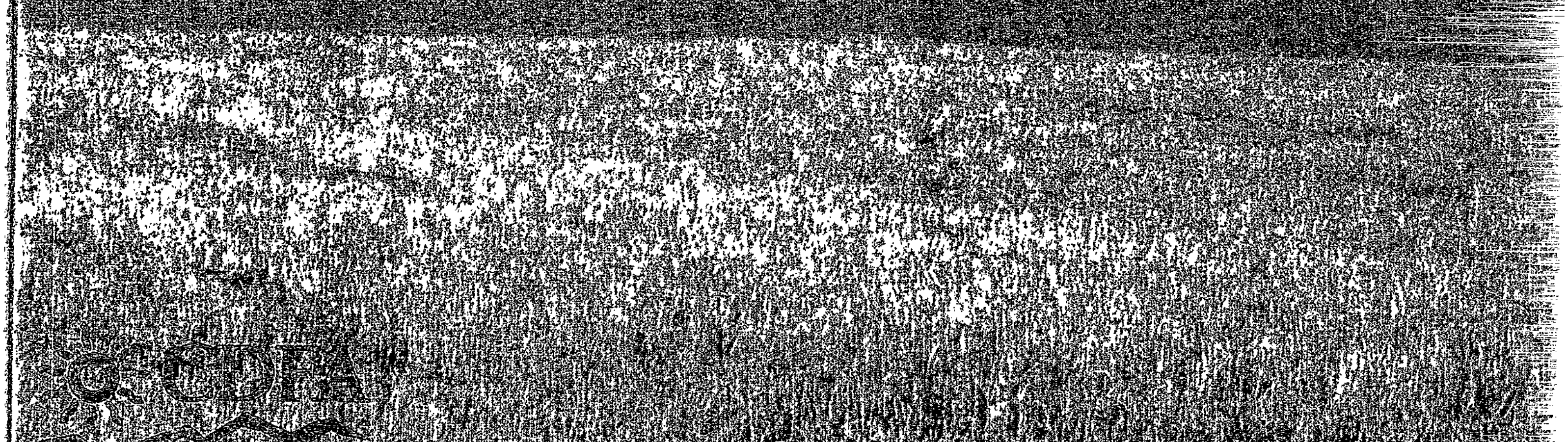
FIFTH ANNUAL Fertilizer Research and Education Program Conference

November 18, 1997
Sacramento, CA



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California Department of Food and Agriculture
California Fertilizer Association
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PROCEEDINGS OF THE

FIFTH ANNUAL

Fertilizer Research and Education Program Conference

NOVEMBER 18, 1997

SACRAMENTO CONVENTION CENTER

SACRAMENTO, CALIFORNIA

Sponsored by:

California Department of Food and Agriculture

California Fertilizer Association

University of California

Sustainable Agriculture Research and Education Program

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FERTILIZER RESEARCH AND EDUCATION PROGRAM: AN UPDATE

Casey Walsh Cady, Research Analyst
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 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 of 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 technical expertise and funding to start these research and demonstration projects. Initial projects were developed in the Salinas Valley and the Fall River Valley. The Salinas project developed improved vegetable farming practices to reduce nitrate contamination, while increasing the efficiency of fertilization and irrigation.

COMPETITIVE GRANTS PROGRAM

In 1990 the Department was authorized to increase the mill tax on fertilizers to conduct research and education projects to advance the environmentally safe and agronomically sound use and handling of fertilizer materials. The program supports 61 projects at a projected cost of $3 million dollars, and $2.5 million dollars in matching funds. Of these sixty-one projects, about half have been completed. Details about these projects, and the information products available, can be found in these and last year's proceedings, and our Resource Guide.

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

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

MONITORING AND ASSESSMENT

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

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

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

1997 ACTIVITIES

This year FREP has been involved with a few of timely issues. As you may be aware the Salinas Valley Basin is under heightened pressure to improve water quality. The State Water Resources Control Board (SWRCB) will hold hearings in early 1998 to take evidence on the necessity for imposing restrictions to groundwater pumping and other regulatory measures affecting fertilizer use in the Salinas Valley.

This kind of action, adjudicating an entire groundwater basin is unprecedented in California. The SWRCB is concerned about the lack of progress in solving the Salinas Valley water quality problems which include seawater intrusion and nitrate contamination to groundwater. The Monterey County Water Resources Agency has convened a technical advisory committee whose participants include the local stakeholders. FREP staff is an active participant on the TAC. You will hear more about the concerns and what's being done to address them by Danyal Kasapligil later this morning. I would encourage you to attend the public hearings and see how this issue unfolds.

Another hot topic this year has been heavy metals in fertilizing materials. For the last three years, CDFA has contracted with Foster Wheeler Environmental Corporation to undertake a risk assessment to establish risk-based concentrations for arsenic, lead and cadmium in commercial inorganic fertilizers. These metals are generally associated with the phosphorus portion of fertilizers since it is a mined material, and to a lesser extent with some micronutrients.

The risk assessment was conducted using a two-step process, the first step narrowed the parameters through a screening process looking at the types of materials and the factors that impact exposure. It answered the question "What is the risk or non-cancer risk associated with the lead, cadmium, and arsenic concentrations in the group of fertilizers with known levels of these metals". The second part of the assessment employed a probabilistic methodology to determine risk-based concentrations that are acceptable in commercial inorganic fertilizing materials.

This effort was undertaken to address the requirements of Proposition 65 and will serve as the basis to determine whether manufacturers of specific fertilizers need to warn the public about any unacceptable cancer or reproductive hazards. The fertilizer industry funded this study through FREP. The results of the risk assessment will be available soon. Please call our office if you would like a copy of the results.

FREP OUTREACH

CDFA has an excellent web site, our web site can now be found on the departments site. The site provides information on the program and how to receive funding from FREP as well as summaries of FREP activities and information. Please visit us at:

http://www.cdfa.ca.gov/inspection/frep/index.html.

We are currently working on additional publications that will be released in 1997-98. These include an updated practitioner handbook on quick tests for vegetable growers featuring newly developed field data, and a comprehensive Best Management Practices Guide for cool season vegetable production that was produced with the assistance of innovative growers.

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

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 fourth consecutive year. The conference is scheduled for January 21 and 22, 1998, in Sacramento.

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

Our latest video, "The Fruits of their Labor: Nitrogen Management in Stone and Almond Production" and the accompanying study guide are available. This video is very well produced and provides a wealth of information on fertilizing orchard crops.

CONFERENCE PROGRAM HIGHLIGHTS

This year's keynote remarks will be made by Dr. Chris Johannsen of Purdue University. He is a leading authority on the use of remote sensing in agriculture. We are excited to learn more about how these technologies may benefit California growers and the environment

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

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

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

ACKNOWLEDGMENTS

Many people deserve recognition for their assistance, insight, and support in the process of developing the Fertilizer Research and Education Program (FREP), including growers, the fertilizer industry, government officials, university people, and individuals concerned about the future of California. Special recognition goes to Carl Bruice, Al Ludwick, Steve Purcell, Wynette Sills, Brock Taylor, Jack Williams, Tom Beardsley and Charles Tyson, members of the Technical Advisory Subcommittee (TASC), and to all the members of the Fertilizer Inspection Advisory Board. TASC members' dedication, insight, and professionalism have been invaluable in helping make FREP a success.

Many thanks to staff at the University of California Sustainable Agriculture Research and Education program for their assistance with our publications.

Many people from the California Department of Food and Agriculture (CDFA) saw this program develop from its infancy and provided their full support and insight. We owe tremendous thanks to Vashek Cervinka, Steve Wong and Stan Buscombe of the Agricultural Commodities & Regulatory Services 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, late Secretary of CDFA and A.J Yates, Undersecretary, 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.

CALIFORNIA CERTIFIED CROP ADVISOR PROGRAM

Project Leaders:
Renee Pinel
California Fertilizer Association
Sacramento, CA

Stuart Pettygrove
Board Chair, California Certified Crop Adviser Program
Dept. Land, Air and Water Resources
UC Davis

Barbara Gast
CA-AZ CCA Program
Phoenix, AZ
(602) 267-1890

Agriculture, specifically the fertilizer industry, faces increasing pressure from state and federal regulations that address the suspected generation of non-point source pollution. This is illustrated by the development of Coastal Planning Zones by regional water boards, and by federal regulations that will be implemented in the Clean Water Act. These regulations will require that growers be able to provide water quality agencies with soil and water management plans that have been developed or approved by professionally certified advisors or consultants.

The objective of the Certified Crop Advisor program (CCA) is to offer a program that certifies those individuals who meet a level of expertise, both educationally and professionally. The approach is one of an education program (the curriculum of which has been developed by a coalition of industry groups, regulatory agencies, growers and educators) that raises or verifies the level of professional knowledge of individuals making recommendations. Individuals who enter the program are provided with study material and classroom style training by the CCA Board, cooperator organizations, and their committees.

Certification participants are given two written tests to validate that they have the appropriate professional knowledge. One test is a national exam that covers broad issues of soil fertility, soil and water management, pest control, and plant development. The state exam closely examines issues unique to California, primarily in soil fertility, and soil and water management issues. After passing these exams, individuals must satisfy continuing education requirements by attending ongoing seminars or training in the required areas, and by signing a professional code of ethics.

By having key grower organizations on the CCA Board, growers remain informed about a program that helps assure them that their field representative has the knowledge to make recommendations that meet regulatory mandates. Growers can request or require field representatives to obtain this certification. Manufacturing, retailing, and individual consultants have an incentive to obtain professional certification to meet the combination of regulatory pressure and grower demand.

The ongoing success of the program will be evaluated by the number of individuals who enter the program and are able to pass the exam, and by the level of acceptance and support by regulatory agencies. The program is utilized by independent consultants, fertilizer manufacturers, and retailers, to raise the level of expertise of consultants and field representatives. It is utilized by growers to assure them that the soil and water nutrient programs they implement will be accepted by regulatory agencies, because the recommendations were made by agency-recognized, certified professionals.

As of August 1997, 494 individuals have been certified as CCAs. Nationwide, over 7000 individuals have been certified. Most major manufacturers and retailers now require the certification of their representatives, and many of the individual retail organizations are now involved in the program. Additionally, the program is now drawing a large sector of public agency representatives who make recommendations in urban settings. These individuals passed both exams, signed a code of ethics, and now participate in ongoing education that is reported on an annual basis.

The program provides pre-test training, and information on available ongoing education programs. We now also provide ongoing education to all segments of the fertilizer industry by coordinating with the Soil Improvement Committee of the California Fertilizer

Association, and the Fertilizer Research and Education Program. The CCA program expects to have an even stronger program this year by utilizing the input that was provided by attendees from the prior two years seminar series. The CCA program is also coordinating with the California Chapter of the American Society of Agronomy to promote their annual conference and provide educational information to CCAs.

The program made a major step forward this year by hiring an administrator that will focus on promoting the program and tracking educational opportunities on a full-time basis. Computers were purchased that are dedicated to the CCA tracking program, a web site was launched for the program (to provide up-to-date continuing educating program and unit opportunities), and a formal CCA quarterly newsletter is now being produced that will inform CCAs of current issues and opportunities.

Along with the large number of individuals who have been certified through the program, support of the program by regulatory agencies has been very positive. Within the state, no new regulations related to fertilizer reporting have been undertaken, and the CCA program is often cited by agencies as an example of what other industries could do to positively protect the environment without adding new mandated regulations from the state.

On the national level, US EPA has approved CCA as being one of the few non-governmental organizations that will have the approval of USDA to write farm management programs for growers involved in federal grower programs. Nationally, there has been no movement towards requiring increased levels of fertilizer reporting to satisfy federal clean water regulations. We believe that the program has been overwhelmingly successful in demonstrating to the government that industry is committed to providing growers with the best soil nutrient recommendations that yield the strongest agronomic and economic returns without compromising the environment.

TRACTORS, PLANES AND SATELLITES: ADVANCES IN REMOTE SENSING FOR AGRICULTURE[1]

Chris J. Johannsen
Professor of Agronomy & Director of the Laboratory for Applications of Remote Sensing (LARS)
Purdue University
West Lafayette, IN.

