BETWEEN N FERTILIZATION AND BACTERIAL CANKER DISEASE IN FRENCH PRUNE

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

Research plots have been established at the UC Davis Department of Pomology's Wolfskill ranch to determine the effects of "fertigation" (N [urea] fertilizers applied through drip irrigation) on growth responses and yields of French prune. Fertigation is thought to be an efficient N delivery scheme and an alternative practice to top-dressing. Unexpectedly, two of our treatment blocks which had no or very low levels of applied nitrogen (N) developed a very high incidence of BC (60% and 32%, respectively). No BC losses occurred in the other 22 treatment blocks that received higher levels of nitrogen. Extensive soil analyses of all nitrogen treatments showed no differences in nematode populations. Thus, the only apparent variable associated with BC at this site was the level of applied nitrogen.

The goal of this two year project is to determine the relationship between the amount of applied nitrogen and the incidence of bacterial canker disease in French prune trees by correlating the disease incidence and severity with rates of nitrogen applied by fertigation and leaf N analyses. Although the study will focus on French prune, it is likely that the results will be applicable to other stone fruit crops in California. Fertilizer recommendations will be developed which minimize the risk of developing BC due to under-fertilization, while minimizing the amount of nitrogen that needs to be applied for adequate tree growth and preventing contamination of ground water supplies.

NITROGEN MANAGEMENT IN CITRUS

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This project proposes a five-year study of nitrogen management in a mature citrus grove. The objective is to develop best management recommendations for nitrogen fertilization. This would result in sustained returns from adequate yields of high quality fruit, while minimizing nitrogen loss to water resources and reducing excess vegetative growth and pruning costs. The trial will be conducted in a mature commercial Navel orange grove with standard management practices. The amount (incremental 0.5 - 2.5 lbs N/tree), application method (irrigation injection, foliar) and timing of nitrogen (continuous, monthly, seasonal split, single annual application) will be evaluated in a statistically replicated trial.

Nitrates in the leachate at depths in the root zone and below the root zone will be monitored throughout the experiment to determine the potential hazard of groundwater contamination. Fruit yield, fruit quality, tree size and leaf nutrient levels will be measured to determine the most profitable fertilization program. Finally, best management practices will be formulated for citrus growers to minimize groundwater contamination by nitrates while maintaining good production. These will be presented to the citrus industry at grower meetings, in newsletters, extension pamphlets, magazine articles and as a computer management program.

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

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The goals of this three-year project are to determine nitrogen fertilizer best management practices for broccoli production in the San Joaquin Valley, to determine if BMP's change for fall versus spring harvested broccoli, and to identify nitrate movement and potential nitrate leaching losses of applied nitrogen fertilizer under furrow irrigation.

A secondary objective is to evaluate the effectiveness and utility of the "Cardy meter" for quick test nitrate values for decision making in broccoli nitrogen management during fall and spring growing seasons. Field days for growers and industry will also be conducted.

EVALUATION OF CONTROLLED RELEASE FERTILIZERS AND FERTIGATION IN STRAWBERRIES AND VEGETABLES

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The objective of this three-year project is to research and field-demonstrate improved nutrient management of strawberries and vegetables. The major emphasis will be on nitrogen management, however, phosphorus, potassium and calcium also will be evaluated since deficiencies occur in this area. Field research trials will be conducted on grower fields during three consecutive years. The research each year will consist of two celery trials, two lettuce trials, and one strawberry trial. The specific objectives are:

1. To evaluate celery, lettuce and strawberry yields and quality using different types of controlled release fertilizers at various rates in combination with fertigation.
2. To monitor nutrient uptake through tissue analysis and develop baseline data for strawberries and vegetables.
3. To balance the nutrient application rate with crop requirements to establish best management practices.
4. To carry out an outreach component through workshops, field days and research reports.

VI OTHER NUTRIENT AND IRRIGATION RELATED PROJECTS

The following section contains summaries of other research and demonstration projects related to FREP's mission, i.e. the efficient use of fertilizing materials. These projects are not funded by FREP, but, we believe they complement FREP's goals and will help provide the reader with a greater understanding of the scope of nutrient and irrigation research being conducted in California. The summaries were drafted using various information sources and have been reviewed by the project leaders. They are believed to be accurate by the editors; however any inaccuracies are our responsibility.

NITROGEN FERTIGATION OF YOUNG PRUNE TREES AND EFFECTS ON HORTICULTURAL PERFORMANCE

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Cooperators:

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Project Status:

Ongoing

Source of Funding:

California Prune Board

OBJECTIVES

This project was initiated to develop information to help prune growers make better decisions with regard to nitrogen fertilization of young prune orchards and to demonstrate that techniques and technologies are available today to address some of the public concerns over excessive use of nitrogen in fruit production. The study objectives were:

1. To determine if frequent application of nitrogen through fertigation during the growing season can lead to improved tree growth and productivity while minimizing the use of nitrogen fertilizer.
2. To evaluate leaf analyses as an indicator of whether nitrogen should be applied to young trees and to measure the impact of that strategy on prune tree productivity.
3. To work toward the development of a nitrogen budget (N inputs and losses) approach for managing N fertilization of prune orchards.
4. To assess buried drip irrigation as a potential high-efficiency alternative to above-ground drip irrigation.

DESCRIPTION

A nine-acre block of prune trees was planted in Winters, CA (Yolo Co.) in February 1991. Trees were planted at distances of 17 ft. between rows and 14 ft. between trees. Two, 1 gal/hr drip emitters were installed per tree in 1991 and two additional in the spring of 1993. All treatments received similar amounts of water and fertilizer nutrients except nitrogen.

Nitrogen was applied in six treatments. Four involved injection of UN32(urea) at the rate of 0, 0.25, 0.5, 1.0 lbs. N/tree/year to the frequent N fertigation on a bi-weekly basis starting on May 1992 and continuing for 20 weeks for that year. The fifth treatment utilized leaf nitrogen analysis (minimum of 2.3% N) to determine whether additional N was necessary after 0.25 lbs N/tree/year application. In the sixth treatment, N was added in a small amount (25 ppm) to the buried drip treatment with every irrigation, for a total of .5 lbs/tree. A randomized complete block design was used (4 blocks with 4 rows) for the six treatments. The two center rows of each treatment replication were used for measurements.

Irrigation water was applied twice weekly from April to May, at 40% ET, increasing through the year to adjust for increasing canopy size. Trunk water potential measurements were made periodically. Trees in the five standard irrigation treatments received approximately 19 inches of water and the buried drip treatment received 12.8 inches of irrigation water plus 3.15 inches of rain through the growing season.

Soil samples were taken, initially in July, 1991, every foot from 1 to 5 feet depths throughout the orchard to identify high or low nitrate areas. This process was repeated in 1992 and 1993 from each replicate with the exception of block 3 which included depths of 5 to 8 feet. The samples were analyzed for NO3-N, NH_4-N and total N.

Tree growth measurements were made by random selection of trees from the population at the time of planting (0 N) and near the end of each successive growing season in the highest and lowest nitrogen treatment. The dry weights and nitrogen contents of the roots, rootstock and trunk and branches were determined. Trunk measurements were made in February 1992 and 1993 on all orchard trees at the same location where soil samples were taken.

Fifty leaves per replicate were randomly sampled from varying tree positions in August of 1993 and nutrient analyses were performed.

RESULTS AND CONCLUSIONS

Tree growth as measured by trunk cross-sectional area (TCSA) was equivalent for all N fertilizer treatments. Buried drip and control 0 N treated trees had lower TCSA than fertilizer treatments of 1.0 lb and 0.25 lb N/tree. The weight of pruned shoots was not different among treatments.

Dry fruit yield/tree did not differ among nitrogen treatments. N fertilizer treatment of 1.0 lb N/tree and 0.25 lb N/tree had higher dry fruit yields/tree compared with buried drip and control

0 lb N/tree treatments. Dry fruit yield/tree was doubled by applying 1.0 lb N/tree compared with 0 lb N/tree. The number of dry fruit/lb and drying ratio was not altered by N treatment. The added amount of N fertilizer led to larger trees and higher yield, but increasing the amount of fertilizer N did not lead to consistently higher dry yield per tree.

Soil samples taken in April of 1994 showed that 0 lb N treatment had lower levels of NO_3-N through the soil profile than other N treatments and buried drip. Higher levels of NO_3-N were found in the soil profile for the 0.25 lb N/tree and where leaf analyses was used to indicate fertilizer N treatment. The higher fertilizer N treatments, 0.5 lb N and 1.0 lb N/tree did not have the highest NO_3-N levels in the soil profile. The buried drip treatment had NO_3-N levels similar to those measured in the 0.25 lb N/tree treatment.

Nutrient analyses were performed on N, P, K, Zn, Mn, S, Na, and Cl. Leaf nitrogen was lowest in the 0 lb N/tree treatment. There was no difference in leaf N among 1.0, 0.5, 0.25 lb N/tree and buried drip treatments. Phosphorous was statistically lower where higher rates of N (1.0 and 0.5 lb N/tree) had been applied (data not shown). Sulfur was lower in the control 0 lb N/tree and in trees where leaf analyses below 2.3% was utilized to determine whether or not to apply N fertilizer.

There was an approximate 3-fold increase in the total dry weight per tree from 1992 to 1993. Trees fertilized with 1.0 lb N/tree accumulated approximately 4 kg more dry weight and grew about 22% more than unfertilized trees. The relative distribution of dry matter into leaves, branches, etc. (on a percentage basis) was similar between 0 and 1.0 lb N treatments. Trees fertilized with 1.0 lb N/tree accumulated 26% (40.4 g) more N than unfertilized trees, indicating an N uptake efficiency of 8.9%. The distribution of N into various tree parts was not altered significantly by N treatment.

The amount of Zn and Mn accumulated in various tree parts was measured again in 1993. The total amount of Zn and Mn increased with increasing dry matter (compare 1992 and 1993), but the amount of variation among trees and their parts led to insignificant statistical differences between 0 and 1.0 lb N/tree fertilizer treatments.