INTRODUCTION

Remote sensing technology has seen many changes in the past five years. Because of improvements in sensors, computer chips, software and services, agriculture is reaping benefits at ground and space altitudes. The term, "precision farming" has captured the essence of what is happening related to remote sensing but also that of other important technologies, namely geographic information systems (GIS) and global position systems (GPS). I personally don't like the term, precision farming as it denotes a level of "preciseness" that we have yet to achieve. I prefer the term "site specific farming". There are other terms such as "prescription farming," and "variable rate technology" that are also used. I have also heard it incorrectly called "GPS" when referring to this technology. Whatever it is called, we are seeing an information revolution occurring and once growers have been provided additional information about their crops, soil and land, they will keep asking for more!

We have literally taken "agriculture into the space age." Growers now have services available that involve satellites collecting data, transmitting locational information, or providing data from a variety of sources. Some of these sources involve having sensors on their tractors, combines, and other equipment; receiving data from sensors on airplanes to aid in crop scouting; and receiving or analyzing satellite information. They can also rely on companies to do all of these services for them for a fee.

1/ Partial funding for this effort was obtained from Stennis Space Center, (NASA Grant NAG13-38).

The importance of GPS should not be minimized in this discussion. GPS makes use of a series of military satellites that can identify the location of an observation or where farm equipment is within a meter of an actual site in the field. It is not quite that simple as I am sure everyone realizes that the more you get involved with technology, the more you find there is a lot of detail that people didn't tell you about! The value of knowing a precise location within a meter or so is that 1) locations of soil samples and the laboratory results can be compared to a soil map or previous yield information, 2) fertilizer and pesticides can be prescribed to fit soil properties (clay and organic matter content) and soil conditions (relief and drainage), 3) tillage adjustments can be made as one finds various conditions across the field, and 4) one can monitor and record yield data as one goes across the field.

SITE SPECIFIC FARMING

The real value from site specific farming is that the grower can perform more timely tillage, adjust seeding rates according to soil conditions, plan more crop protection programs with more precision, and know the yield variation within a field. These benefits can enhance the overall cost effectiveness of crop production, however the grower must be willing to make adjustments in his or her management styles to make it work.

The ability to vary the depth of tillage along with soil conditions is very important to proper seedbed preparation, control of weeds and fuel consumption and therefore cost to the grower. Many growers who are using conservation tillage know that it works better or easier on some soils then others The use of GPS in making equipment adjustments as one goes across the different soil types would mean higher yields and safer production at lower cost. This part of precision farming is in its infancy. The equipment companies are and will be announcing tillage equipment with GPS and selected controls tailored to site specific farming. It costs money for the equipment companies to change the production of standard equipment and they will be making changes as the market demand is there.

Hybrid seeds perform best when placed at spacing that allow the plants to obtain such benefits as maximum sunlight and moisture. This is best accomplished by varying the seeding or planting rate according to the soil

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conditions such as texture, organic matter and available soil moisture. One would plant fewer seeds in sandy soil as compared to silt loam soils because of the influence of soil properties. The lower plant population usually has larger heads (ears) of harvested seeds per individual plant providing for a maximum yield however, a word of caution - researchers do not have solid proof that varying plant population in many crops will guarantee increased or maximum yields. Since soils vary even across an individual farm field, the ability to change seeding rates as one goes across the field allows the grower to maximize this seeding rate according to the soil conditions. A computerized soil map of a specific field on a computer fitted on the tractor along with a GPS can tell growers where they are in the field allowing the opportunity to adjust their seeding rate as they go across their fields.

The application of chemicals and fertilizers in proper proportions are of environmental and economic concern to growers. Environmental regulations are calling for the discontinuance of certain pesticide applications within 100 feet of a stream or waterbody or well or within 60 feet of an intermittent stream. Using a GPS along with a digital drainage map, a grower is able to apply these pesticides in a safer manner. In fact, the spraying equipment can be preprogrammed to automatically turn off when it reaches the distance limitation or zone of the drainage feature. Additionally, growers can preprogram the rate of pesticide or fertilizer to be applied so that only the amount needed as determined by the soil condition is applied varying this rate from one area of the field to another. This saves money and allows for safer use of these materials.

The proof in the use of variable rate technology (adjusting seed, pesticide, fertilizer and tillage) as one goes across the field is in knowing the precise yields. Combines and other harvesting equipment can be equipped with pressure plates or weighing devices that are coupled to a GPS. One literally measures yield on the go. With appropriate software, a yield map is produced showing the yield variation throughout the field. This allows growers to inspect the precise location of the highest and the lowest yielding areas of the field and determine what caused the yield difference. It allows one to program cost and yield to determine the most profitable practices and rates that apply to each field location. In my opinion, the use of yield monitors is a good place to start if one wants to get started in precision farming, however that may not be practical or available for some crops. Yield data from the same field over 3+ years would define the weak spots in the field and narrow down the probability of what is causing a low yield.

SENSORS FOR AGRICULTURE

We should not think of remote sensing as obtaining data only from satellites. The tractor and other field equipment has and will have a big role in the use of agriculturally oriented sensors. Purdue University researchers have devised a machine system to rapidly measure soil nitrate and pH using ion-specific, field-effect-transistors (ISFETS). The system consists of a rolling core sampler and a computer-controlled, automated analysis station mounted on a toolbar and connected to a GPS receiver in order to map the field location of each measurement. UC Davis researchers have also been developing and testing sensors with similar capabilities. In another Purdue effort, the "sound" of a tillage tool pulled through the soil is being correlated to soil texture, specifically the percentage of sand and clay. These efforts are additions to the research which led to the development of a patented sensor for soil organic matter which enables site-specific applications herbicides.

Remote sensing technology has seen many changes in the past five years. From the tractor, we are using sensors that measure soil and plant parameters; from an airplane, we are obtaining aerial photography and digital images showing anomalies in a field; from satellites we will be obtaining images with spatial resolutions that previously were top secret. The major changes are that from satellite altitudes we are or will be able to 1) image or see with more detail, a smaller piece of land, 2) define more precisely the specific colors or light responses reflecting off of the field and 3) obtain data on a regular interval of every other day or every 5-7 days. These changes make for real advances to agriculture as we need to be able to view those small areas in the field that are giving us problems, determine what the problem is within a field by interpreting remotely sensed data and receive data/information on a regular interval. We will review these changes in more detail as they are important to the future of agriculture and how we gather data and information.

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SPATIAL RESOLUTION: THE SPACE BETWEEN MY DATA POINTS

When you view a yield image map, you are looking at about 750 to 1,500 data points per acre depending on how fast the harvester was traveling and how often (1, 2 or 3 seconds) the yield measurement was recorded. The area that one can see on an image, whether yield monitor or remotely imaged is called "spatial resolution". Spatial resolution in satellite data collection is improving. With current satellites, one can see areas that are 30 meters x 30 meters (4.5 measurements/acre), 20 x 20 meters (10 measurements/acre) and 10 x 10 meters (40 measurements/acre). With future satellites, we will be receiving data that have a variety of spatial resolutions or pixels (short for picture elements) that in some cases will be as detailed as 1 x 1 meter or over 4046 data points per acre.

Table 1. Conversion of Spatial Resolution from Images to Data Points on the Ground

Resolution (meters)	Data Points (Pixels)/Acre	Points/Hectare
1000	0.004	0.01
80	0.6	1.56
30	4.5	11.1
23.5	7.3	18.1
20	10	25.0
15	18	44.4
10	40	100
5	162	400
4	253	625
3	450	1111
2	1012	2500
1	4046	10000

In terms of sensor technology, we are seeing improvements in spatial resolutions that allow one to see greater detail. At recent conferences, we have learned that there is a potential for over 50 land observing satellites to be launched before the year 2007 that provide an interesting choice of data (Table 2). These satellites which are both government and commercial will have a large range of spatial resolutions from 1 meter to 1 kilometer. The highest resolution is proposed by Space Imaging Inc. and EarthWatch (QuickBird satellite) who plan to launch satellites in the next few years that will have 1 meter panchromatic and 4 meter digital data. EarthWatch (EarlyBird satellite) and other companies like Resource21 and GER are promising data in the 5 to 15 meter spatial range. Note that we are not limited to thinking only about satellite coverage for remotely sensed data. Several companies are providing sensor coverage by airplane from a variety of altitudes at the time that the grower would like to see what is happening to the crop. The other choice is that companies are developing sensors that can provide specific measurements for specific elements or conditions. As mentioned previously some of these involve sensors that will be placed on tractors and similar equipment.

Table 2. Remotely Sensed Data Choices of the Future and Some Characteristics

Satellite Platforms

- Spatial Resolutions:
  - 1, 2, 3, 4, 5, 10, 15, 20, 23.5, 30 meters
- Spectral Resolutions:
  - 5, 10, 50, 100 nanometers
- Temporal Resolutions:
  - 1-5 days, 8-10 days, 14-16 days

Aircraft Platforms

- Sensors similar to satellite platforms
- Greater flexibility in obtaining coverage
- Fly under the clouds!

Tractor Platforms

- Potential sensors for organic matter content, pH, soil texture, soil moisture
- Sensor measurements relate to specific tasks
- Sensors will work under a variety of conditions

SPECTRAL RESOLUTION: THE "VARIOUS COLORS" OF MY DATA POINTS

When remote sensors talk about the variation of light energy and its measurement, they call it spectral resolution. Improvements in color differentiation and refinement of measurement response have been in measuring a smaller portion of light energy or spectral wavelength bands measured in nanometers. The sensors placed in future satellites will take advantage of technology that will allow for measurements of narrower bands from 100 down to 5 nanometers and therefore a better measurement of the different colors and of areas that the human eye cannot see in the near infrared.

Currently satellites like Landsat have 7 wavelength bands and SPOT has 4 wavelength bands with bandwidths of about 50 nanometers. TRW has launched the Lewis satellite on August 23, 1997 under a NASA contract with 384 wavelengths. The 5 nanometer bandwidth of the Lewis sensors will certainly provide a more detailed look at the reflective nature of light coming from soil and plant conditions. The Lewis satellite has developed problems and the entire remote sensor community is anxiously waiting. Other companies will learn from this data in their selection of specific wavelength bands for specific measurements of plant conditions such as stress, nutrient deficiencies and similar variations effecting crop yield.

TEMPORAL RESOLUTION: THE NUMBER OF TIMES THAT I CAN SEE MY DATA POINTS

When we look at the same field or location on repetitive dates, we are using temporal resolution. We are looking for the variation that occurs over time or "change detection." With current satellite data, one has the potential of receiving data every 2-6 days (SPOT) or every 16 days (Landsat). Future opportunities will be either 2, 3 or 5 days depending on the company. The value of receiving repeat data would be in identifying a change where one could perform an activity that would correct or improve the change. If you are irrigating, it may be in changing the rate or amount of water, or adding nutrients with the water. If the change is due to some stress factor such as weeds, insects, diseases, or similar pests, one would need to decide if correcting the problem through application of a pesticide would be economical.

Growers are also interested in estimating the yield of their crop prior to harvest. Remotely sensed data, especially with a temporal view, can give valuable clues to the potential yield; however this will vary by growth and maturity of the crop. Not all crops will provide high correlation of vegetation mass to yield. Variation in corn varieties, for example, has shown that some varieties have more vegetative cover than others and may not be related to actual yield. Much work needs to be done in this area. The use of more wavelength bands at narrower bandwidths may also hold promise for determining more information about yield and yield quality.

SUMMARY & CONCLUSIONS

Remote sensing technology will improve by increasing spatial, spectral and temporal resolutions starting during this year. There will also be an effort to provide the data within 24-48 hours after it has been acquired. Another technology besides remote sensing that will assist in improving answers and interpretation will be Geographic Information Systems (GIS). The ability to merge soil maps with remotely sensed data to understand crop variability is a great asset to interpretation. Many growers have commented that they would like more detailed soil information than currently provided by the standard soil maps. The ability to take other data such as terrain data, slope, aspect or even other remotely sensed data and look at crop variability causes many people to see many opportunities for better understanding of what is causing the variability.

Where does (GIS) and remote sensing fit with Site Specific Farming? Several companies are starting to market GIS record-keeping systems so growers can record all of the field operations such as planting, spraying, cultivation and harvest (along with specific information such as type of equipment used, rates, weather information, time of day performed, etc.). Additionally, growers are able to record observations through the growing season such as weed growth, unusual plant stress or coloring and growth conditions. Data collected by the GPS operations can be automatically recorded with the GIS program. Remotely sensed data can be analyzed and added to the GIS using soil maps, digital terrain and field operations information as ground truth.

More attention is being paid to the type of information that growers will need. It would appear that most remote sensing vendors will not be delivering raw images directly to all growers. Rather they will provide data/information to the "information multipliers" or the "value-added vendors" such as agricultural business dealers, extension personnel, crop consultants, and special agricultural information services who in turn will analyze and interpret the data and deliver it to the grower. Growers are collecting a lot of supporting data and those analyzing the remote sensing data will need to gain access to the grower's data. Growers will be in a position to perform their own image analysis but we must remember the needed training aspects for this to be successful.

Advances in remote sensing technology are changing the way we will look at agriculture. The success of remote sensing will be measured by the type of information that is provided to the grower, how quickly the information is delivered and the fee that is charged for the information. Competition for the grower's business should help in making the success a reality.

NITROGEN MANAGEMENT IN CITRUS UNDER LOW VOLUME IRRIGATION

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OBJECTIVES

1. Using modern orchard technologies, evaluate the nitrogen needs of citrus trees, including amount and timing of nitrogen fertilizers for maximum production.

2. Determine the potential of nitrogen fertilizer timing, amounts and application techniques to add nitrates below the root zone in a citrus orchard, and to contribute to groundwater contamination.

3. Examine the effect of nitrogen amount, timing and application method in a modern orchard on fruit quality and vegetative growth.

4. Using the objectives listed above, determine best management practices for a modern citrus orchard based on economic and environmental considerations.

5. Appraise citrus growers, packers and industry affiliates of the project's progress, results and ultimate conclusions in articles in trade magazines, newsletters and through presentations at grower meetings.

SUMMARY, RESULTS, AND CONCLUSIONS

We identified a grower cooperator in the Exeter-Woodlake area of Tulare County in 1996. The 15.3 acre experimental site is a mature navel orange grove (Frost Nucellar) on Troyer Citrange rootstock. The tree spacing is 22' x 20'. Twenty-five experimental treatments were selected for the project (Table 1). Each experimental plot consists of 12 trees with the central 2 trees serving as the data trees. The cooperator's irrigation system was modified to accommodate the differential nitrogen treatments during Spring/Summer 1996. Differential treatments were imposed commencing January 1997. Samples for leaf analysis were collected in September 1996 (data not presented) to establish a baseline nutrient status of the orchard. In March 1997, all data trees were harvested in order to gather background data on fruit quality from the orchard.

Table 1 lists the 25 experimental treatments included in the study. In March 1997, all data trees were harvested and subsequently a subsample of fruit (Size 72) were waxed with a commercial citrus wax and stored at 5°C (41°F) for 2.5 weeks, 10°C (50° F) for 10 days and 20°C (68°F) for 7 days in order to simulate a commercial shipping period. Fruit were sized, graded and prepared for storage at the UC Lindcove Research and Extension Center Fruit Quality Facility in Lindcove, CA. All fruit were stored at the UC Kearney Agricultural Center in Parlier, CA.

Based on production (number of fruit per tree) the field consistently yields approximately 872 fruit per tree pair. The peak fruit sizes were sizes 56 and 72. Although statistical differences were detected at $P < 0.05$ these differences are not related to treatment effects. There were slight block effects with Blocks 3

Table 1. Schedule of experimental treatments for nitrogen management project.

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

Foliar Only

Applications[z]	Lb N/tree/yr
0	0
1	0.25
2	0.50
4	1.00

Soil Only

Lb N/tree/year	Timing[y]
0.5	1, 2, C
1.0	1, 2, C
1.5	1, 2, C
2.0	1, 2, C

Combination Treatments

Soil Application: lb N/tree/yr[x]	Foliar Applications: # applications[z]	Total lb N/tree/yr
0.5	1, 2, 4	0.75 - 1.50
1.0	1, 2, 4	1.25 - 2.00
1.5	1, 2	1.75 - 2.00
2.0	1	2.25

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[z] Foliar Application: Low Biuret Urea will be applied to foliage at a rate of 0.25 lb/tree per application. Trees receiving one application will have urea applied in late May. Trees receiving 2 applications will have an additional application in late winter. Trees receiving 4 applications will have additional applications at the pre-bloom stage and 30 days following the late May application.

[y] Soil Application: All applications will be made through the irrigation system: 1 = single application per year in late winter; 2 = split application, late winter and early summer; C = Applied with every irrigation from late winter through summer.

[x] Soil Nitrogen will be applied as in the "C" treatment described above for the soil applications.

and 4 yielding slightly lower numbers of total fruit per plot.

As with the yield and size distribution data, there were statistical differences detected between treatments, for fruit quality. Although these differences were slight and not related to the differential nitrogen treatments. Not surprisingly, the largest differences were related to the duration of storage. As expected, the soluble sugar content and titratable acidity content of the juice (SSC, TA, respectively) changed with storage. We also noted more fruit decay following storage, although the amount of decay was relatively minor. We also measured puncture resistance of the peel and peel thickness. There were no consistent differences detected between treatments or field blocks. The data we have thus far collected provides the necessary background data for the project and provides us with an idea of site variability.

DEVELOPMENT OF A NITROGEN FERTILIZER RECOMMENDATION MODEL FOR CALIFORNIA ALMOND ORCHARDS

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OBJECTIVES:

1. Conduct field validation of leaf nitrate analysis in almonds.
2. Develop an "on-site" test of tissue nitrate concentration throughout the growth season.
3. Determine almond tree seasonal and total N demand for optimum yield.
4. Develop a grower-used, computer-based, site-specific N management program.

SUMMARY

The nitrate-N and total N in leaf and fruit were determined every two weeks in early growth stage and will be determined every month after nut fill from plots in one mature and one young almond orchard currently growing with differential N level. Nitrate level in fresh leaves and immature fruits was tested by using different portable methods and the results were compared with those determined using standard laboratory procedure (Carlson's method). However, no single field test method is ideal and further work is required. The results of using different tissue extraction methods indicated that a simplified method of using only deionized water can effectively extract nitrate from tissue slices. This suggests that development of an "on-site" test of tissue nitrate is possible if a suitable detection method can be found. Given the low levels of nitrate in the early growth stage in tree species, this will be challenging. Preliminary results show that significant amounts of nitrate appeared in both leaves and immature fruits only immediately after application of N fertilizer. This suggests that N supplied to the new growth from storage N is not present as free nitrate form.

Results indicate that there is no statistical difference in tissue nitrate level detected using the standard 2 % acetic acid extraction method and using only DDI water extraction, though boiling the tissue usually showed higher nitrate level. This suggests that a simplified method of tissue extraction using only deionized water is applicable in the field. Compared with the laboratory method, the portable nitrate meter (HORIBA Inc.) is inadequately sensitive for measuring tissue extracts of tree species. The semiquantitative method (Merck color indicator strips) provides only limited sensitivity in measuring nitrate level in the tissue extracts. Nitrate detection method using nitrase provided by the Nitrate Elimination Co. provided similar sensitivity as Carlson's method, but is not suitable for "on-site" testing because it requires the use of a spectrophotometer.

There is no detectable NO_3-N present in leaves or immature fruits prior to the first N fertilizer application in both locations, even though total N content in the leaves ranges from 3.0 to 4.0%. Significant amount of nitrates appeared in both leaves and immature fruits 3 days after the first split application of N fertilizer. This suggests that N supplied to the new growth from storage N is not present as free nitrate form.

For objectives 3, an extensive tree sampling was conducted to choose optimal experimental trees for tree excavation at the Delta College orchard in Manteca, CA. The relevant data are being analyzed. Twenty-five ideal trees will be identified for five sequential harvests. The first tree excavation will be initiated in late 1997.

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

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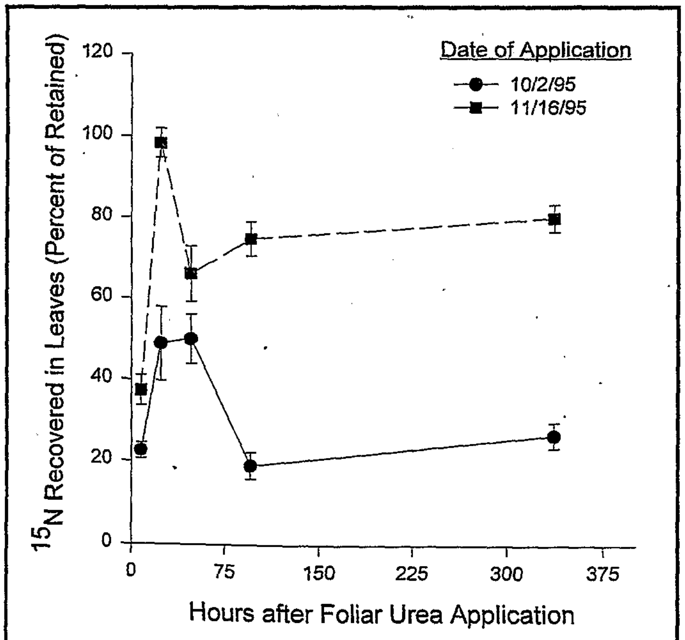

Figure 1. ^{15}Nitrogen uptake by nectarine leaves as a percentage of total ^{15}N retained on leaf surfaces following urea application on October 2 and November 16. Leaves were sampled 8, 24, 48, 96, and 336 hours after foliar applications of a 10% labeled urea solution. Shown are the means + SE for six leaf replicates, with small error bars incorporated into the symbol.

INTRODUCTION

Fertilization practices for tree fruits that include foliar applications of N should become increasingly popular, in light of the potential contribution of soil-applied N to groundwater contamination. Foliar nitrogen sprays could greatly reduce the potential for nitrate leaching into the groundwater.

We have been investigating the approach of applying high concentrations of low biuret urea in the fall when leaf damage is not a major concern. Results indicate that urea is quickly absorbed (80% in 48 hours) and largely transported out of the leaf within one week, before extensive leaf-fall occurs. Therefore, this approach appears to be a very efficient way to supply the tree with N.

OBJECTIVES

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

RESULTS

Nectarine leaves take up foliar-applied urea-N very rapidly, but translocation of urea-N out of leaves depends on the time of application. Nectarine leaves absorbed 80% of the labeled urea solution with 48 hours of application in early October or mid-November. In early October, translocation of ^{15}N-urea was virtually complete within 96 hours of application and only 20% of the total ^{15}N retained initially on leaf surfaces remained in the leaves at that time (Fig 1). In contrast, 80% of the ^{15}N applied in November remained in the leaf two weeks after application. Thus, very little urea ^{15}N was translocated out of senescing leaves when applied in mid-November. This suggests that timing of foliar N applications is critical in maximizing N uptake and transport into perennial tissues of nectarine trees. We will look at the optimal timing issue next year.

To study long-term productivity, an experiment on Early Maycrest peach was initiated in the spring of 1996 at the UC Kearney Agricultural Center. Treatments were set up comparing soil-applied N fertilizer to foliar urea sprays applied in October. Four treatments were compared:

1. Unfertilized control.
2. Soil N only–50 lbs. N/acre in April, 50 lbs. N/acre in September.
3. Soil: 50 lbs. N/acre in April, Foliar: 50 lbs. N/acre in October.
4. Soil: 50 lbs. N/acre in September, Foliar: 50 lbs. N/acre in October.

Applying soil and foliar N in the fall (treatment 4) looked very promising (Table 1). The advantages of treatment 4 over the other treatments include:

1. highest level of stored N,
2. highest N concentration and weight in its flower buds,
3. highest fruit weight at thinning time,
4. low vegetative growth.

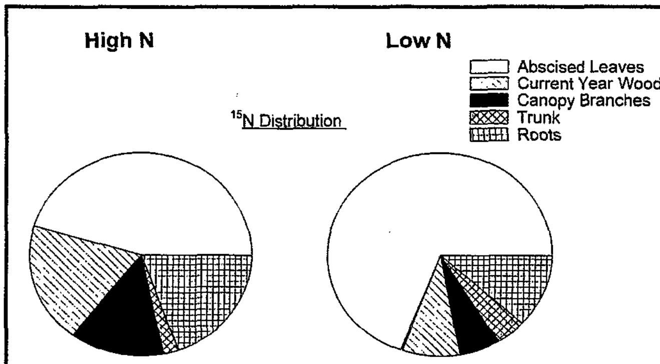

Figure 2. ^{15}Nitrogen on seven-year-old nectarines previously supplied with 250 N lbs/acre (High N) or not supplied with N (Low N). Four trees (2 High and 2 Low N) were sprayed with a 15% urea solution on November 1, 1995 and excavated on January 23, 1996.