An unexpected observation in this experiment has been the development of bacterial canker symptoms in an experimental block that had not been fertilized with N. We believe the

incidence of disease is high enough and correlates with low N so that a strong linkage can be made for low N status leading to higher incidence of bacterial canker. The recommendations made above with regard to fertilizer N application rates are consistent with good orchard practice to minimize tree loss to bacterial canker.

(Ed. note: The above situation regarding bacterial canker has led to a new research project funded by FREP. Please see Section V, page 73 for a description of the project).

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A copy of the latest annual report titled, "Nitrogen Fertigation of Young Prune Trees and Effects on Horticultural Performance" is available from the California Prune Board.

COMPARISON OF FOLIAR VS SOIL-APPLIED NITROGEN FOR MAINTAINING ITS SUFFICIENCY IN FRENCH PRUNE

Project Leader:

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Cooperator:

Steve Southwick

Project Status:
Terminated, Started 1992

Source of Funding:
California Prune Board

OBJECTIVES

The objective of this 3-5 year study was to determine if prune N requirements can be wholly or partially satisfied by foliar applied N. In French Prunes, an accepted practice is to apply 80-100 lbs N in a split application, 2/3 in late March or April and the remainder in late June or July. N applied to soil has a potential to leach below the root zone and to ultimately contaminate ground water. A well timed foliar approach to N management might limit N movement into the soil.

DESCRIPTION

A seven-year old French Prune orchard in Farmersville, CA (Tulare Co.) was selected in 1992. The trees, spaced 18 ft. by 20 ft. (121 trees/ac) were vigorous, growing on Myrobalan 29-C rootstock in a Foster fine sandy loam soil. Nitrogen was applied in five treatments, in 1992 and 1993, as follows:

1. Control - no treatment.
2. 4 lbs/ac N foliar (Unocal - Plus liquid urea (1.81 lbs N/gal), <500 ppm biuret) in Fall (1992) and 4 lbs/ac N foliar applied one month following anthesis (1993).
3. 4 lbs/ac N foliar applied in Fall (1992) plus 4, 4 lb/ac N foliar applications applied monthly beginning one month following anthesis (1993).
4. 80 lbs N/ac soil applied in a split application in 1993, 2/3 April, 1/3 June.
5. 50 lbs N/ac (ammonium nitrate) soil applied in 1993 in a split application, 2/3 April, 1/3 June.

Treatments were applied to four-tree by four-tree plots (sixteen trees total). Within the plot, the center four trees were used to obtain yield, quality, and nutritional data. The treatments were configured into a randomized, complete block design consisting of six replications per treatment.

PRELIMINARY RESULTS

There were no significant differences in percent leaf N or yield data in 1993. This was not unexpected, since fruiting positions, and thus yield, were determined during the summer of 1992 prior to our first treatment. (The trees had been maintained in a vigorous condition and were of optimal health that year). There was no difference in number of fruit per dry pound of yield or in pounds of dry yield per tree—which meant no difference in fruit numbers per tree.

Further, it is suspected that residual N in the soil and in the tree's storage organs were high during the first experimental year. This resulted in inability to obtain differential N levels in the experimental treatments. Greater differences are anticipated during subsequent years of the test. It should be noted that, in error, foliar rates of N applied in the first year were low and per acre rates were below those of the soil treatment. These were raised to the appropriate levels in the 1993 fall treatments.

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A copy of the latest annual report titled, "Comparison of Foliar vs. Soil Applied Nitrogen for Maintaining its Sufficiency in French Prune" is available from the California Prune Board.

EVALUATION OF ALTERNATIVES TO SOIL-APPLIED LEACHABLE NITROGEN

Project Leader:

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Cooperators:

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Carlos Crisosto
Kevin Day

Project Status:

Study 1 - Ongoing, 1992-1993
Study 2 - Ongoing, 1992-1994

Source of Funding:

California Tree Fruit Agreement

OBJECTIVES

Preliminary studies conducted in 1992 and 1993 on the use of high concentrations of foliar applied low biuret urea indicated that this was an effective way of delivering nitrogen into peach and nectarine leaves. These studies showed that the nitrogen is taken into the leaves within two hours and approximately 80% of the material applied is absorbed within a 24-hour period. The leaf nitrogen concentration begins to drop after one week following the spray treatment, indicating that the nitrogen is mobilized and moved out of the leaves and into other plant tissues such as the trunk, shoots, buds, and roots. The focus of the studies in 1994 were to determine if the nitrogen applied to the leaves in the fall of the year was indeed present in higher concentrations in the shoots and roots during the dormant season and therefore available in the spring for plant growth. Since the foliar low biuret sprays are applied in the fall, when zinc sprays are normally applied by many growers, a second study was begun to determine if these treatments could be combined and if the high urea concentrations might increase the uptake of zinc.

DESCRIPTION

In the fall of 1993, a small block of Early Maycrest peach, located at the Kearney Agricultural Center, was selected for determining if foliar applied low biuret urea sprays mobilized the nitrogen sufficiently to move out of the leaves and into other plant parts such as the shoots and roots. This trial consisted of four replications of the following four treatments:

1. Unfertilized control
2. 100 lb nitrogen (ammonium nitrate), soil applied in September
3. 150 lb nitrogen (Unocal Plus), foliar low biuret urea applied in three sprays of 50 lb nitrogen per spray in September and October.
4. 150 lb nitrogen (Unocal Plus), foliar low biuret urea applied as a single spray in October.

With the very positive results shown from this Early Maycrest study, a much larger commercial field study was undertaken in a ten-acre Summer Beaut nectarine orchard using commercial spray and soil fertilizer treatments. This trial consisted of eight treatments with six replications. Each plot was three rows wide. Data was collected from the center row. Each plot was 80 trees long with a total of 240 trees. The treatments were:

1. Unfertilized control
2. 100 lb N/ac foliar urea (Unocal Plus), fall (Oct)
3. 100 lb N/ac soil applied CAN 17 split, 50 lb N/ac spring (April) and 5 lb N/ac fall (Sept)

4. 100 lb N/ac foliar urea (Unocal Plus) with 12 lb/ac zinc sulfate 36%, fall (Oct)
5. 12 lb/ac zinc sulfate 36% alone, fall (Oct)
6. 100 lb N/ac soil applied CAN 17 split 50 lb N/ac spring plus 50 lb N/ac fall; plus 12 lb/ac zinc sulfate 36% (Oct)
7. 50 lb N/ac soil applied CAN 17 spring (April) and 50 lb N/ac foliar urea (Unocal Plus), fall (Oct)
8. 50 lb N/ac soil applied CAN 17 spring (April) and 50 lb N/ac foliar urea (Unocal Plus) with 12 lb/ac zinc sulfate 36%, fall (Oct)

The percentage of leaf defoliation was monitored weekly from October 11 through November 22, 1994.

DISCUSSION

The results show no significant difference in dormant pruning weight per tree among any of the treatments on Early Maycrest peach. Both of the foliar applied low biuret urea sprays (one spray of 150 lb N/ac or three sprays of 50 lb N/ac) and the soil applied nitrogen (100 lb N/ac) significantly improved the nitrogen content of the dormant roots and shoots over the unfertilized control, but there was no significant difference between the soil applied and foliar applied nitrogen treatments. The spring leaf nitrogen sampling showed significantly higher nitrogen percentages where the foliar low biuret urea sprays were applied compared to the soil applied nitrogen and the control. The single spray of 150 lb N/ac produced significantly higher leaf nitrogen levels than the three sprays of 50 lb N/ac treatment. There was no significant difference between any of the treatments in fruit density (number of fruit per length of fruiting wood), but the three 50 lb N/ac foliar spray treatment had significantly fewer flowers than the soil applied nitrogen treatment or the control.

The data collected thus far in the Summer Beaut nectarine orchard indicates that prior to the soil or foliar nitrogen treatments there was no significant difference among any of the eight treatments. Significant increases in leaf nitrogen levels were recorded the first two days following the low biuret sprays. The leaf levels were significantly higher where the foliar sprays had been applied compared to the levels found in the soil treatments. Although the leaf nitrogen levels began to drop by the 16th day following the foliar applications, they continued to contain significantly more nitrogen than did the soil applied nitrogen treated trees.

The foliar applied treatments affect the leaves to bring on earlier fall color and leaf drop. The 36% zinc sulfate alone treatment causes spotting of the leaves and earlier fall color and leaf drop compared to unsprayed leaves. The low biuret urea sprays cause a small amount of marginal and leaf tip burning along with earlier leaf yellowing and leaf drop. The combined treatment of 36% zinc sulfate plus the foliar low biuret urea sprays show both the spotting as well as the leaf marginal and tip burning and a slightly more rapid leaf fall. These are not dramatically different from what growers are used to seeing following a standard fall zinc spray application. Trees which received the fall soil nitrogen application but no zinc or low biuret spray remained green well beyond any other treatment.

(Editors' note: This research has led to a more thorough investigation of the use of foliar urea on peaches by Scott Johnson and Harry Andris and is being supported by FREP. Please refer to page 6 for a description of the project.)

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INFLUENCE OF NITROGEN AND CROP LOAD ON PEACH FRUIT GROWTH POTENTIAL, YIELD AND NITROGEN UPTAKE

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Cooperators:

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Source of Funding:

California Tree Fruit Agreement

Project Status:

Ongoing, 1994-1995

OBJECTIVES

Nitrogen fertilization of peach trees is a common practice in the central valleys of California. It is commonly believed that providing relatively high levels of fertilizer N increases fruit size and yield, but may have deleterious effects on fruit quality. However, it is not known whether tree N status directly affects fruit growth potential or if the increases in fruit size and yield only occur through increased photosynthesis and carbohydrate availability that are used to support more crop.