Finally, we examined how tree N status affects the distribution and translocation of foliar-applied ^{15}N-urea in nectarine trees during the post-harvest season. Unfertilized, low N trees remobilized significantly lower quantities of foliar-applied ^{15}N-urea than trees replete in N (fertilized with 250 lbs. N/acre, Fig 2.). Abscised leaves contained less than half of the total ^{15}N recovered in high N trees, but over two thirds of the ^{15}N recovered in low N trees. Thus, most of the urea applied to low N trees was subsequently removed in the abscised leaves and not translocated to perennial tissues. These results indicate that tree N status must be taken into account when developing a N foliar fertilizer program.

Table 1. The effect of low biuret foliar urea sprays on Early Maycrest Peaches

	Treatments 1	2	3	4	Significance
	Unfertilized Control	**Soil Fertilized Control**	**Split April - Soil Oct. - Foliar**	**Split Sept - Soil Oct. - Foliar**	
1/96 Shoot N (%)	1.02 d	1.28 b	1.16 c	1.40 a	.0001
1/96 Root N (%)	.70 d	1.33 b	.97 c	1.59 a	.0001
12/95 Flowerbud N (%)	4.49 c	4.59 c	4.76 b	4.95 a	.0001
1/96 Flowerbud N (%)	4.82 b	5.39 a	5.21 b	5.38 a	.0001
12/95 Flowerbud weight (mg)	.34 b	.36 ab	.34 b	.37 a	.008
1/96 Flowerbud Weight (mg)	73.0 c	.78 ab	.72 b	.81 a	.03
4/96 Fruitlet wt (g)	1.70 c	2.50 a	2.10 b	2.70 a	.0001
5/96 Yield (kg/tree)	8.40 b	12.80 a	10.70 ab	12.60 a	.008
5/96 Fruit Weight (g)	97.70 b	114.80 a	110.30 a	113.50 a	.0004
7/96 Pruning weight (kg/tree)	2.40 b	5.90 a	5.00 a	3.50 b	.0005

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RELATIONSHIP BETWEEN N FERTILIZATION AND BACTERIAL CANKER DISEASE IN FRENCH PRUNE

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INTRODUCTION

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 (N) to these crops.

SUMMARY

Research plots were 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 response 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 N developed a very high incidence of BC (60% and 32%, respectively in 1995). In 1996, 90% of the trees in the block receiving no nitrogen either died of BC and had been replaced or were symptomatic. By June, 1997 an additional three trees had been replaced, seven others were likely to die, and three replants had begun to exhibit symptoms of BC. In the low N treatment (0.14 lbs/year/tree), 47% of the trees had to be replaced or were symptomatic of BC in 1996 and 49% by June, 1997 However, in the blocks receiving higher N rates (0.5-1.0 lbs/year/tree), only 0-6% of trees had been replaced or were symptomatic in 1996 and 1997.

Leaf analysis in May, 1995 showed that trees receiving no or low N were deficient in N (N<2.3%). Leaf N levels in 1996 were 2.19% and 2.32% for the no N and low N treatments respectively. Leaf N levels in 1997 are not yet deficient in no or low N treatment blocks, but are already lower than those in treatment blocks receiving higher applied N. Soil analysis of all treatment blocks in 1994-96 showed no areas of the orchard where soil nitrate from fertilizer leaching was especially high or low.

As expected, trees receiving higher N treatments grew more each year than trees receiving no N. No difference in prune dry yields were observed in 1995 (first good cropping year), but in 1996 yields from the 0 N and low N treatments were significantly lower than treatments receiving more N. The highest doses of N fertilizer (1 and 0.5 lbs N) may stimulate more shoot growth, but not necessarily higher yields than the moderate rate 0.25 lbs N treatment. These preliminary data would support a recommendation to fertigate at the moderate rate (0.25 lbs/year/tree) unless symptoms or a history of BC exist. On sites with a history of BC, higher N rates may reduce or eliminate BC symptoms.

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

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INTRODUCTION

Nitrogen is the fertilizer used most often in California vineyards. Most of the studies conducted on grapevines to determine vine nutritional requirements and the determination of vine nutrient status were conducted in vineyards located in the San Joaquin Valley. In addition, these studies were conducted on vines growing on their own roots. Little nutritional research has been conducted on vines growing in the coastal regions and those that have been conducted were with vines growing on rootstocks that are not currently in high demand (i.e. in replant situations).

Vine nutritional status of grapevines is usually measured by analyzing nutrients in petioles opposite the cluster at a particular phenological stage (generally at bloom or veraison). This technique is also used to determine the efficiency of a fertilizer application in fertilizer experiments. Unfortunately, petiole analysis only gives an instantaneous measure of the vine nutrient status at the time the samples are taken and does not provide quantitative measures of the efficiency of application of the particular nutrient being studied. Other methods have also been used, such as the analysis of the amino acid arginine in the fruit. The use of this technique may be a more appropriate method to determine vine nutritional status. The only way to definitely determine N fertilization use efficiency in a field situation is to use ^{15}N labeled fertilizer. ^{15}N labeled N is a non-radioactive isotope of nitrogen. The amount of ^{15}N present in plant tissues can be quantified with the use of a mass spectrometer.

OBJECTIVES

1. Quantify total uptake of nitrogen and potassium in Chardonnay and Cabernet Sauvignon scions grafted onto various rootstocks at different locations.
2. Use isotopically labeled nitrogen (^{15}N) to determine fertilizer use efficiency of premium wine grapes on different rootstocks in the coastal valleys of California.
3. Compare the efficiency of N fertilizer uptake and total N and K uptake by various scion/rootstock combinations with other means to determine vine nutritional status (for example, petiole analysis at bloom and cluster N and K analysis at harvest).
4. Develop fertilization recommendations for premium wine grapes grown in the coastal regions of California.

SUMMARY

This study will use ^{15}N labeled ammonium nitrate to determine fertilizer use efficiency of two wine grape cultivars (Chardonnay and Cabernet Sauvignon) grown in coastal valleys on different rootstocks. Two different locations will be used per cultivar and at each location similar rootstocks will be used. The rootstocks for the Chardonnay cultivar are 110R, 5C and Freedom. The rootstocks for Cabernet Sauvignon are 110R, 5C and 3309 at one location and 110R, 5C, 1103P, 140 Ru and Freedom at the other location.

The study was initiated in May, 1997, for the Chardonnay vineyards and in June, 1997, for the Cabernet vineyards (shortly after berry set for each cultivar). Vineyard yield was estimated from previous years' harvests and total N required for fruit growth was determined. Previous research indicates that grapes will require approximately 3 lbs of N for each ton of fruit. Therefore, the amount of ammonium nitrate required to replace the amount of N

removed by the crop at harvest this growing season was applied to six individual vine replicates of each rootstock. This amounted to anywhere from 27 to 40 lbs total N per acre, depending upon the vineyard. The fertilizer was applied beneath emitters while the vineyard was being irrigated. The vines were irrigated at full evapotranspiration (ET). ET was determined by multiplying potential evapotranspiration (ETo) by a crop coefficient (kc). The kc was developed on Chardonnay vines grown in the Napa Valley.

At the time the fertilizer was applied, shoots were harvested from each rootstock treatment to determine total N in the vine at that time. Fruit will be harvested at maturity, leaves will be collected as they fall from the vine, and prunings will be taken during the winter months. All organs will be weighed, dried and analyzed for total N, ^{15}N, and total potassium. This will allow for the determination of fertilizer use efficiency and if there are differences among rootstocks with regard to N and K uptake and utilization. Lastly, petiole samples were taken from each rootstock treatment at all locations and will be analyzed for mineral nutrient composition.

This summary was prepared prior to any analysis of vine material. Therefore, no conclusions can be drawn at this time. It is anticipated that the data will provide information regarding fertilizer use efficiency for different grape cultivars grafted onto different rootstocks at two locations. It will also provide information regarding the relationship between total vine uptake of N and K and petiole analysis.

EVALUATION OF PRE-SIDEDRESSING SOIL NITRATE TESTING (PSNT) TO DETERMINE N REQUIREMENTS OF COOL-SEASON VEGETABLES

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INTRODUCTION

It is generally acknowledged that intensive vegetable production as practiced along California's central coast contributes to nitrate contamination of groundwater. Heavy fertilization of two or more crops per year is the norm; annual fertilizer N input is commonly twice as high as N removal in harvested product. Soils in vegetable rotations also tend to be quite active in cycling organic N into mineral forms (NH_4-N and NO_3-N) available for plant growth. In vegetable fields it is common to find high soil NO_3-N concentration persisting throughout the cropping season. In-season soil NO_3-N testing could identify fields with high residual soil NO_3-N levels, helping growers determine field-specific sidedress N requirements. This approach has been researched extensively in the Midwest for corn production. Called the pre-sidedressing soil nitrate test (PSNT), it is now in widespread commercial use. This project proposed to adapt the PSNT technique to coastal vegetable production, and to refine a simple analytical technique for on-farm soil NO_3-N analysis.

OBJECTIVES

1. Evaluate the use of pre-sidedress soil nitrate testing (PSNT) to estimate sidedress N requirement of cool-season vegetables.
2. Document the accuracy of an on-farm soil "quick test" for NO_3-N determination.
3. Survey commercial vegetable fields in the Salinas and Santa Maria Valleys to determine the range of soil NO_3-N concentrations common at the time of first sidedressing.
4. Conduct outreach efforts to disseminate results.

DESCRIPTION

A total of 10 field trials were conducted in commercial vegetable fields in the 1996 season; 4 were planted in head lettuce, 2 each in cauliflower, celery, and broccoli. Planting dates were staggered from late March to mid-August. All fields were sprinkler irrigated to establish the crop, then switched to furrow irrigation to complete the season. Fields were chosen that had soil NO_3-N at or above 20 ppm NO_3-N prior to the first sidedress N application, as measured by an on-farm "quick test" procedure; the test procedure is described below.

The nitrogen fertilization program in each field was determined solely by the participating growers. In each field two levels of reduced N application were established by skipping one or more sidedress N applications. These reduced N treatments, with replicate 4-bed-wide by 100' long plots in each quadrant of the field, were compared with adjacent plots receiving the growers' full N program.

Periodic plant and soil sampling was done to document N status throughout the season. Soil samples (2-12 inches) were collected at each sidedressing and at harvest; NO_3-N concentration in 2N KCl extracts was determined by conventional laboratory analysis. Petiole (broccoli and celery) or midrib (cauliflower and lettuce) samples, as well as whole plant samples, were collected prior to the second sidedress N application and at harvest. After oven drying, the petioles and midribs were analyzed for NO_3-N concentration, the whole plant samples for total biomass and total N content.

Plots were harvested by experienced personnel from commercial harvest crews. Harvested plants were evaluated for size and condition based on established market standards. Celery and lettuce fields were harvested once, broccoli and cauliflower either once or twice, depending upon the percentage of plants ready for harvest on the first evaluation date.

A survey of commercial vegetable fields was conducted to determine typical soil NO_3-N concentration at the time of first sidedress application. More than 20 fields in the Salinas, Santa Maria and Oxnard areas were sampled from May through August, 1996. Composite soil samples (2-12 inches depth) were collected by field quadrant immediately prior to the first scheduled sidedress N application. NO_3-N concentration, in 2N KCl extracts of moist soil, was determined by standard laboratory technique. Some of these soil samples, plus others from the field trials, were also analyzed for NO_3-N by the quick test technique. The results of the two analytical methods were compared to document the accuracy of the quick test technique.

RESULTS

Eliminating one or both sidedress N applications had no effect on marketable lettuce yield in any field (Table 1). In each field the no sidedress N treatment received a seasonal total of no more than 110 lbs N/acre. The very low fertilizer N total of the no sidedress treatment in field 1 (40 lbs N/acre) may be misleading, since the irrigation water used on that field contained substantial NO_3-N, adding a seasonal total of approximately 60 lbs N/acre. In field 3 the plots receiving no sidedress N could be visually distinguished by lighter color at harvest; late season soil NO_3-N was also low (less than 5 ppm), yet yield was unaffected.