Excessive application of fertilizer nitrogen has several potential negative effects. It stimulates excessive shoot growth and decreases canopy light penetration which lead to poor fruit color and weak fruiting wood for bearing the next year's crop. Also, there is increasing concern about the potential contribution of excessive fertilizer N applications to the leaching of nitrogen into groundwater. Although there is some general understanding about the effects of N availability on fruit size and yield of peach trees, there is almost no information on the effect of crop load and yield on N uptake in mature peach orchards. Since heavy crop loads are known to depress root growth in many tree species they may also decrease fertilizer N uptake efficiency. Understanding nitrogen/cropping relationships is essential for managing trees for optimal fruit size and yield, as well as for the efficient use of fertilizer nitrogen.

The objectives of this project are:

1. To determine the direct influence of tree N status on fruit growth potential, as well as the more general effect on fruit yield
2. To determine the effect of cropping on nitrogen accumulation during the growing season.

DESCRIPTION

A mature 2-acre orchard of O'Henry peach trees trained to a perpendicular "V" system has been divided into 4 replicated blocks with 4 nitrogen treatments (No fertilizer N, 200 lbs/acre N applied in the fall, 200 lbs/acre N applied in the spring, 200 lbs/acre applied as a split application in the spring and fall) per block. Each separate treatment consists of 5 rows with 9 trees in each row. The two outside rows of each sub-plot are guard rows for the N treatment. Each of the center three rows of each subplot will be subjected to one of 3 thinning treatments (unthinned, normal crop load of approximately 200 fruit/tree, heavily over-thinned to approximately 50 fruit/tree). These treatments will allow determination of N effects on maximum fruit growth potential (under minimal crop load), N effects on maxi-

mum yield potential (on excessively cropped trees) and use of these results to understand N effects on fruit size and yield of normal cropped trees.

The effects of crop load on N uptake efficiency were determined by excavating four whole trees in the guard rows of the fall N application treatment subplots and in the spring application treatment subplots during the winter of 1993-94 prior to bloom. Then shortly after fruit harvest in the summer, 4 trees in each of the crop load fertilizer N treatments (excluding the split application N treatment) were excavated and divided into leaves, branches, trunk and roots. The effects of crop load on tree N uptake and use will be evaluated by determining tree dry weight and analyzing tissue N concentration. The product of tissue N concentrate and dry weight represents N content. The difference between tree N content in the winter and summer represents tree N uptake.

RESULTS AND CONCLUSIONS

Although the final report is still pending, preliminary results indicate that fruit growth rate and final fruit size were significantly less in the non-fertilized treatment, even on the undercropped trees. This indicates that fruit growth is apparently directly influenced by nitrogen availability and not just affected indirectly by reductions in carbohydrate availability. Trees receiving the fall application of nitrogen tended to have the largest fruit size for a given fruit yield and fruit quality.

At harvest, fruit samples at a uniform stage of maturity (according to flesh color), were evaluated by the KAC postharvest research facility. Nitrogen application treatments affected initial fruit quality. Red color and SSC were the lowest in fruit from the low N treatment. Acidity and pH were not affected by nitrogen treatments. Time of N application did not affect any initial quality parameters measured except fruit firmness. Fruit from the spring/fall nitrogen application treatment had the lowest flesh firmness. Fruit firmness measured at the cheek was always higher than at other points on the fruit. Fruit firmness determined on the shoulder was the lowest followed by the suture and the tip. Crop load did not significantly affect SSC and pH. Fruit from the low crop load had the lowest red color, the highest acidity and fruit firmness. Fruits from the commercial and high crop loads had medium and the lowest acidity, respectively. Nitrogen and crop load treatments did not influence internal breakdown incidence in fruit after cold storage. Internal browning symptoms were not observed in fruit after 6 weeks of cold storage and bleeding incidence was not higher than 9%.

In February, 1994, before spring N was applied, 4 whole trees within the fall applied N treatment and the spring N treatment were harvested to provide whole-tree N data prior to the cropping season. After fruit harvest in August 3, whole trees from each of the 3 crop load treatments within each of 3 N treatments (no N, fall N, spring N) were harvested and divided into their constitutive parts (roots, main scaffolds, old stems, current season shoots, leaves, fruit). Each part was weighed and subsampled for N, K and Ca content. Samples and data from this part of the experiment are still being analyzed, but preliminary data indicate that there were clear differences in dry matter and N partitioning between cropping and N treatments. These data will be further analyzed to determine the influence of cropping and N treatment on N uptake and N use efficiency.

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RELATIONSHIP BETWEEN N FERTILIZATION, IRRIGATION, YIELD, VEGETATIVE VIGOR AND CANOPY EXPOSURE, FRUIT SIZE AND QUALITY, AND POST-HARVEST BIOLOGY OF BARTLETT PEARS

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Project Status:

Ongoing

Source of Funding:

California Pear Advisory Board

OBJECTIVE

A research trial was established to investigate the effects of variable irrigation rates (100%, 85%, 65% of ET) and high fertilizer N application rates (400 lbs N/A vs. 0) on fruit size, quality and storage potential for two years (1992, 1993) in a "Bartlett" pear orchard in Ukiah, CA. The relationship between position in the tree canopy and fruit size, maturity and quality was also studied.

DESCRIPTION

A mature orchard of 239 Bartlett pear trees at a spacing of 12' x 12' , near Ukiah, CA, was selected in 1992. The orchard was divided into two blocks in which three irrigation treatments were established by utilizing different sprinkler nozzle sizes to approximate 100%, 85%, and 65% of calculated ETo. To establish a tree nitrogen differential, four experimental trees in each of the six irrigation plots received four nitrogen fertilizer broadcast applications, equivalent to 400 lbs calcium nitrate per acre prior to irrigation. Four trees in each of the six irrigation plots were identified and left unfertilized as controls for the nitrogen treatment. Leaf samples from each of the trees were taken to determine tree nitrogen status. Soil samples were taken to monitor the status of nitrogen in the soil profile as a result of the fertilizer applications. Tree water potential was also measured mid-season.

The test trees in the experiment were divided into three vertical sectors for harvest. One-third of the crop was harvested on July 22 and the remaining two-thirds harvested one week later. The fruit was weighed, counted, sorted, and evaluated for skin color (CIE), firmness, percent soluble solids and percent titratable acidity. Samples of fruit from both first and second picks were taken from storage after two and three months for color and firmness determinations. At four months, fruit were evaluated both before and after ripening.

To determine the influence of canopy position, 75 fruitful spurs were tagged in each of three canopy locations and specific leaf weight (SLW) was determined.

In the Spring of 1993, neutron probe sites were installed and distributed throughout the orchard. Soil moisture measurements were taken to depth of 5 feet with pre- and post-irrigation event monitoring. Neutron probe readings were taken at approximately weekly intervals. They coincided with plant water status monitoring whenever possible. Midday stem water potential of 48 experimental trees was measured bi-weekly from April to

August and weekly thereafter until August 2, using a pressure chamber.

Irrigation system application rates and irrigation uniformities were determined with a catch can test. Sprinkler operating pressures were also determined throughout the orchard using a pitot tube and pressure gauge.

RESULTS AND CONCLUSIONS

In 1993, we were able to begin to establish a differential irrigation effect, as measured by midday stem water potential, but there continues to be large tree to tree differences in tree water status, irrespective of irrigation treatment. One possible explanation for these differences might be impaired root health and function. A plant-based measurement of tree water status such as used in this study could be very useful to detect early signs of the spread or severity of a root problem.

There is a high correlation between July-August midday stem water potential of individual trees and fruit size. This suggests that the "pressure bomb" could become a practical tool by which to assess tree water status and make irrigation management decisions. Growers could substantially improve average fruit size simply by reducing the extreme variability in tree water status which seems to currently exist in pear orchards.

There is also a high correlation between April-June midday stem water potential of individual trees and shoot growth. In contrast, no correlation is seen between nitrogen levels and shoot growth. Thus, tree water status would seem to be much more important than nitrogen in dictating the extent to which excessive shoot growth is a problem and perhaps alleviated through proper management. Since fruit size is also dependent on tree water status, however, there may be some difficulty in using controlled stress to moderate vegetative growth without sacrificing fruit size as well. This is an area that needs further investigation but it does lend some credence to the use of controlled moisture stress known as regulated deficit irrigation (RDI) as has been suggested by some researchers.

The 'Bartlett' pear tree is nitrogen tolerant and the fruit is nitrogen insensitive based on results from this study. Other nitrogen fertilization trials in the past have suggested the same thing, reinforcing our conclusion that water rather than nitrogen is a much more important management consideration in the production of 'Bartlett" pears.

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A copy of the latest annual report titled, *Relationship Between N Fertilization, Irrigation, Yield, Vegetative Vigor...* is available from the California Pear Advisory Board.

APPLE TREE NUTRITION AS RELATED TO COVER CROP AND FERTILIZATION MANAGEMENT

Project Leaders:

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Paul M. Vossen, Farm Advisor
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Source of Funding:

UC Sustainable Agriculture Research and Education Program
USDA Sustainable Agriculture Research and Education Program

Project Status:

Completed

OBJECTIVES

A systems approach was established to compare the components of organic and conventional apple production systems, including tree growth, yield and fruit quality; as well as biological and chemical nutrient supply systems and economic performance, for 4 years, 1990 through 1993.

DESCRIPTION

Conventionally and organically treated plots were established in a dry-farmed apple orchard (Graton, CA) and replicated four times. Plot sizes ranged between 1.5 and 2.2 acres. Total acreage was 7.5 for organic treatments and 8.2 for conventional treatments. Trees were planted in 1964 on 21-by-24-feet spacing. Half the plots were alternate rows of Golden Delicious and Gravenstein; the other half were Red Delicious. The organic growing methods were chosen to meet current standards for certification for the California Certified Organic Farmers (CCOF) Association. Conventional practices were those chosen by the grower. The soil type in this orchard was classified as a Goldridge fine sandy loam, which is a well-drained 60-inch-deep-soil, underlain by a clay loam subsoil and sandstone.

The organic system received an annual spring application of 2 tons per acre of compost, equivalent to 52, 35, 39 and 30 pounds per acre of nitrogen for 1990, 1991, 1992 and 1993 respectively. Total phosphorous (P_2O_5) additions were 47, 66, 53 and 48 pounds per acre, and potassium (K_2O) was 53, 34, 43 and 43 pounds per acre for those same years. The organic system also incorporated a bell bean/vetch mixed cover crop. Additions of total nitrogen from the bell bean/vetch legume planting, based on above ground biomass measurements, were from 0 to 30 pounds per acre greater than the conventional plots having resident vegetation containing 25 to 40 pounds of nitrogen per acre. A supplemental application of kelp and fish meal (Mermaid-12% N, 0.5% P_2O_5, 10% K_2O) was foliar-applied the first 3 years at a rate of 4 pounds per acre.

In 1990 and 1991, the conventional system received annual spring applications of granular calcium nitrate at a rate of 100 pounds of nitrogen per acre. In 1992, the same rate of ammonium nitrate was applied. No fertilizer was applied in 1993 because of high tissue levels of nitrogen. Two or three applications of foliar chelated micro-nutrients, at low rates, were made each year, including boron, zinc, copper, iron and molybdenum. Calcium was included in the foliar mixture at a rate of 2.6 pounds per acre per year to prevent bitter pit. No phosphorus (P_2O_5) or potassium (K_2O) was applied in this system.

Leaf samples were taken from two nine-tree subplots on a monthly basis from May through October during 1990 and 1991, and three times

per year (May, July and September) in 1992 and 1993. Nutrient concentrations were determined for nitrogen (N), phosphorus (P) , potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), zinc (Zn), iron (Fe), manganese (Mn), copper (Cu) and boron (B) in 1990 and 1991; in 1992 and 1993 only N, Ca, Zn, and B concentrations were determined. Soil samples consisting of 12 cores from each of the same two nine-tree subplots were collected from depths of 0 to 6 inches, 6 to 12 inches, and 12 to 18 inches in April and May of 1991; April, May and June of 1992; and April of 1993. Total nitrogen, NH_4-N and NO_3-N were determined. Apple fruit samples were also analyzed for N, P, and K to determine nutrient removal by the crop.

Hand-thinning was conducted in the organic system in 1990 and 1992 on the Gravenstein and Golden Delicious varieties and on the Red Delicious in 1990 only, due to heavy fruit set. In the conventional system, in 1990 and 1992 the Golden Delicious were chemically thinned with cabaryl (Sevin), followed by supplemental hand-thinning. Because the grower was not confident of results using chemical thinning on Gravenstein and Red Delicious, these varieties were hand-thinned those two years. In 1991 and 1993, the conventional system received no thinning except for the Red Delicious, which required hand-thinning.

RESULTS AND CONCLUSIONS

Over a four-year period (1990-1993), the organic system yielded approximately 40% less than the conventional system. There was a significant difference in yield for all varieties. The organic system produced 14.2 tons per acre, and the conventional system 19.8 tons per acre. In 3 out of 4 years, the organic system yields were lower for all three varieties. The worst year was 1993, when per acre yield was 1.3 tons in the organic system compared to 3.4 tons in the conventional system for Gravenstein; 6.8 tons in the organic system compared to 21.0 in the conventional system for Golden Delicious, and 5.3 tons in the organic system compared 10.6 in the conventional system for Red Delicious. In 1992, however, yields were almost equal in the two systems for Gravenstein and Golden Delicious. In 1990, the Delicious yield was slightly higher in the organic system. Most of the yield loss was attributable to early season scab *Venturia innequalis* infection, which caused blossom drop.

Both organically and conventionally treated plots had leaf concentrations within or above the adequate range for all nutrients. In 1990, the conventionally treated plots had significantly higher N, P, Zn, Fe, Mn, Cu and B concentrations. Monthly leaf samples, taken in April through October of 1990 indicated significantly higher N, Ca, Zn, Cu and B concentrations during much or part of the year in the conventional plots. Only P, Zn, and Cu were significantly higher in 1991, but monthly samples indicated slightly higher (some significant) levels of N, P, Ca, Zn, and Cu, and lower S concentrations for the conventional plots. Leaf-tissue levels in 1992 and 1993 were similar for N, Ca and B, but had a higher Zn concentration in the conventionally treated plots.

Soil total N, NH_4-N and NO_3-N concentrations were essentially the same for the organically and conventionally treated plots. The data suggested a possible weak trend during 1992, when the organic plots had slightly higher NH4-N and slightly lower NO3-N concentrations than the conventional plots.

Fertility maintenance is fairly easy to achieve in both organically grown and conventionally grown apples because the annual nutrient removal by the fruit is fairly low. Nutrient removal by the fruit in a 20-ton crop was 29, 4, and 56 pounds per acre of N, P_2O_5, and K_2O respectively, based on laboratory analyses performed on apple samples. Soil levels of P and K were adequate to supply the above-mentioned nutrient removals, plus those necessary for tree-maintenance requirements.

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SOIL BUILDING WITH COVER CROPS IN CALIFORNIA ALMOND ORCHARDS

Project Leader:

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Project Status:

Ongoing, Started in 1992

Source of Funding:

UC Sustainable Agriculture
Research & Education Program

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Glenn Arnold
Glenn Anderson
Toki Takhar
Paul Yasaitis
Cynthia Lashbrook
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OBJECTIVES

1. To evaluate the effects of cover crops on soil fertility and pest management in five innovative almond orchards.
2. To evaluate eight cover crop species in a replicated trial for effects on soil fertility.

DESCRIPTION

A cover crop trial comparing 10 cover crop mixes was planted November 9, 1992 at the Arnold Family orchard on Cressey Way, Atwater. Each plot is 2 middles wide by 14 trees long, replicated twice, with the Nonpareil row in the center. Comparisons are also being made in five orchards with established covercrops.

The following covercrops are being compared at Arnold's:

Annual grasses: Blando brome, Zorro fescue

Annual legumes: Cahaba white vetch, sub clover mix, rose clover, non-till clover, bur medic, annual cover mix

Mixed species: Resident vegetation, Beneficial Blend, Insectary Mix

Measurements have been made for organic matter (OM) monthly in spring and summer. Leaf samples for nutrient analysis were collected in mid-June from the Nonpareil row in each cover crop plot and from each orchard. The cover crop and trees were surveyed periodically for insect, mite and spider activity. Both PTB and NOW taps were maintained to monitor these pests. Covercrop height was measured periodically, and number of mowings, and timing were recorded for each cover.

RESULTS AND CONCLUSIONS

Samples show moderate OM levels for all cover crop species in the newly planted cover crop trial. The two highest OM levels are in the Beneficial Blend and Insectary Mix. Both of these have a wide variety of plant species which grow over a long time period. The resident vegetation, which has been established several years, shows the highest OM levels in the Arnold orchard. The lowest OM levels are in the annual grass plots, Blando brome and Zorro fescue. In the five established orchards, the OM levels are very high for sandy soils in the Central Valley. The top OM averages are in the long-established vetch covers in the Ray Eck and Glenn Anderson orchards and in the resident vegetation in the Ron Anderson orchard.

Nutrient levels are adequate in all orchards and cover crops. It is very interesting that the certified organic orchards of Eck and Lashbrook have very high N levels, and very good K and Zn levels as well. Using certified

organic methods does not need to result in low fertility.

Ladybird beetle numbers are highest in dense, diverse covers such as the Beneficial Blend, the Insectary Mix, vetches and clovers. These are covers in which plentiful supplies of prey insects flourish. Numbers were low in the resident vegetation, Blando brome, Zorro fescue, and in the poor stand of bur medic which support fewer prey insects. The numbers of beneficial, parasitic wasps are highly variable, but appear to be in lower numbers in the resident vegetation and higher in the planted covers.

High earthworm numbers indicate good soil health and viability. The highest numbers of earthworms were in the Glenn and Ron Anderson orchards and in the Eck orchard where soil organic matter levels are high.

Again in 1994, it was confirmed that high reject levels from peach twig borer (PTB) damage do not necessarily follow high PTB trap catches. Navel Orange Worm (NOW) egg numbers were extremely low in the test orchards in both '93 and '94, and damage was also very low both years. NOW survival is very low in heavily cover cropped orchards with high levels of beneficials.

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IMPROVING ZINC STATUS OF WALNUT WITH FOLIAR SPRAYS

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Project Status:

Ongoing, Started 1992

Source of Funding:

Walnut Marketing Board

OBJECTIVES

Foliar sprays are recommended for the correction of Zn and Cu deficiency in California fruit production and may also be important in correcting B deficiency. Factors controlling uptake of these nutrients into the leaf are not understood. Foliar zinc uptake has been shown by Uriu (1990) to be best during early fall and just prior to bud break in the spring. Such practices have also been recommended for apple and other tree crops (Neilsen & Hogue, 1983). In the case of Zn, late fall or early spring applications appear to be effective only when extremely high rates (14.4 lbs. Zn/ 100 gal) are applied. This suggests that the efficiency of this method is extremely low. Even at these high rates, results are variable and the residual effect is minimal.

The ineffectiveness of foliar zinc fertilization may be due to the physical barrier of the leaf or lack of mobility of zinc after penetration through the plant cuticle. The mechanism of foliar zinc uptake and its influencing factors is not clear. Zn deficiency is a major problem in many orchards of California and has been difficult to correct through soil application. The feasibility of foliar sprays of zinc in walnut has not been adequately explored. Our latest research in pistachio shows that growth stage has a significant effect on the effectiveness of Zn foliar sprays. Several zinc sources have been shown to be effective in increasing Zn status of pistachio leaves if they were applied at the right time. The purpose of this project was to study the effectiveness of foliar zinc sprays at different growth stages in increasing walnut leaf nutritional status, and to gain an understanding of the mechanism of foliar Zn uptake and the factors that may influence it.