In both celery trials the grower fertilization program–somewhat higher than the industry norm–featured 4 sidedress applications. To ensure that an N regime far below industry standards was evaluated, the reduced N treatments skipped 2, 3, or all 4 sidedress applications. Even in the lowest N treatments, which received only 206 lbs N/acre (Field 1) or 114 lbs N/acre (Field 2), crop yield (expressed either as mean plant weight or plant size distribution) was unaffected (Table 2). Similarly, N treatment had no effect on leaf color or degree of pithiness of the stalks.

Skipping the first sidedress N application did not reduce crop productivity in any broccoli or cauliflower trial (Tables 3 and 4). For each crop, one of the field trials showed no adverse effects from skipping 2 sidedress applications, while in the other trial, this lowest N treatment did reduce crop yield. In the cauliflower trial (Field 2), this yield reduction cannot be attributed directly to lack of N application, since even the low N treatment received more than 250 lbs N/acre. Rather, aggressive irrigation on the light textured soil undoubtedly reduced N availability through leaching. The modest yield reduction in the broccoli trial (Field 2) may have been more directly related to limited N supply, but even here it would be wrong to interpret these results to suggest that the 108 lbs N/acre was insufficient for maximum productivity. In this trial all N was applied either preplant or just after emergence, more than 60 days before harvest. Repeated irrigation, and several fall rains, provided ample opportunity to leach NO_3-N before the period of peak N demand (just prior to harvest). The same seasonal N rate, applied later in the season, may have performed better.

Taken together, these trials clearly demonstrate that, in fields with substantial residual soil NO_3-N concentration (more than 20 ppm), early season sidedressing is not required for optimum crop performance. The agronomic success achieved in most fields in treatments where several sidedress applications were eliminated is further corroboration that there is substantial opportunity for reducing fertilizer input in coastal production of cool-season vegetables.

Maintaining high productivity with seasonal N applications of 100 lbs/acre or less may seem unlikely, but a rough N budget analysis can be instructive. Soil NO_3-N concentration of 25 ppm represents approximately 100 lbs N/acre in the top foot, 150 lbs N/acre in the top 18 inches. Net N mineralization rates of 1.0-1.5 lbs N/acre per day have been documented in medium texture coastal vegetable soils; in a 70 day crop, mineralization of organic N could add 70-100 lbs of available N/acre. Given the NO_3-N concentration

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Table 1. Response of head lettuce to varying nitrogen regimes.

	N Treatment	Total N (lb/acre)	24's (% of plants[z])	30's (% of plants[z])	Culls (% of plants[z])	Average head wt. (lb.)	Leaf color[y]
Field 1	grower practice	240	94	2	4	2.3	18.6
	skip sidedress 1	140	95	2	3	2.3	19.2
	skip sidedress 1 and 2	40	95	1	4	2.2	18.7
			ns	ns	ns	ns	ns
Field 2	grower practice	210	92	5	3	2.5	18.7
	skip sidedress 1	160	94	4	2	2.4	19.3
	skip sidedress 1 and 2	100	93	4	3	2.5	18.9
			ns	ns	ns	ns	ns
Field 3	grower practice	232	93		7	2.1	18.1
	skip sidedress 1	165	93		7	2.1	18.1
	skip sidedress 1 and 2	102	94		6	2.1	16.0
			ns		ns	ns	
Field 4	grower practice	277	82	11	7	2.0	23.3
	skip sidedress 1	210	83	11	6	2.0	22.6
	skip sidedress 1 and 2	110	85	11	4	2.1	23.0
			ns	ns	ns	ns	ns

[z] sized by standard commercial categories, in head count per 50 lb net wt. box

[ns] treatment means not significantly different at p = .10

[y] no sidedress treatment mean significantly different at p = .10

Field 1. Loam texture, seeded March 12. Sprinkler irrigated, final irrigation delivered by furrow; 40 lbs N/acre (as AN-20) appl through sprinklers after emergence. 2 sidedressings of 100 lbs N/acre each (as UN-32). Harvested 6/7/96. Soil NO_3-N at first sidedress = 21 ppm.

Field 2. Sandy loam texture, seeded March 28. Germinated with sprinklers, furrow irrigated; 60 lbs N/acre preplant, 40 lbs N/a (as AN-20) applied through sprinklers. 2 sidedressings of a total of 110 lbs N/acre (as AN-20). Harvested 6/14/96. Soil NO_3-N first sidedress = 29 ppm.

Field 3. Sandy loam texture, seeded April 23. Germinated with sprinklers, furrow irrigated; 60 lbs N/acre preplant, 40 lbs N/ac (as AN-20) applied through sprinklers. 2 sidedressings of a total of 130 lbs N/acre. Harvested on 7/10/96. Soil NO_3-N at first sidedress = 28 ppm.

Field 4. Loam texture, seeded April 27. Germinated with sprinklers, furrow irrigated; 70 lbs N/acre preplant, 40 lbs N/acre (as AN applied through sprinklers. 2 sidedressings of a total of 170 lbs N/acre. Harvested on 7/16/96. Soil NO_3-N at first sidedress = 47 p common in irrigation water, between 15-30 lbs N/acre could be added during a cropping season. Clearly, a crop such as lettuce, which normally contains less than 120 lbs N/acre in its total biomass at harvest, could be well supplied at very modest N fertilization rates provided that irrigation was efficiently applied, minimizing leaching losses.

The commercial field survey documented that high levels of soil NO_3-N at the time of the first sidedress N application are common. Of the 21 fields sampled, only 3 had soil NO_3-N less than 20 ppm; 8 fields were 40 ppm or more. Caution is appropriate in interpreting these results. This survey concentrated on late spring-summer planted fields; fields planted in early spring would typically have much lower NO_3-N soil levels due to the effects of leaching winter rains. Also, a substantial portion of the soil NO_3-N measured in this survey undoubtedly represented N fertilizer applied preplant or through sprinklers following crop emergence. However, the main point to emphasize is that at the time the growers were preparing to make large sidedress N applications, the majority of these fields did not need additional N, and would not for weeks to come. As the field trials demonstrated, a number of these fields would not require any additional N to achieve maximum yield and quality. In-season soil sampling is a crucial part of efficient N management. The soil NO_3-N quick test proved to be a valuable tool for assessing soil NO_3-N status. Across a wide range of NO_3-N concentrations the quick test was closely correlated with conventional laboratory analysis ($r^2 = 0.82$, Fig. 1).

Accuracy may be further improved by the use of a battery-operated colorimeter which eliminates the error associated with visually estimating the intensity of color of the test strip. Additional field trials are underway in Oxnard, Santa Maria, and the Salinas Valley. By the end of the 1997 season a total of at least 18 separate field trials will have been conducted evaluating the PSNT approach to N management.

SOIL NO_3-N "QUICK TEST" PROTOCOL

Procedure:

1. Collect a composite soil sample representative of the main root zone of the crop; blend thoroughly in a container.
2. Fill a volumetrically marked tube or cylinder to the 30 ml level with .01 M calcium chloride.
3. Add field moist soil to the tube until the liquid level rises to 40 ml; cap tightly and shake vigorously until soil is thoroughly dispersed. Let sit until soil particles settle out.
4. When solution is reasonably clear, dip a Merckquant® nitrate test strip into the solution, shake off excess solution, and wait 60 seconds. Compare strip color with the color chart provided.

To minimize the variability inherent in soil sampling, run duplicate tubes for each field soil evaluated.

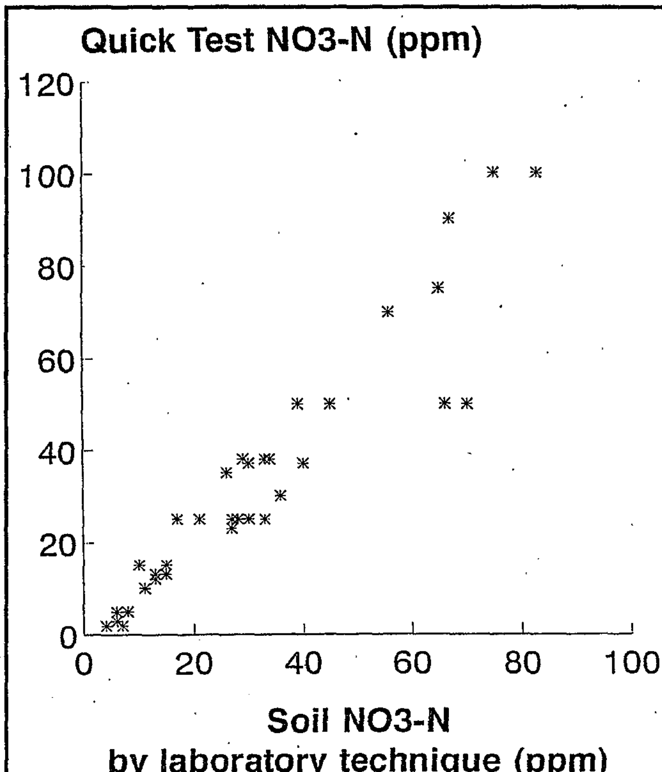

Figure 1. Correlation of the soil "quick test" technique with conventional laboratory analysis of soil NO_3-N concentration.

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Interpretation:

The strips are calibrated in parts per million (ppm) NO_3. The approximate conversion to PPM NO_3-N on a dry soil basis will require dividing by a correction factor based on soil texture and moisture.

Strip reading (ppm NO_3) ÷ correction factor = ppm NO_3-N in dry soil

Correction factor

Soil texture	Moist soil	Dry soil
sand	2.3	2.6
loam	2.0	2.4
clay	1.7	2.2

Soil less than 10 ppm NO_3-N would be considered low; levels above 15-20 ppm NO_3-N have enough available N to meet immediate crop needs.

Note: If nitrate measurement is done with a nitrate-selective electrode more consistent results may be obtained using an extracting solution of 0.025 M aluminum sulfate.

Table 2. Response of celery to varying nitrogen regimes.

	N Treatment	Total N (lb/acre)	18's	24's	30's	36's	48's	Small	Average head wt. (lb)	Leaf color[y]
			% of plants							
Field 1	grower practice	517	2	51	26	16	3	3	2.3	32.6
	skip sidedress 1 and 3	310	5	60	20	14	2	2	2.4	33.4
	skip sidedress 1, 2 and 3	206	1	54	23	17	2	3	2.3	33.9
			ns	ns	ns	ns	ns	ns	ns	ns
Field 2	grower practice	535	2	26	36	29	5	1	1.8	31.8
	skip sidedress 1	329	5	20	40	27	8	1	1.9	33.8
	skip sidedress 1 and 2	114	5	21	35	30	8	1	1.8	31.1
			ns	ns	ns	ns	ns	ns	ns	ns

[ns] treatment means not significantly different at p = .10

[z] sized by standard commercial categories, in head count per 60 lb net wt. box

[y] relative leaf color of canopy leaves, as measured by leaf reflectance meter

Field 1. Loam texture, transplanted 7/22/96. Sprinkled in, furrow irrigated. Preplant application of 55 lbs N/acre; 42 lb N/acre (AN-20) applied through sprinklers. Four sidedress applications of a total of 420 lbs N/acre, of various N sources. Harvested 10/28/96. Soil NO_3-N at first sidedress = 43 ppm.

Field 2. Loam texture, transplanted 7/9/96. Sprinkled in, furrow irrigated. Preplant application of 71 lbs N/acre, 42 lbs N/acre (AN-20) applied through sprinklers. Four applications of a total of 421 lbs N/acre, of various N sources. Harvested 10/15/96. Soil NO_3-N at first sidedressing = 35 ppm.

Table 3. Response of broccoli to varying nitrogen regimes.

	N Treatment	Total N (lb/acre)	% of plants: Crowns[z]	Bunch[z]	Small	Average head wt. (lb)
Field 1	grower practice	372	14 b[y]	5	81	0.86
	skip sidedress 1 and 2	202	13 b	2	85	0.84
			*	ns	ns	ns
Field 2	grower practice	314	23 a	12	65	1.4 a
	skip sidedress 1	208	20 a	13	67	1.3 a
	skip sidedress 1 and 2	108	15 b	14	71	1.1 b
				ns	ns	

[*,ns] treatment means significantly different, or not significantly different at p = .10

[z] "crowns" and "bunch" represent different types of commercial packs; cosmetic standards for crowns are higher than for bunch

[y] mean separation among N treatments by Duncan's Multiple Range Test, p = .10

Field 1. Sandy loam texture, seeded 6/13/96. Germinated with sprinklers, furrow irrigated. Preplant application of 51 lbs N/acre; 42 lbs N/acre (AN-20) applied through sprinklers. Three sidedress applications of a total of 241 lbs N/acre, mostly UN-32. Late season water-run application of AN-20 at 39 lbs N/acre. First harvest 8/19/96. Soil NO_3-N at first sidedressing = 36 ppm.