DESCRIPTION

The effectiveness of foliar fertilization with different zinc carriers was investigated. A completely randomized design involving 10 Zn treatments, with four replications, was established in a eight year-old walnut orchard in Yolo County. Sprays were applied at late dormancy; bud break; early spring flush; late spring flush and leaf maturity. Zinc solutions include NZN, S & A liquid zinc, zinc sulfate ($ZnSO_4$-$7H_2O$) and $ZnSO_4$-buffered-complex. Different cations were also tested to evaluate their compatibility with zinc sprays. High concentrations of Zn (5.6 lb Zn/Ac) were used in sprays to dormant and bud break tissue whereas lower concentrations (0.7 lb Zn/Ac) were used at later dates. Each tree was sprayed with about one gallon of solution using a gasoline-powered backpack sprayer.

In order to evaluate the mobility of Zn absorbed by the leaves, four vegetative buds or twigs of each tree were chosen randomly and covered with plastic bags before spraying. Each treatment was sprayed to run off. On 5/17/1992, leaf samples were taken from bag-covered branches, and branches receiving sprays. Leaves were returned to the laboratory and washed in mild detergent tap water, 0.2 N HCl solution for 15 minutes, and finally rinsed with double deionized water. (Preliminary

experiments had shown that hydrochloric acid wash was necessary to reduce the surface contamination of Zn following foliar sprays). Leaf samples were then dried in a mechanical convection dryer at 70° for 72 hours and ground in a stainless steel bladed Wiley mill to pass a 20 mesh stainless steel screen. Zinc content of these leaf samples was analyzed by ICP-AES.

Two months after treatment, trees were visually assessed for phytotoxicity on a scale of 0 (no necrotic spots) to 5 (considerable necrotic spots or leaf burn). Leaf samples were also collected in July 20, 1992.

A second short term experiment, using detached walnut leaves, was conducted to study the mechanism of foliar absorption of zinc and its influencing factors. Mature walnut leaves were collected from trees growing at the student orchard, University of California, Davis. The subterminal leaflets with petiole attached were detached and cultured in test tubes with distilled water in the growth chamber under controlled conditions.

Some treatments that are effective in improving Zn content of pistachio were not effective for walnut. Treatments after leaf maturity did not improve Zn status of covered leaves. This suggests that there is a significant effect of timing of foliar spray on zinc nutritional status of walnut trees.

Zn uptake and translocation by walnut is highest when the leaf is still expanding. This phenomenon was also confirmed in short term experiments in which higher zinc uptake was observed in young leaflets than mature ones.

The Zn content of leaves grown from limbs that received zinc spray (0.7% Zn) at late dormant and bud break show no significant difference from non-sprayed control trees. This confirms the previous studies that extremely high dosages of zinc are needed to improve zinc nutritional status in walnut if sprays are conducted in late dormant and bud breaking stage.

Use of N as a carrier of Zn results in high Zn accumulation in the sprayed leaves but not in the covered leaves. The high content of zinc corresponds to the higher phytotoxicity rating for these treatments. At the same concentration, sulfate zinc and S & A liquid zinc do not show such high phytotoxicity. Presence of urea or other N forms has been reported to enhance cuticular permeability and cellular absorption of mineral nutrients (Yamada et al., 1965; Smith and Storey 1979). The results of this experiment confirm that presence of N in zinc fertilizer may be helpful for Zn penetration as reported, however, it does not prove useful in enhancing translocation of zinc to other parts of the plants. Thus, it is not advantageous in walnut.

CONCLUSIONS

Foliar sprays of zinc at late dormant and bud break were not effective in improving zinc status of walnut leaves. Foliar sprays at early spring flush were not as effective as late spring flush sprays when the leaves are expanding most rapidly. Sprays after leaves mature were not effective. The most effective method of increasing Zn nutritional status of the walnut tree was application at late spring flush, with S & A liquid zinc and zinc sulfate added with pH adjusted solubor. Use of N as a carrier in Zn spray solution will increase Zn retention by leaves but not translocation. Addition of other micronutrients (Fe, Cu and B) did not inhibit uptakes of Zn by walnut but did cause obvious phytotoxic symptoms on leaves. Acidified Zn spray solutions were more effective than high pH solution. Addition of the surfactant Vatsol OT and Kinetics improved walnut foliar zinc uptake.

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ASSESSMENT OF NITROGEN UPTAKE CAPACITY DURING ALTERNATE BEARING CYCLE IN PISTACHIO

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Cooperators:

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Project Status:

Complete

Source of Funding:

California Pistachio Commission

OBJECTIVE

Efficient use of nitrogen (N) fertilizer is more difficult to determine in orchard crops than in annual crop species. The large woody biomass as well as storage of N over winter in the perennial tree parts (shoots, trunk, roots) and its redistribution in spring make it difficult to determine when fertilizer N is absorbed in mature pistachio trees. The situation is further complicated in pistachio because alternate bearing (i.e., differential crop load) probably influences the patterns of nitrogen usage and uptake. Trees in their off year absorb 60% more nitrogen (applied in late January) than trees in their on year (Weinbaum et al., 1993). However, the mechanism of nitrogen uptake and how N uptake varies over the season in alternate bearing trees is not known.

The objectives of this study are to:

1. Assess the ability of alternate bearing trees to take up isotopically labeled nitrogen at different times during the cropping season.
2. Evaluate the patterns of nitrogen accumulation in leaves, fruit, wood, and roots over the cropping season in both on- and off-year trees.

This information should allow us to increase the efficiency of fertilizer N recovery in pistachio orchards by matching N availability in the soil with the tree's capacity for fertilizer N uptake.

DESCRIPTION

A pistachio orchard at the S & J Ranch in Madera County was selected for the project. Soils at the site are coarse textured, well drained, with little or no hardpan present (Ramona sandy loam series). The orchard is micro-sprinkler irrigated. Tree spacing is 15 ft. within the row and 30 ft. between rows. In May 1992, 44 uniform-appearing trees were identified for inclusion in the project, and 22 were defruited to generate populations of both on- and off-year trees.

RESULTS AND CONCLUSIONS

In 1993, the seasonal patterns of N accumulation in both on- and off-year trees were determined by sampling branches [i.e., fruit (on-year trees only), current year wood, one-year-old wood, leaves] and roots monthly.

Labeled fertilizer N was applied at three different growth stages (spring flush, nut fill, and postharvest) in 1994, and mature trees were excavated two months after each application. Excavated trees were separated into various tree parts, weighed, and analyzed for labeled N content to determine seasonal patterns of fertilizer N uptake in both on- and off-year trees. During the spring flush uptake period, labeled N uptake by on-year trees was almost double that of off-year trees. Most of the labeled N was found in the developing fruits and leaves. Total labeled N recovery during this period, however, was low, indicating that much of the N in the fruit came from N reserves from within the tree rather than uptake from the soil. During the nut fill

period, on-year trees took up more than twice the nitrogen as off-year trees, with much of the N accumulating in the fruit.

Significant amounts of N were taken up from the soil during this period. Thus, it appears that fruit and nut demand for N drives uptake. From a management point of view, these results suggest that less N fertilizer should be applied in off-compared to on-years during the spring and summer.

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A copy of the latest annual report titled, *Assessment and Nitrogen Uptake Capacity During the Alternate Bearing Cycle* is available from the California Pistachio Commission.

RESIDUAL EFFECTS OF WATER DEFICITS AND IRRIGATION STRATEGIES ON ALMONDS

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Project Status:

Ongoing, 1990-95

Source of Funding:

California Almond Board

OBJECTIVES

The proper use of water in California is a major topic of discussion. Fueled by drought conditions, a suggestion often heard is that the tree growers could easily reduce tree water use during periods of water shortage. Additionally, when the water shortage is alleviated, full irrigation could be resumed with no long-term crop effects. Such a management strategy has not been verified and it is therefore essential that information be developed before adoption of such a strategy.

The objective is to evaluate the growth and reproduction of almond which previously experienced reduced yield and vegetative growth as a result of water deficits under full water use conditions.

DESCRIPTION

This study is conducted in cooperation with San Joaquin Delta College, using part of their teaching farm orchard located near Manteca, California. A 10-acre block of 14-year old trees is being used as the experimental area. The orchard is planted to 50 percent Nonpareil and equal numbers of alternating rows of Peerless and Price. The soil is a sandy loam of moderate depth with excellent quality irrigation water. Irrigation is provided by a solid set sprinkler system.

Imposed treatments included one treatment which provides water for full consumptive use (100% ET) and four treatments which provide for less than full water use (70% and 50% ET) on a seasonal basis while imposing water deficits during either midseason or postharvest. A sixth treatment (PII or plant-indicated irrigation) utilizes leaf water potential as an indicator of plant water status for scheduling irrigations after June 15, rather than using set values of water use and static times of deficit imposition. Treatments were imposed beginning in the 1990 season and continued through the 1993 season.

In 1994, all six previous treatments were irrigated equally to meet the full mature almond tree water requirement. An on-site CIMIS weather station was used to estimate full water use. Neutron probe measurements were used to verify adequate irrigation and to ensure adequate water storage during orchard floor harvest preparation and harvest. A measurement of 7.5 inches of water was used from soil storage, while 40 inches of irrigation water was applied.

RESULTS AND CONCLUSIONS

Summary of previous trials

After four years of imposed irrigation treatments, varying the amount of water and timing of its use, we found significant differences in yield, progression of hull split, hull tights and vegetative growth (weight of prunings). No differences were found in other quality parameters. Yield reductions were primarily a result

of fewer nuts per tree, with a small component due to decreased nut size. In high-set years, nut number is of greatest importance while in low-set years, kernel size takes on increased importance. The reduced vegetative growth occurring in the less than full water use treatments also contributes to reduced potential nut load by producing less fruitwood.

One of the most encouraging treatments was the plant indicated irrigation (PII). Over the four-year duration of the experiment, this strategy has resulted in 93% of the yield of the full water treatment while using an average of 66% of the water. Of concern was the slight lack of vegetative growth observed, which may lead to a long term production decline. This method of using a pre-dawn leaf water potential threshold of -12 bars to schedule irrigation looks promising as a strategy to minimize the effect of a reduced water supply.