Field 2. Loam texture, seeded 8/15/96. Germinated with sprinklers, furrow irrigated. Preplant application of 68 lbs N/acre; 40 lb N/acre (AN-20) applied through sprinklers. Two sidedress applications (UN-32) of a total of 206 lbs N/acre. Harvested 11/26/96. Soil NO_3-N at first sidedressing = 47 ppm.

Table 4. Response of cauliflower to varying nitrogen regimes.

	N Treatment	Total N (lb/acre)	% of plants: 9's	12's	16's	Small	Average head wt. (lb)
Field 1	grower practice	284	9	47	23	22	2.2
	skip sidedress 1	184	9	59	13	19	2.2
	skip sidedress 1 and 2	84	7	52	20	21	2.2
			ns	ns	ns	ns	ns
Field 2	grower practice	405	4	38	39	19	1.8
	skip sidedress 1	333	2	40	31	26	1.6
	skip sidedress 1 and 2	262	1	32	41	27	1.3
			ns	ns	ns	ns	

[ns] treatment means not significantly different at p = .10

[*] grower practice and no sidedress treatment means significantly different at p = .10 by orthogonal contrast

[z] sized by standard commercial categories, in head count per 30 lb net wt. box

Field 1. Loam texture, transplanted 7/5/96. Sprinkled in, furrow irrigated. 42 lbs N/acre preplant, 42 lbs N/acre (AN-20) applied through sprinklers. Two sidedressings of UN-32 at 100 lbs N/acre each. First harvest 9/3/96. Soil NO_3-N at first sidedress = 18 ppm.

Field 2. Sandy loam texture, transplanted 5/17/96. Sprinkled in, furrow irrigated. Preplant application of 82 lbs N/acre, 42 lbs N/acre applied through sprinklers. Three sidedressings of a total of 239 lbs N/acre; late season water-run application of AN-20 at 42 lbs N/acre. First harvest 7/17/96. Soil NO_3-N at first sidedress = 30 ppm.

D-040061

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

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INTRODUCTION

Declining profitability in food and feed grains in the 1980s stimulated an interest in alternative crops, such as fresh vegetables in the southern San Joaquin Valley. As growers sought to diversify their production base and capitalize on rising consumer demand for vegetables, broccoli acreage and value began to increase. In 1980 less than 1000 acres of broccoli was reported for the valley in local county agricultural commissioner reports, but by 1994 nearly 10,000 acres were in broccoli production. Broccoli is a cool-season vegetable that grows well year round in California's coastal valleys, but the weather conditions in the interior valleys are more extreme and severely affect produce quality and yields.

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

Broccoli is a crop that can create a high potential for nitrate leaching losses because it requires high N inputs, tends to be irrigated frequently, has a relatively shallow root system, and is a high value crop. There is also a tendency to add excess nitrogen since it is apparently not harmed by excessive nitrogen. Although several broccoli field research projects have been conducted over the years in California to investigate fertilizer timing and amounts, only a few have been grower directed and none have investigated the movement of nitrate from nitrogen fertilizer applications performed under San Joaquin Valley growing conditions.

OBJECTIVES

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

DESCRIPTION

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

Data measurements include sampling petioles and whole plants at key stages of broccoli production: thinning, rapid vegetative growth, button formation, preharvest, and postharvest. Samples are subject to laboratory analysis and nitrate quick testing. Results from the lab are correlated to the quick test. Soils sampled to a depth of 60 inches (150 cm) are collected before planting and at harvest and sent to the lab for nitrate analysis. Ion exchange resin bags are buried at two depths (18"/45 cm and 36"/90 cm) prior to seeding and removed after harvest to investigate nitrate movement through the soil profile. Yield and quality characteristics are also assessed.

Three of four proposed broccoli field tests have been planted and harvested at the UC West Side Research and Extension Center. Preliminary results from the first field study harvested in spring 1996 were summarized in last year's FREP Conference Proceedings. A complete report is now available. Data from the second spring field test (spring 1997) is still being analyzed and summarized, and is not ready for comparison. This report focuses on the fall harvested broccoli crop and presents results from the first of two field tests (fall 1996). The second test is scheduled to plant in early August and harvest in fall 1997.

1996 Fall Broccoli Field Study: A fall broccoli study was direct seeded on August 23, 1996, and harvested on December 15 (115 days after seeding). The thirteen nitrogen treatments using preplant, single, and double sidedress applications are outlined in Table 1 along with the soil and plant sample timings.

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

Broccoli petiole samples were collected four times throughout the growing season. Fresh petiole sap was tested for nitrate with the Cardy ion meter, and dry petiole samples were sent to the UC DANR Lab for nitrate content analysis.

Table 1. 1996 Fall Broccoli x Nitrogen Best Management, Planted August 23, 1996

Code	Nitrogen Fertilizer Treatments				Soil Samples preplant 8/16/96 postharvest: 2/18/97	IER Bags buried: 8/19/96 excavated: 2/27/96	Petioles T1: 9/18/26 T2: 10/7/96 T3: 10/27/96 T4: 11/23/96	Whole Plant T1: 9/19/26 T2: 10/7/96 T3: 10/27/96 T4: 11/23/96	Yield 12/16/96
	Preplant 8/21/96	Sidedress #1 9/23/96	Sidedress #2 10/9/96	Total (lbs N/acre)	x	x	x	x	x
	0	0	0	0	x	x	x	x	x
	15	15	30	60	x	x	x	x	x
	30	30	60	120	x	x	x	x	x
	45	45	90	180	x	x	x	x	x
	60	60	120	240	x	x	x	x	x
	75	75	150	300	x	x	x	x	x
	30	30	0	60	x	x	x	x	x
8	45	45	0	90					
9	60	60	0	120	x	x	x	x	x
10	75	75	0	150					
11	90	90	0	180	x	x	x	x	x
12	240	0	0	240	x	x	x	x	x
13	0	240		240	x	x	x	x	x

RESULTS AND DISCUSSION

Substantial new information on nitrogen utilization and fertilization of broccoli in the San Joaquin Valley has been obtained in this experiment. Due to adequate nitrogen depletion in the soil before the trial began, it was possible to observe the effects of a wide range of nitrogen availabilities to fall harvested broccoli. Overall, the effects of nitrogen stress were: delayed head development (Table 2), decreased weight per head, but not number of heads per plant, and decreased yield (approximately 40 percent lower in the non-fertilized plot compared to the highest yielding plot, Table 3). Similar results were obtained in last year's spring harvested broccoli crop.

In terms of total seasonal nitrogen application, including two sidedressings, yields were statistically similar at application rates between 180 and 300 lbs N/acre, despite higher numerical yields at the highest application amount. Application of preplant nitrogen also played a role with these total nitrogen rates. Rates of 45 to 90 lbs/acre applied preplant produced maximum yield, while 240 lbs/acre preplant or as an early sidedress led to a slight yield reduction. In all cases higher yields or equally high yields were obtained in a single sidedress application than in two sidedress applications. In these instances decent yields were obtained with as little as 60 to 150 lbs N/acre. Further work will provide more information on optimizing scheduling and amounts of nitrogen for broccoli in this area.

A useful indicator for sufficient nitrogen application was dry petiole nitrate nitrogen (Table 4). Higher values were observed in treatments with more than 120 lbs N/acre as were values for harvestable yield. Like yield, dry petiole nitrogen showed little response to the higher nitrogen application rates (except when a very large amount was applied as a sidedressing). Readings of nitrate concentrations in the fresh petiole sap made with the handheld Cardy meter showed similar trends (Table 5).

In a previous field study evaluating spring harvested broccoli, substantial nitrate appears to have been leached below the root zone in all but the lowest N application

Table 2. Head Development of Broccoli 1996 Fall Broccoli x N Rate and Timing
Planted: Aug 23, 1996 Harvested: Dec. 16, 1996 • Sidedress #1: Sept. 23, 1996 Sidedress #2: Oct. 9, 1996

Days after seeding								89			96			105
Date								Nov. 20			Nov. 27			Dec. 6
Code	Nitrogen Lbs/Acre													
	P	+	S1	+	S2	=	T*	Head diameters estimated in inches						
1	0	+	0	+	0	=	**0**	3/4-15/8	(1.19)**	d	11/2-25/8	(2.06)	d	21/2-3
2	15	+	15	+	30	=	**60**	3/8-11/8	(1.81)	c	2-31/5	(2.75)	cd	31/2-4
3	30	+	30	+	60	=	**120**	11/8-23/4	(1.94)	bc	25/8-41/4	(3.44)	abc	31/2-5
4	45	+	45	+	90	=	**180**	15/8-23/4	(2.19)	abc	23/4-43/8	(3.56)	ab	31/2-5
5	60	+	60	+	120	=	**240**	11/4-31/8	(2.19)	abc	27/8-47/8	(3.88)	ab	31/2-5
6	75	+	75	+	150	=	**300**	11/2-3	(2.25)	abc	3-43/4	(3.88)	ab	5-6
7	30	+	30	+	0	=	**60**	11/2-27/8	(2.19)	abc	21/8-41/2	(3.13)	abc	11/2-4
								11/2-27/8	(2.19)	abc	21/4-41/2	(3.19)	bc	31/2-4
9	60	+	60	+	0	=	**120**	13/4-31/4	(2.50)	a	21/2-43/4	(3.63)	ab	31/2-5
								21/8-3	(2.56)	a	3-47/8	(3.94)	a	4-6
11	90	+	90	+	0	=	**180**	11/4-27/8	(2.06)	abc	23/8-4	(3.19)	bc	31/2-51/2
12	240	+	0	+	0	=	**240**	17/8-3	(2.44)	ab	23/4-43/8	(3.56)	ab	2-5
13	0	+	240	+	0	=	**240**	13/8-23/4	(2.06)	abc	21/4-33/8	(2.81)	c	21/2-5

* Preplant + Sidedress 1 + Sidedress 2 = Total Lbs N/Acre

** Mean separation based on the average of the diameter range rates. Leached nitrate, as estimated by trapping nitrate nitrogen in ion exchange resin bags at 90 cm (below the main rooting zone of broccoli), increased to more than 200 lbs N/acre at application rates above 60 lbs N/acre. There was a tendency toward greater leaching with higher nitrogen application, but the data were not significant statistically. Data from deep soil cores at preplant and harvest tended to corroborate greater accumulation of nitrate deep in the profile in treatments with high nitrogen application.

In the fall harvested broccoli crop, lesser amounts of nitrate appear to have been leached below the root zone (Table 6). The two highest nitrogen applications of 240 lbs preplant and 300 lbs total tended toward greater leaching. All other treatments were significantly lower, and many were no different than from the check plot with no added nitrogen fertilizer.

By taking a systems approach to evaluate crop performance as well as soil nitrogen fates and losses, this study has shown that best management practices for fertilizer scheduling must consider the relative benefits of adding excess fertilizer as well as the relative costs of leaching nitrate. Further work will clarify these relationships at other times of the year and in different seasons.

Table 3. Yield Results 1996 Fall Broccoli x N-Rate and Timing
Planted: Aug. 23, 1996 Harvested: Dec. 16, 1996 • Sidedress #1: Sept. 23, 1996 Sidedress #2: Oct. 9, 1996

Code	Nitrogen Lbs/Acre							Tons/Acre		Lbs/Head		Heads/Plot	
	P	+	S1	+	S2	=	T*						
1	0	+	0	+	0	=	**0**	47	e	0.31	d	35	a
2	15	+	15	+	30	=	**60**	5.7	d	0.37	cd	35	a
3	30	+	30	+	60	=	**120**	6.1	cd	0.42	abc	34.5	a
4	45	+	45	+	90	=	**180**	7.1	ab	0.45	abc	36	a
5	60	+	60	+	120	=	**240**	7.0	ab	0.45	abc	35.75	a
6	75	+	75	+	150	=	**300**	7.9	a	0.49	a	36.25	a
7	30	+	30	+	0	=	**60**	6.6	bcd	0.41	bc	37	a
8	45	+	45	+	0	=	**90**	6.8	bc	0.44	abc	36	a
9	60	+	60	+	0	=	**120**	6.9	bc	0.41	bc	38.25	a
10	75	+	75	+	0	=	**150**	6.7	bc	0.43	abc	35.5	a
11	90	+	90	+	0	=	**180**	7.2	ab	0.45	ab	36.25	a
12	240	+	0	+	0	=	**240**	6.8	bc	0.44	abc	35.25	a
13	0	+	240	+	0	=	**240**	6.9	bc	0.41	bc	38.00	a
	Average							**6.6**		**0.42**		**36.06**	
	LSD .05							0.9		0.08		6.56	
	CV%							9.7		12.54		12.68	

* Preplant + Sidedress 1 + Sidedress 2 = Total Lbs N/Acre

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Table 4. Dry Petioles NO3-N ppm (lab analysis) 1996 Fall Broccoli x N-Rate and Timing
Planted: Aug. 23, 1996 Harvested: Dec. 16, 1996 • Sidedress #1: Sept. 23, 1996 Sidedress #2: Oct. 9, 1996

Code	Nitrogen Lbs/Acre							9/18/96 3-6 True Leaves	10/7/96 7-8 True Leaves	10/27/96 15-16 True Leaves	11/22/96 1-2" Head Diameter
	P	+	S1	+	S2	=	T*				
1	0	+	0	+	0	=	**0**	9870 d	10450 c	5605 b	815 f
2	15	+	15	+	30	=	**60**	13620 bc	17350 b	8955 a	1508 ef
3	30	+	30	+	60	=	**120**	14030 bc	18350 ab	8168 a	2623 cde
4	45	+	45	+	90	=	**180**	15800 ab	21130 ab	8595 a	4175 ab
5	60	+	60	+	120	=	**240**	18080 a	20380 ab	9458 a	4850 a
6	75	+	75	+	150	=	**300**	18000 a	22130 ab	10330 a	4353 ab
7	30	+	30	+	0	=	**60**	15850 ab	20950 ab	8800 a	2003 def
9	60	+	60	+	0	=	**120**	18030 a	22050 ab	9055 a	3050 bcd
11	90	+	90	+	0	=	**180**	16930 ab	22480 ab	8825 a	3630 abc
12	240	+	0	+	0	=	**240**	18730 a	23200 a	9683 a	4600 a
13	0	+	240	+	0	=	**240**	11530 cd	22100 ab	9955 a	4348 ab
			Average					**15497**	**20052**	**8857**	**3269**
			LSD .05					3621	5599	2513	1378
			CV%					16.118	19.34	19.65	29.2

* Preplant + Sidedress 1 + Sidedress 2 = Total Lbs N/Acre

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Table 5. Petiole Sap NO_3-N ppm (Cardy Meter NO_3- X 226) 1996 Fall Broccoli x N-Rate and Timing
Planted: Aug. 23, 1996 Harvested: Dec. 16, 1996 • Sidedress #1 Sept. 23, 1996 Sidedress #2 Oct. 9, 1996

Code	Nitrogen Lbs/Acre				9/18/96 3-6 True Leaves			10/7/96 7-8 True Leaves			10/27/96 15-16 True Leaves			11/22/96 1-2" Head Diameter		
	P +	S1 +	S2 =	T*	meter 1	meter 2	mean 1&2	meter 1	meter 2	mean 1&2	meter 1	meter 2	mean 1&2	meter 1	meter 2	mean 1&2
1	0 +	0 +	0 =	**0**	2325	2150	2238	2650	2700	2675	1175	1150	1163	520	528	524
2	15 +	15 +	30 =	**60**	2950	2750	2850	2100	1825	1963	1300	1350	1325	548	535	541
3	30 +	30 +	60 =	**120**	3125	2875	3000	2425	2125	2275	1425	1424	1425	895	888	891
4	45 +	45 +	90 =	**180**	3425	3075	3250	2550	2250	2400	1350	1325	1338	938	933	935
5	60 +	60 +	120 =	**240**	3775	3475	3625	2575	2175	2375	1475	1475	1475	1078	798	938
6	75 +	75 +	150 =	**300**	3975	3475	3725	2375	2125	2250	1550	1550	1550	850	1075	963
7	30 +	30 +	0 =	**60**	3225	3150	3338	2650	2300	2475	1500	1450	1475	633	628	630
9	60 +	60 +	0 =	**120**	3750	3300	3525	2675	2325	2500	1450	1525	1488	768	768	768
11	90 +	90 +	0 =	**180**	3850	3450	3650	2575	2225	2400	1500	1425	1463	980	963	971
12	240 +	0 +	0 =	**240**	3875	3500	3688	2900	2475	2688	1625	1650	1638	1175	1125	1150
13	0 +	240 +	0 =	**240**	2975	2625	2800	2875	2450	2663	1525	1525	1525	1175	**1125**	**1150**
	Average				**3052**	**2759**	**2906**	**2361**	**2077**	**2219**	**1302**	**1300**	**1301**	**792**	**753**	**773**
	LSD .05				613.1	570.3	588.5	595.3	1078	789.3	162	180.5	163.6	263.1	266.6	217.8
	CV%				12.44	12.85	12.56	15.99	32.89	22.55	7.78	8.67	7.85	20.97	21.69	17.54

* Preplant + Sidedress 1 + Sidedress 2 = Total Lbs N/Acre

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ONGOING PROJECTS

Table 6: Ion Exchange Resin Bags: NO_3-N Content 1996 Fall Broccoli X N Rate and Timing
Planted: Aug 23, 1996, Harvested: Dec 16, 1996, Sidedress #1 Sept 23, 1996 Sidedress #2 Oct 9 1996

Code	Nitrogen Lbs/Acre	45 cm depth ppm		45 cm depth Kg/ha		45 cm depth Lbs/acre		90 cm depth ppm		90 cm depth Kg/ha		90 cm depth Lbs/acre	
	P + S1 + S2 = T*												
1	0 + 0 + 0 = **0**	4.68	e	4.07	e	4.56	e	29.48	c	26.64	c	28.71	c
2	15 + 15 + 30 = **60**	14.22	de	12.36	de	13.84	de	34.47	bc	29.98	bc	33.57	bc
3	30 + 30 + 60 = **120**	45.43	cde	39.51	cde	44.25	cde	30.78	c	26.76	c	29.98	c
4	45 + 45 + 90 = **180**	71.88	bc	62.50	bc	70.01	bc	44.94	bc	39.08	bc	43.77	bc
5	60 + 60 + 120 = **240**	75.12	bc	65.32	bc	73.16	bc	42.77	bc	37.19	bc	41.66	bc
6	75 + 75 + 150 = **300**	112.50	b	97.79	b	109.50	b	77.64	ab	67.52	ab	75.62	ab
7	30 + 30 + 0 = **60**	38.06	cde	33.10	cde	37.07	cde	12.41	c	10.79	c	12.09	c
9	60 + 60 + 0 = **120**	80.18	bc	69.72	bc	78.09	bc	31.01	c	26.97	c	30.20	c
11	90 + 90 + 0 = **180**	68.53	bcd	59.59	bcd	66.74	bcd	30.13	c	26.21	c	29.35	c
12	240 + 0 + 0 = **240**	258.00	a	224.40	a	251.30	a	122.10	a	106.20	a	118.90	a
13	0 + 240 + 0 = **240**	76.73	bc	66.73	bc	74.73	bc	51.42	bc	44.71	bc	50.08	bc
	Average	**76.85**		**66.83**		**74.84**		**46.10**		**40.19**		**44.90**	
	LSD .05	56.16		48.84		54.70		44.63		38.81		43.47	
	CV%	50.61		50.61		50.61		67.03		67.03		67.03	

*Preplant + Sidedress 1 + Sidedress 2 = Total Lbs N/Acre

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

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INTRODUCTION

Solid-set sprinkler irrigation and fertigation using hand-move pipe is the most common irrigation system for production of high value vegetable crops in California. The most common design uses 30 foot lengths of pipe with 2 foot sprinkler risers set up in laterals with a 40 to 48 foot spacing. The average distribution uniformity (DU) of 65 Mobile Lab Irrigation evaluations in Kern County from 1988 to 1993 for a variety of spacings was found to be 65.5%. This level of uniformity, coupled with high N fertilizer applications, poses risks of nitrate leaching to groundwater in these shallow-rooted cropping systems.

Other laboratory and field work suggest that decreasing lateral spacing to 35 feet could boost DU to 80 to 90%, but this means increased capital cost to the grower for additional pipe. This study was designed to assess the benefits of narrower spacings on improving yield, irrigation uniformity and reducing nitrate leaching.

OBJECTIVES

To evaluate the effectiveness of standard and alternative sprinkler lateral spacing on water and N fertilizer use efficiency, crop yield, and crop quality. This data is then to be used to field calibrate a computer model adapted to assess water and N fertilizer management under various sprinkler lateral spacings.

DESCRIPTION

1996 Field Trial: In the west 60 acres of a 100 acre carrot field planted on 1/29/96 in 40" beds and harvested 6/4/96, solid-set sprinkler laterals were set up to test the efficiency of irrigation and nitrogen utilization for three different spacings. Groups of four laterals spaced at 10 beds (33.3'), 12 beds (40.0'), and 14 beds (46.7') were randomized and replicated 3 times across the field.

Nitrogen as UN-32 was applied at 120 lbs/acre preplant and an additional 120 lbs/acre applied through the sprinklers during the season.

One intensively sampled grid with each node consisting of 2 beds wide by 5' long was established between sprinklers in each of the spacings. Soil samples, irrigation catchcan evaluations, and hand-harvested yields were determined for these grids to better understand the pattern of precipitation and yield under the different spacings. This required 30 to 42 sample points depending on lateral spacing. In addition to these grids, five replicated sites measuring yield, soil water content, precipitation, and nitrate leaching were established at 3 locations in each lateral spacing in an attempt to sample the spots of high, medium, and low precipitation. Anion exchange resin bags were installed at 3' and retrieved three times during the season to monitor nitrate leaching.

1997 Field Trials:

1. A 32 acre demonstration field planted to carrots on 36" beds 3/16/97 and harvested 6/27/97 was set up with one set of 20 laterals spaced at 42' and the second set spaced at 48'. Replicated monitoring was done as listed above for each set but spacings were not replicated across the field. Four laterals were set up on a 36' spacing for evaluation of DU only.

2. The same field and experimental design as in 1996 will be repeated starting mid August.

RESULTS AND DISCUSSION

Irrigation Uniformity: Sprinkler distribution uniformity (DU) was determined with catchcans eight times for the 33.3' spacing, six times for the 40.0' and seven times for the 46.7' spacing. Precipitation for each grid element (2 beds wide by 5' in length) was normalized as a percent of the average depth of applied water for that irrigation. Mean normalized DU for the season was found to be 84.1, 81.6, and 89.9 for the 33.3', 40.0' and 46.7' spacing, respectively (Table 1 and Fig. 1). That the 46.7' lateral spacing achieved the best DU is in contrast to most other field evaluations of solid-set sprinkler systems. The fundamental difference between this and most current evaluation techniques is that we measured DU throughout the duration of the irrigation event (8 to 12 hours) with 30 to 42 catchcans depending on spacing, and the measurements were repeated several times in the same location during the growing season. In contrast, most field evaluations measure precipitation only 1 to 3 hours during an irrigation event. Twenty-one separate evaluations over the season provide a high degree of confidence for these findings. The pipe and sprinklers in this trial were either new or had less than 300 hours of use.

Preliminary data from 1997 gave more expected results with DU's from evaluations in May at 70.6, 84.6, and 66.0% for the 36', 40', and 48' spacings, respectively. (Table 1 and Fig. 3). Nozzle pressures varied from 62 to 72 psi between sets due to changes in irrigators checking the field. Excessive atomization at pressures greater than 65 psi contributed to lower uniformities in the 36' and 48' spacings. Sprinklers were at least two years old.