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REGULATED DEFICIT IRRIGATION FOR ALMOND

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Project Status:

Ongoing, 1993-1995

Source of Funding:

California Almond Board

OBJECTIVES

Regulated deficit irrigation (RDI) is a technique that purposely stresses trees at specific times of the season. While stress is normally considered detrimental to tree performance, we believe that there are periods during the season when almond trees are tolerant to stress. Thus, the successful RDI regime in a normal water year saves water while not reducing nut yields or quality. In a drought year, the successful RDI program minimizes the impact of severely restricted irrigation on current and subsequent orchard production. The goal of this project is to develop the optimal RDI regimes for almonds for various water availability scenarios.

DESCRIPTION

This report documents 2nd year Nonpareil results. The experimental site is a mature orchard on microsprinklers located near McFarland in Kern County. Potential orchard water use (ETc) is about 39 acre-inches/acre (hereafter referred to as inches). Ten irrigation treatments (including the control) each replicated 6 times were initiated in 1993. Three seasonal irrigation amounts (22, 28, and 34 inches), each applied with 3 different stress timing regimes, are being evaluated. The "A" treatments impose the stress primarily before harvest and emphasize reserving water for some postharvest irrigation. The "B" treatments do just the opposite; emphasizing preharvest irrigation and save relatively little water for postharvest. The "C" treatments impose the stress over the entire season. Regardless of the seasonal irrigation amount, care is taken in the "A" and "B" regimes to provide as much water as possible in the 4 week period just before and after harvest. This is to enhance hull split and successful flower bud development, respectively.

RESULTS AND CONCLUSIONS

There are two major yield components in almond—individual kernel weight and tree nut load. Individual kernel weight was significantly lower when less water was applied preharvest (the "A" treatments). For example, 22A was 1.04 gm/kernel compared with 1.24 gm/kernel for the control. Providing more water preharvest at the expense of postharvest irrigation (the "B" treatments) increased individual kernel weight. However, irrigation at a constant deficit rate over the season (the "C" treatments) resulted in the largest kernels. For example, 34A, B, and C had individual kernel weights of 1.10, 1.2, and 1.22 gms/kernel, respectively. The "A" and "B" regimes resulted in a greater impact on kernel weight than shell weight. For example, with 28B, individual kernel weight relative to the control was reduced by 9.7% (1.12 vs. 1.24 gms/kernel) while shell weight was virtually unchanged. This resulted in lower kernel/nut ratios for most of the "A" and "B" treatments. No differences in kernel/nut ratio were observed in the "C" regimes.

Hull splitting was reduced and partial split and hull tight nuts increased only in 22A. No significant differences were noted in kernel shrivel or NOW kernel damage. Commercial hulling and kernel quality analysis was not completed by the submission deadline for this report.

There were no statistically significant differences in nut load. However, note that the 2 lowest nut loads occurred in 22B and 28B, the treatments that biased stress toward postharvest. Interestingly, the 2 highest nut loads were in treatments 22A and 28A, the regimes that biased stress toward preharvest. These trends will be monitored closely in years 3 and 4 of this study to determine if the "A" and "B" treatments tend to increase and decrease nut loads, respectively.

Kernel yields were significantly lower only in treatment 22B. The smaller individual kernels in the "A" treatments were offset by the higher nut loads. It should be pointed out that this is only the second study year and additional years are needed to establish sustained effects. We suspect that the impact of any reduced shoot growth on subsequent nut load may not be evident until study year 3.

In summary, the 22 and 28 inches treatments had reduced kernel yield due primarily to smaller kernels. The postharvest biased stress regimes had the lowest yields. With 34 inches, the "B" and "C" treatments had yields nearly identical with the fully irrigated control.

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ALTERNATIVE METHODS FOR SUPPLYING NITROGEN REQUIREMENTS OF PINK BEANS

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Project Status:

Complete, 1991-1993

Source of Funding:

California Dry Bean Advisory Board

OBJECTIVE

There has been considerable interest in using rhizobium inoculants as seed treaments on legumes, to try to improve plant growth and yield with minimal inputs of synthetic nitrogen (N). However, studies conducted in this area during the past several years have shown mixed results. Therefore, it is not surprising that some growers use inoculants as seed treatments, whereas others do not. This inconsistency in inoculant use by growers led us to conduct a two-year study at UC Davis to investigate the efficacy of bacterial seed treatments in dry bean production. Specifically we were interested in evaluating several types of inoculants along with different supplemental levels of starter N to see whether we could reduce recommended fertilizer rates without compromising yields. In addition, we were interested in determining whether chemical seed treatments are compatible with rhizobium inoculants, as some are thought to be deleterious to the bacteria.

DESCRIPTION

The rhizobia inoculant that we were most interested in was HiStick, a bacterial formulation produced and patented by MicroBio Division of AGC in England. This inoculant was studied for two reasons:

1. The rhizobium concentration is 20-100 fold higher than other commercially available inoculants as the bacteria are produced using sterilized peat.
2. The HiStick bacteria are encapsulated in a copolymer coating which protects them from desiccation and chemical seed treatments.

Nine treatments were evaluated and compared in a randomized complete block design with four replications. Treatments included no inoculant plus 80 lbs of inorganic N; a control with no inoculant and no N; treatments of seeds with HiStick plus 80, plus 40, plus 20, and plus 0 lbs of N; a treatment with HiStick, 0 lbs N, and fungicide-treated seed; a treatment with commercial inoculant plus 0 lbs N; and a treatment with commercial inoculant plus 0 lbs N and fungicide-treated seed. The seeds were treated with the appropriate inoculant one day prior to planting and side-dressed with ammonium nitrate two weeks after planting.

This trial was conducted at the UCD agronomy field station with Yolano pink beans. The beans were planted at the Sustainable Ag Farming Systems Project into an area following wheat. This ground did not have a prior history of beans for at least 4 years. Plot size was 4 rows by 9.4 meters with beans planted at 4 seeds per foot. Soil samples were taken from the control and inoculated plots at time of planting and 14, 37, and 63 days after planting (DAP) to determine available N for plant growth and percent organic matter.

Parameters measured during the growing season included stand count per 3 meters at 12 DAP, plant biomass at 14 and 36 DAP, root weight at 36 DAP, and number of nodules per plant per 0.3 meters at 18 and 36 DAP. We also estimated flowering at 35 DAP. At 71 DAP we took a subsample of plants in a 1 meter area from plot borders and looked at above-ground biomass, seed weight, pods per plant, seeds per pod, seeds per plant, seed

weight, and seed size. Seed size was determined by separating beans into four different size categories using mesh screens that were <6.5, 6.5-16, 16-18. and >18, 1/64th inch in size. At 80 DAP we cut and windrowed 6.4 meters from each of two center rows, and mechanically threshed the beans when dry.

RESULTS AND CONCLUSIONS

At time of planting, soil samples indicated that the total amount of available N was 86 lbs/A at a depth of 0-12 inches and 65 lbs of N at 12 to 24 inches. Thereafter, total available N decreased to an average of 60 lbs/A on 7/26, increased to 73 lbs/A on 8/17, and then dropped to an average of 45 lbs/A on 9/13. Organic matter was 1.3% at time of planting.

Stand count at 12 DAP varied between 17 and 33 plants per 3 meters, with no differences among treaments at P=0.08. Above ground biomass prior to N use varied by about 20% between the treatments, P=0.89. At 36 DAP, there were no differences in biomass between inoculated and non-inoculated plots, although plant biomass was 30% greater with 80 lbs of N per acre compared to no N, P=0.34. At 18 DAP there were slightly more nodules in the inoculated plants than in non-inoculated plants, P=0.29. At 36 DAP, there were no differences in nodulation between the inoculated and non-inoculated plants, although the number of nodules was 25% less in plants fertilized with 80 lbs of N (P=0.2). Root weight at 36 DAP was no different between treatments (P=0.87).

At 71 DAP, a 1 meter plant sample was taken and measured for above ground biomass, seed weight, pods per plant, seeds per pod, seeds per plant, weight per seed, and seed size. After considerable analyses, no differences or trends for any of these parameters between the inoculated and non-inoculated plots were found. Additionally, there were no interactions for any parameter measured between the inoculated plots and different supplemental levels of N. At 80 DAP, the plots were harvested and yield samples for each of the nine treatments were taken. Again, no differences in yield per acre between the inoculated and non-inoculated plots were found, nor were there any interactions between the inoculants and different supplemental levels of N. The use of chemically treated seed likewise did not affect any yield parameter at harvest. Stand count had no effect on any of the analyses and yield values measured.

Although there were no differences in plant responses to inoculated versus non-inoculated seed, we did find highly significant differences in several plant growth and yield components within the different N levels. The 80 lb N plots consistently showed higher yields than the non-fertilized plots (2916 lbs/A versus 2495 lbs/A, P=0.0002), greater plant biomass (2318 lbs/A versus 1688 lbs/A, P=0.001), more pods per plant (28 versus 19, P=0.001), and more seeds per plant (88 versus 68, P=0.05). However, the 80 lb rate of N also increased the number of blank pods per plant from 0.7 to 1.9 (P=0.004), as well as the number of culled seeds per plant from 25 lbs/A to 63 lbs/A, P=0.005. The numbers of seeds per pod, seed weight per 100 seeds, and percent seeds in the 6.5-16, 16-18, and >18 categories were not affected by N (P=0.2 for all parameters. There was no difference in harvest index across N levels (P=0.2). In random non-quantitive samples during the growing season, the degree of nodulation in the high N plots was extremely low compared to areas with no N added to the soil.

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INFLUENCE OF ROOTSTOCK ON BLOOMTIME PETIOLE ANALYSES OF SELECTED GRAPE CULTIVARS

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Project Status

Ongoing, 1993-1994

Source of funding:

American Vineyard Foundation

OBJECTIVE

To determine the influence of rootstock on nutrient status of Chardonnay, Cabernet Sauvignon and Zinfandel grapevines.

DESCRIPTION

In coastal areas, phylloxera-infested vineyards are being removed and replanted with alternative, resistant rootstocks. However, little is known about how these rootstocks will influence vine nutrient status as determined through the routine analyses of petioles. Over two years, 1993 and 1994, petioles were gathered at bloomtime in three trials, one each of cultivars: Chardonnay, Cabernet Sauvignon and Zinfandel. In each trial, scions were grafted onto 14 rootstocks: Harmony, Freedom, 3309C, 101-14 Mgt, 5C, 5BB, 420A Mgt, 110R, 1103P, St George, 1616C, 44-53 Malègue, Ramsey, and O39-16.

RESULTS AND CONCLUSIONS

Petioles were analyzed for NO_3-N, NH_4-N, K, P, and Mg. NO_3-N and K levels were highest in Chardonnay, followed by Cabernet Sauvignon and Zinfandel. Among rootstocks, NO_3-N levels in a given year differed by as much as 16-fold (126 to 2064 µg/g), NH_4-N by as much as 4-fold (253 to 1028µg/g), K, P and Mg by about 3-fold (9.7 to 30.6 mg/g, 1.8 to 6.3 mg/g, and 2.9 to 7.5 mg/g, respectively). Freedom had the highest levels of NO_3-N. Ramsey had moderate levels of NO_3-N but had the highest levels of NH_4-N. The rootstock 420A Mgt was consistently low in NO_3-N, NH_4-N and K. Freedom was among the highest in K content. The rootstock 44-53 Malègue had high levels of K and low Mg.

Although bloomtime sampling is the currently recommended practice, it is not clear whether these early season differences among rootstocks will hold throughout the year, especially in the critical period between the onset of ripening and harvest.

More research is needed to confirm these preliminary observations. UC farm advisors and vineyard managers often report that petiolar nitrate nitrogen is a particularly unreliable measure of vine nitrogen status, irrespective of rootstock. The values change with variety and are strongly influenced by meso-climate, vineyard floor management, or other cultural practices.

The next stages of this project are: i) to confirm the influence of rootstocks on vine nutrition, especially N and K, at other times of the growing season; ii) to investigate the influence of differing nutrient status by correlation with vegetative and reproductive growth; and iii) to test for negative trade-offs in fruit quality (excessive K or N). The overall objective is to investigate the relationship of rootstocks to vine nutrient status in the hope of reducing fertilizer inputs.

In addition to vine nutrient status, we will need to gather important vine attributes including: yield components (crop weights, cluster number, berry number, and berry wt), dormant season growth (pruning weights and shoot numbers) and standard fruit maturity indices (juice soluble solids, titratable acidity, pH, color and phenolics).

The timing of this project is critical because replanting is in progress. Growers who have replanted vineyards need rootstock-specific fertilizer recommendations. Those who are planning vineyard replacement have an opportunity to choose a rootstock more suited to their site. Local deficiencies in N, K or P may be ameliorated by proper rootstock choice. By knowing more about a rootstock's nutrient uptake dynamics we may find long-term, genetic solutions to fertility limitations. Future vineyard fertilizations will be more efficient and cost effective, with a low environmental impact.

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DECOMPOSITION OF PLANT RESIDUES AND SUPPRESSION OF ROOT DISEASES IN ORGANIC FARMS

Project Leader:

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Department of Plant Pathology

Source of Funding:

United States Department of Agriculture (USDA)

Project Status:

Ongoing, 1993-95

OBJECTIVES

The goal of this project is to identify indicators to predict disease suppression in soil and contribute to an understanding of the mechanisms underlying the natural controls observed in organic farms. The specific aims are to:

1. Characterize stages of decomposition of cover crops that are associated with suppression of root diseases of tomato.
2. Assess microbial activity and functional diversity in soil during decomposition of cover crops.
3. Identify the most important indicators for disease suppression by relating measurements on cover crop decomposition and microbial activity and functional diversity to root disease severity.

DESCRIPTION

Mixtures of vetch and oats were grown and turned under in plots previously fertilized or cover cropped (henceforth called conventional and organic, respectively). One week before incorporation of the residues and one, three, and five weeks after incorporation, crude organic matter was extracted from soil samples from four organic and four conventional plots. Dry weight, lignin, cellulose, and acid-soluble components of the extracted organic matter were assayed by crude fiber analysis.

The microbial status was monitored by measuring nitrogen mineralization potential, microbial activity and biomass, and by quantifying major groups of decomposers (bacteria, actinomycetes, and fungi) over time by fluorescence microscopy.

In a following experiment, functional groups of microorganisms were monitored using a sole carbon utilization assay based on the BIOLOG plate technique.

Soils at the four stages of decomposition were also tested for suppressiveness to damping-off and root rot diseases of tomato caused by *Rhizoctonia solani* and *Pythium aphanidermatum* in growth chambers. Problems were encountered with naturally occurring inoculum of *Pythium aphanidermatum* in all plots. Suppressiveness of the two pathogens was therefore assessed using natural field soil and autoclaved soil in an in-vitro bioassay.

RESULTS AND CONCLUSIONS

Generally, the highest microbial activity as measured with FDA hydrolysis was observed one week after incorporation of the cover crops. However, highest biomass of active fungi, actinomycete and bacteria was assessed after three weeks of incorporation of the cover crop residue.

The cellulolytic activity was highest three weeks after incorporation.

Suppressiveness was highest at three and five weeks after cover crop incorporation, and higher in organic than in conventional soil when cellulolytic ability was high and soil nitrate and ammonium were high. Multivariate analyses to relate suppressiveness to all substrate and microbial indicators are currently underway.

This project will have important implications for soil health in the Central Valley of California where tomatoes are grown on 352,500 acres. However, the significance of this project goes beyond tomato production in California, since it will contribute to an understanding of mechanisms underlying suppressiveness of root diseases in alternative crop ecosystems. In particular, a relationship between microbial diversity and disease suppression has not been established.

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COMPOST USE AND RESEARCH NEEDS OF CENTRAL VALLEY VEGETABLE FARMERS

Project Leaders:

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Cooperators:

B. Goldman
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Project Status:

New; Started - 1994

Source of Funding:

UC Sustainable Agriculture Research and Education Program

OBJECTIVES

California generates roughly 45 million tons/year of waste. Approximately 64 percent of the waste stream is paper, cardboard, yard waste and food waste. (Community Environmental Council, 1991). These materials are currently landfilled or incinerated, yet all are biodegradable and can be composted. The process of composting itself improves the handling of solid waste, eliminates odor, reduces insect and pathogen infestations, lowers the risk of pollution from runoff and leaching, and can serve as a secondary income for farm operations.

It will in fact be necessary to compost a large fraction of this biodegradable portion of the waste stream in the near future because California has mandated (AB939) that each city divert 50% of its waste stream by the year 2000. As a result, as much as 4 million tons of finished compost could be produced in the state annually.

Marketing the finished compost will then become a critical issue. Application of compost produced from municipal solid waste to agricultural land is regularly identified as the largest potential market. Many municipalities and compost producers are attempting to establish links with the agricultural community in their effort to develop markets for the finished compost.

Composting is not a new technology, nor is the use of compost as a soil amendment or mulch new to agriculture. Compost and manures were applied routinely to farms as an important component in maintaining productivity until the 1940's and 50's, when petroleum-based fertilizers were introduced and became widespread. They are now receiving renewed attention for their role in maintaining soil organic matter and soil productivity. Composted municipal solid waste contains more than 50% organic matter. Compost also suppresses a wide variety of soil borne pathogens, and can supply nitrogen for crop production, depending on the crop and the content of the soil. In addition, long term incorporation of organic matter improves aggregate formation and stability, decreases crusting and increases porosity for improved water holding capacity, and can help improve soil structure and tilth.

However, there are drawbacks in using compost and potential users have many questions about its incorporation in agroecosystems. The composition and quality depends on the nature of the composting process, the raw materials and the maturity of the compost and therefore is highly variable. Standards are ill-defined or lacking. Nutrient contents are variable and are slowly released. Nitrogen immobilization and

deficiency can result. This variability and uncertainty lead to many questions regarding the amount and timing of application.

In addition, compost can be expensive to purchase and apply. It may contain contaminants, including plastics or glass. These issues result in many questions about application rates and the number of years compost can be incorporated into the soil.

The objectives of this project are to develop an understanding of the use of compost and the limitations to its use by the annual vegetable producers in the central region of California's Central Valley; and to develop an appropriate compost research agenda to address the limitations to compost use. Our specific goals are:

1. To collect and compile information on the use of composts in the production of annual vegetable crops in the central region of the Central Valley of California, including:
   - Who uses compost in their annual rotations and who does not?
   - What are the factors influencing compost use and its management?
   - What are the limitations/barriers to compost use?
   - What are the sources of information on compost use and benefits or drawbacks?
2. To develop a focus group of annual vegetable farmers in order to define and prioritize composting research needs and objectives.
3. To produce and publish a summary of the identified issues and problems.
4. To develop on-farm research projects addressing the identified issues.

A summary report of the findings of the survey will be drafted. This will also include information on the research priorities from the semi-structured interviews and comments or conclusions from focus group discussions. A research agenda will be developed for one of the identified issues in the use of compost. The report and research agenda will, in turn, be reviewed by the farmer focus group. This report and findings will be made available to the farming community, the state's compost producers and the agricultural research community at UC Davis and elsewhere.

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COMPOST DEMONSTRATION PROJECTS

Project Coordinator:

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California Integrated Waste Management Board

Composting is a rapidly expanding industry in several states, including California, because of the recovery of organic materials previously destined for landfills. A major challenge facing this expansion is the development of additional markets for products made from these organic material resources. Public/private partnerships are cultivating agricultural markets for urban mulch and compost products.

Farmers near urban centers are exploring opportunities to obtain mulch or compost products and are putting these urban resources to beneficial use. California soils are characteristically low in organic matter content. Farmers can realize several benefits from the use of compost in the commercial production of various crops, including increase in soil organic matter, more diverse soil microbial population, decrease in leaching of soil nutrients, better moisture retention, and reduction in fertilizer applications needed to sustain crops.

The California Integrated Waste Management Board (CIWMB) awarded funds on a one-time basis for compost agricultural demonstrations in May 1994. The five demonstration projects involve cooperative teams working in three counties of the San Joaquin Valley and five counties near the Salinas Valley. Each demonstration team is comprised of farm operators, technical experts, compost/mulch processors, and local government representatives.

The goal of the demonstrations is to promote the use of urban mulch or compost in commercial agriculture. A common element of each demonstration is increased communication between compost producers and farmers. Data generated will assist California farmers who are considering compost use in the production of several different crops.

An educational video will be produced by the end of 1996 with some of the cooperating farmers describing their mulch or compost use. Commercial agriculture is the target audience for the video highlighting benefits of mulch and compost use in crop production.

PROJECT SUMMARIES

Fresno County

This demonstration project, on a fresh shipping peach orchard owned by Wawona Orchards, began in 1993 using industry funds. Traditional fertilization methods, including manure, slow-released pellets, and ammonium nitrate, are being compared with various composts. Materials are applied at different rates that will provide equal amounts of nitrogen.

The contact is Harry Andris, of the University of California Cooperative Extension, Fresno County, at (209) 456-7557.

Tulare County

Commercial production of cotton at the Bergman Ranches, with and without compost, are subjected to a cost-benefit analysis in this demonstration. Cotton plots using compost receive less chemical fertilization than conventional plots. The economic value of nutrients in the compost and the soil enhancement attributes associated with compost application at five tons per acre are evaluated by the cooperative team.

The contact is Carol Frate, of the University of California Cooperative Extension, Tulare County, at (209) 733-6363.

Stanislaus County

A cooperative team compares yields of watermelon, sweet corn, and tomatoes using compost (5 to 30 tons of per acre) and traditional fertilizer, on the C.J. Rumble Ranch. Compost

and growing media mixes are also being used in containers to grow various plant species at the Grover Nursery and at Modesto Junior College. These participants are working with Stanislaus County, the City of Modesto and the University of California Cooperative Extension to bring commercial uses of compost to the attention of local farmers and nurserymen.

The contact is Kevin Williams, of the Stanislaus County Department of Environmental Resources, at (209) 525-4160.

Monterey, San Benito and Santa Cruz Counties

Herbert Ranch, Felice Ranch, Tonascia Ranch, Rural Development Center, and Jefferson Ranch, located in San Benito and Monterey Counties, will produce and/or use compost products in the commercial production of peppers, lettuce, onions, broccoli and cauliflower. On-farm composting is being conducted at one of the five farms cooperating in this demonstration. A variety of compost products will be made using landscape trimmings, waxed cardboard, wood waste, agricultural by-products, manure, or a combination of these feedstocks.

The contact is Marc Buchanan, of the University of California, Santa Cruz, at (408) 459-3668.

Santa Clara County

Farmers are applying 30 to 40 tons per acre of mulch or compost on plots of grapes, peppers, lettuce, strawberries, apricots, corn, beans, tomatoes, and hay. Urban compost products are made from residential yard trimmings by three local processors for Wente Brothers Winery, Joe Perry Farms, Frazier Lake Farms, Chiala Farms, Hoey Ranch, Van Dyke Ranch and Valley Farms located in Alameda, San Benito, and Santa Clara Counties. The City of San Jose has set up a dedicated telephone line at (408) 277-2989 that farmers can call for information.

The contact is Jo Zientek, of the City of San Jose Environmental Services Department, at (408) 277-5533.

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DEVELOPMENT OF A SOLID-STATE NITRATE SENSOR FOR USE IN CONTAINER SOILS

Project Leader:

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Department of Environmental Horticulture

Project Status:

Ongoing, 1993-1995

Source of Funding:

California Association of Nurserymen

PROJECT OBJECTIVE:

The basic methodologies of irrigation and fertilization in container-grown crops evolved in an era when water was plentiful, fertilizer prices were low, and governmental run-off regulations were non-existent. However, during the last few years, water and fertilizer costs have risen, water supplies have been reduced for many growers due to drought, and governmental regulations are making the discharge of nitrate-laden run-off a perilous activity for many growers. In many areas of the U.S., regulations are forcing growers to eliminate run-off. Similar local ordinances have been put into effect in Oregon and California; large fines have already been levied indicating that these regulations will be enforced stringently. Here in California, growers are aware of the problem and looking for new production techniques to deal with this pressure.

The overall goal is to minimize water/fertilizer use and waste, thus diminishing the probability of adverse environmental impacts. This will be accomplished by using a system that irrigates and fertilizes plants based on soil moisture tension and soil nitrate concentration. The goal is a self-contained irrigation/fertilization system characterized by low or no water run-off for the nursery environment.

The project involves routine NO_3-N and NH_4-N analyses using the Carlson apparatus (Carlson, 1978) of water run-off leached from experimental plants growing in containers. A specific nitrate ion electrode is being developed and tested to see whether it will be functional in our computer-controlled system. The accuracy of the nitrate electrode will be determined by direct comparisons to values obtained from the Carlson apparatus. The nitrate electrode is an important component to be added to the computer-controlled irrigation system, since it (along with the tensiometer) will provide continuous monitoring of nitrate and water status of the container soil. A system capable of measuring soil moisture tension and soil nitrate concentration and controlling an irrigation/fertilization system based on these measurements will be very useful in accomplishing our overall objectives.

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VIII BIOGRAPHIES

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.

Mike Chrisman is the Undersecretary of the California Department of Food and Agriculture (CDFA), appointed by Governor Pete Wilson in 1994. As Undersecretary, he assists the Secretary of CDFA in providing leadership to the Department's seven Divisions. Prior to joining CDFA, Chrisman served for three years as Deputy Secretary for Operations and Legislation with the Resources Agency, overseeing legislative activities and advising the agency Secretary on agriculture and water issues. He has provided leadership to a number of agricultural organizations, including, the Central Valley Regional Water Quality Control Board, the Tulare County Fair Board, the California Farm Bureau Federation, the California Cattlemen's Association, and the Visalia Chamber of Commerce. He served for five years as Chief of Staff to Assemblyman Bill Jones, and in 1991, worked as the Staff Director for the Assembly Republican Caucus. Since 1966, Chrisman, a native Californian, has owned and operated Chrisman Ranches, a family farm, producing walnuts and beef cattle. He received his B.S. in Agronomy/ Plant Science and his M.S. in Agricultural Education from the University of Arizona. Chrisman is also a graduate of the California Agricultural Leadership Program.

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 also 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.

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.

Jack Hodges is Chief of the Agricultural Nonpoint Source Unit of the State Water Resources Control Board in Sacramento, California. He has been with the State Department of Water Resources for 13 years, involved in water resources development and water quality investigations and studies. Other duties include Northern California land and water use studies, San Joaquin Valley Drainage investigation and Sacramento and San Joaquin Delta/ Bay studies. Hodges also has 22 years of experience working with the State and Regional Water Quality Control Board's water quality planning and regulation programs; such as Water Quality Control Plan Development and Implementation, NPDES Permit/Waste Discharge Requirement issuance and related

activities, and Nonpoint Source Water Quality Control Program activities. He received his BS degree in Agricultural Engineering from Cal Poly San Luis Obispo, and has California Registration as a Professional Engineer in Agricultural Engineering.

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 related services. Johnson 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. Johnson received his B. A. from the University of Utah and Ph.D. from Cornell University.

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.

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. Mathews received both his B. S. and M. S. from the University of Arizona and his Ph. D. from the University of Illinois.

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

Jack Pandol is the Undersecretary of the California Environmental Protection Agency, appointed by Governor Pete Wilson in 1993. He is the President of Pandol Bros., Inc., a worldwide importer and exporter of fresh fruits and vegetables. He also serves on the Board of Directors for Pandol Bros. Packing and is Trustee of the Estate of Steve Pandol. Pandol is also the Production Manager of Pandol & Sons, which farms 4,500 acres in Tulare and Kern counties. Their principal crops include table grapes, citrus, almonds, kiwifruit, Asian pears, apples, and wheat, and in addition, is currently involved in managing 600+ acres of table grapes in the Coachella Valley and 1,000+ acres of citrus in the Delano area. Pandol & Sons has extensive expertise in advanced water management and irrigation techniques, has helped to pioneer alternative pest control techniques, and has developed new quality control methods, using new and innovative approaches. Mr. Pandol has been a member of several agricultural committees or boards, and has traveled worldwide representing the agricultural industry. He earned his Bachelor of Science Degree in Plant Science, at the University of California at Davis in 1976, and was a member of Class XII of the California Agricultural Leadership Program.

Roberta Parry is an analyst in the Agricultural Policy Branch of the Environmental Protection Agency. She joined EPA in 1989 and has been involved in policy analysis of a broad spectrum of agriculture and water quality issues including developing administration

positions for the Clean Water Act, Safe Drinking Water Act, and the 1995 Farm Bill; serving as EPA Liason to the Sustainable Agriculture Task Force of the President's Council on Sustainable Development; and serving on the Board of Directors of the Certified Crop Advisor Program. She holds a master's degree in Public Administration from the John F. Kennedy School of Government at Harvard University.

Steve Purcell is an agronomist with Unocal Corporation having responsibilities in research of new and established products, technical support and marketing. He has also worked internationally as a consultant in the Middle East and Southeast Asia. Current agricultural interests include foliar plant nutrition, new product development and marketing of agricultural products. He is a graduate of the University of California-Davis.

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

Kurt Schulbach is an Irrigation and Vegetable Crops Farm Advisor in Monterey County, California. Current research topics include measuring water use of vegetables, evaluating "surge flow" furrow irrigation, investigating irrigation and disease interactions in lettuce and cauliflower, and development of nitrogen quick tests for fertilizer scheduling in vegetables. He received his B.S. in Agronomy from Chico State University and his M.S. in Irrigation Science from Utah 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.

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

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. He has active research efforts in several crops, but 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.

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