Yield and Quality: There were no significant differences in 1996 total carrot yield and quality among the three spacings for either the intensive grids (Table 1 and Fig. 2) or for the replicated locations between laterals. Neither

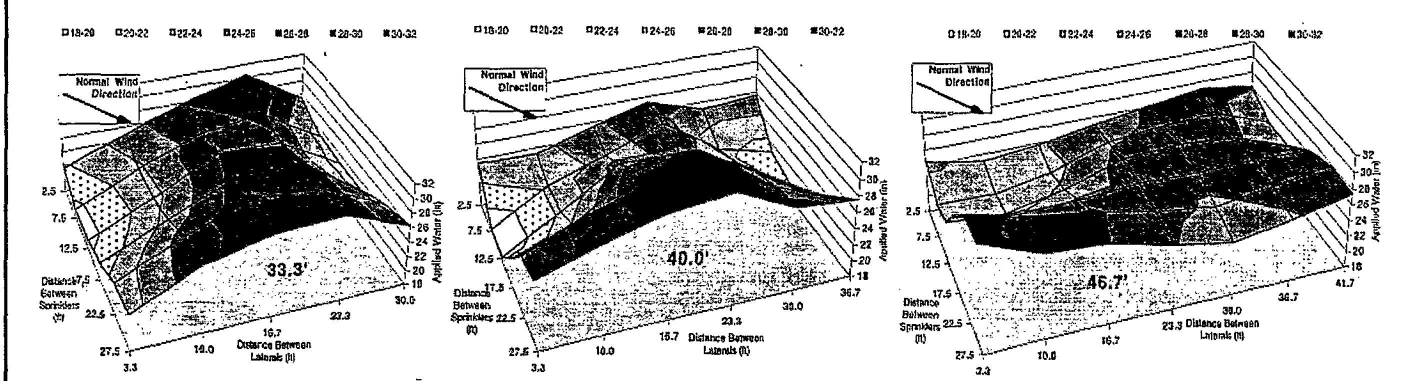

Figure 1. Surface plot of applied water for the entire season for all lateral spacings. Total applied water for each 5' by 6.7' (2 beds) grid element determined by normalized applied water from 6 to 8 sprinkler evaluations.

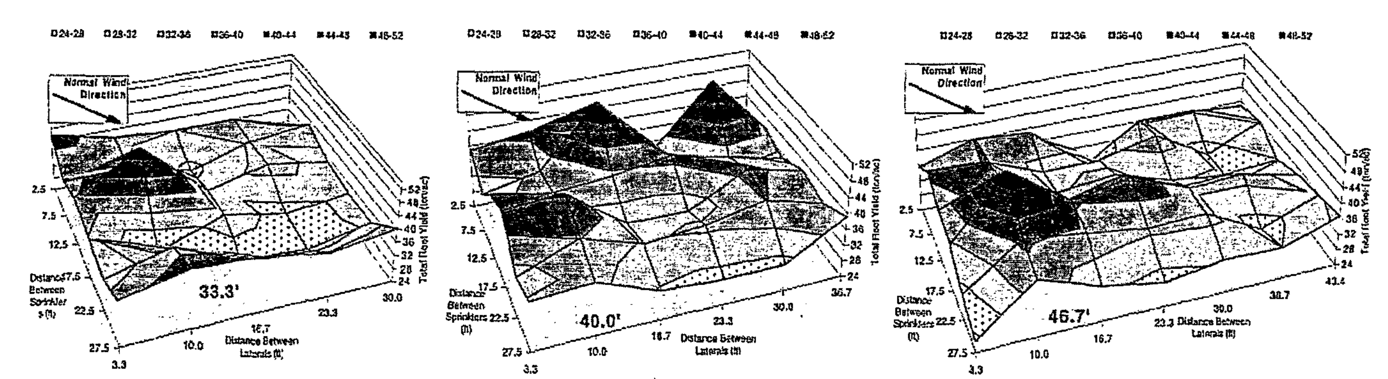

Figure 2. Surface plot of total root yield from intensively sampled grids corresponding to mean applied water shown in Fig. 1.

was any significant correlation found between applied water and final root yield in the intensive grids. In 1997, yields of 36.9 ton/acre for the 42.0' and 35.5 ton/acre for the 48.0' spacing show the same trend for the replicated locations even though there is a greater disparity in the irrigation DU of the two spacings. The intensive grids, however, showed a significantly greater yield of 38.8 ton/acre for the 42.0' spacing compared to 32.5 ton/acre for the 48.0'. This difference is likely anomalous as even the driest nodes in the grids received at least 80% of crop evapotranspiration (ET) over the season.

Water Use and Deep Percolation: Initiation of irrigation sets was determined by the Bolthouse irrigation foreman using only a shovel and assuming an application amount of 2". Only the duration of the irrigation set was provided by the researchers to match the variable spacing. Deep percolation below the rootzone in 1996 can be seen by the increased water content in the 2.5' to 5' depths (Fig. 4). This increase (about 2.5") stabilized by April at a value consistent with the field capacity of this fine loamy sand. Continued deep percolation is estimated at 1.5" below 5' as crop ET was measured at 22.0" and applied water was about 26". This is an excellent standard of irrigation scheduling.

The mid-March planting date in 1997 required about 8" of water for germination due to warm temperatures and 3 to 12 mph winds. Most of this went to evaporation. Total applied water was about 30" with ET of this shorter season crop at 18.7". About 6" of water is estimated to have gone to deep percolation.

Nitrate Leaching and Computer Modeling: The resin-bag measured nitrate leaching during the growing season was 19.60, 12.56, 24.23 lbs/acre NO_3-N for the 33.3', 40.0' and 46.7' lateral spacings, respectively. The 40.0' spacing had significantly lower ($p<0.05$) nitrate leaching. With

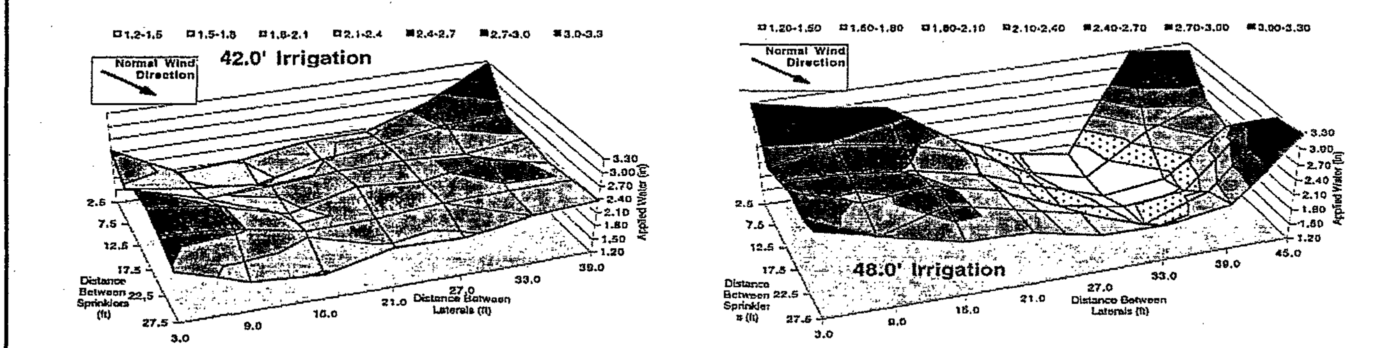

Figure 3. Surface plot of applied water for 42' lateral spaing (5/6/97, DU = 84.6%) and 48' lateral spacing (5/7/97, DU = 66.0%).

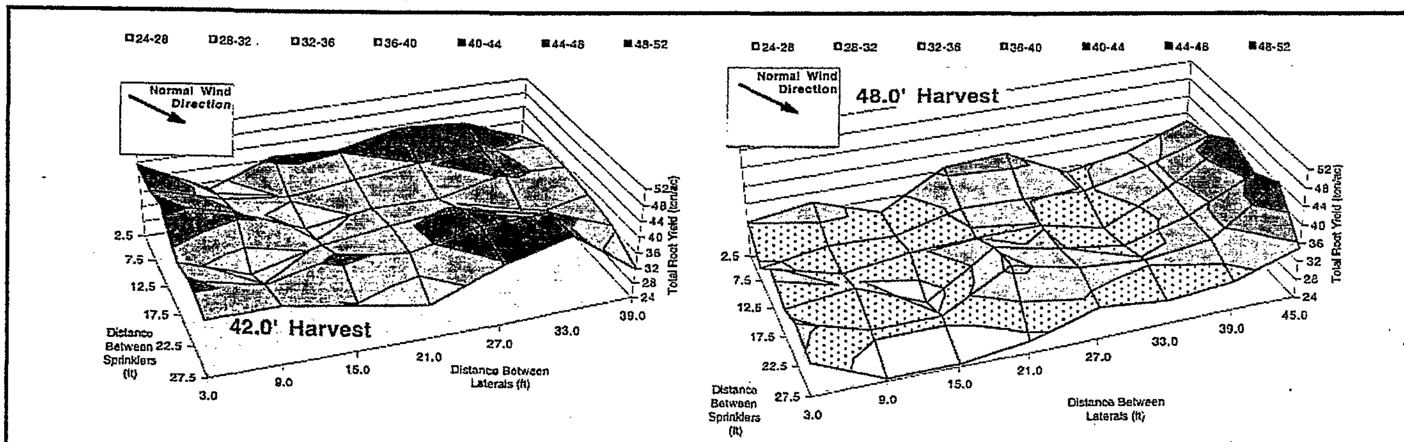

Figure 4. Surface plot of total root yield from intensively sampled grids corresponding to applied water shown in Fig. 3. Harvested 6/27/97.

almost the same amount of applied irrigation water on each of the lateral spacings, the difference must be attributed to the variability of soil hydraulic properties at the sampling sites within treatments. Our simulation model reveals that nonuniform leaching could happen in a spatially variable soil even though the DU is 100%. This data is not yet available from the 1997 trial.

A column study using the 1996 field soil revealed an average recovery of 84.3% of leached NO_3-N with the resin bags at roughly equivalent rates of fertilizer applied to the field. Thus the estimated nitrate leaching in the carrot field may range from 14.9 to 28.7 lbs/acre NO_3-N. This represents 6 to 12% of the nitrogen applied to the field, which is an excellent standard for production agriculture, but may still pose a long-term threat to groundwater quality. That the most uniform spacing–46.7'–was also the one shown to have the greatest nitrate leaching, reveals that soil hydraulic variability may be more important in affecting nitrate losses to groundwater than the uniformity of the irrigation system. Since mean DU's from this study were greater than 80% this is a reasonable assumption. There is, however, most likely a lower threshold at which irrigation system DU is of greater importance than soil variability.

CONCLUSION

Significant differences in irrigation uniformity for varying sprinkler lateral spacings were verified in the field. The 1996 trial revealed the widest spacing (46.7') to be the most uniform, while the 1997 spring trial showed a 48.0' lateral spacing to have the worst uniformity, which is the expected result. Of all lateral spacings, a 40' to 42' spacing provided the most consistent performance (DU's of 78 to 85%). This spacing also produced the lowest estimate of leached nitrate. However, total yield or quality was found to be unaffected by spacing as the

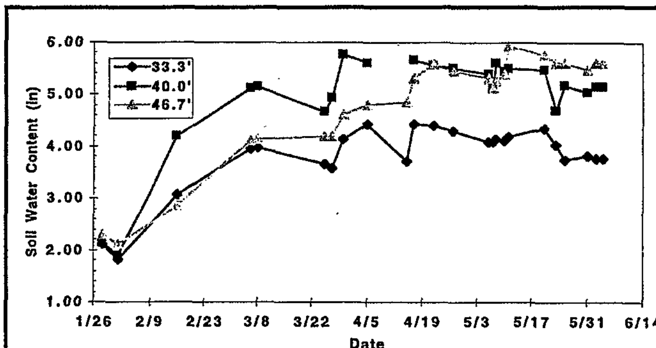

Figure 5. Total water content change by lateral spacing below the rootzone (2.5' to 5.0 'depth).

Table 1. Typical irrigation set times, sprinkler and root yield distribution uniformity (DU) characteristics for intensively sampled grids under varying sprinkler lateral spacings.

	Lateral Spacing (feet)	Typical Irrigation Set Time (inches)	Applied Water per set (inches)	Total Irrigation for Season plots (ton/acre)	Mean root yield for gridded DU (%)	Mean normalized sprinkler	Yield DU (%)	R2 for mean sprinkler and yield DU
1996 Trial	33.3	8.5	2.21	25.62	35.95	84.1	84.3	0.047
	40.0	10	2.16	25.63	37.35	81.6	81.5	0.114
	46.7	1	2.23	26.08	36.03	89.9*	85.4	0.073
1997 Trial*	42.0	10	2.41	30.90	38.8**	84.6	89.3	0.054
	48.0	12	2.64	29.10	32.48	66.0	85.2	0.042

*Irrigation data from single evaluation 5/6 and 7/97.
** Significant at 0.05.
***R2 values are for a second order polynomial regression of a grided plot yield and the normalized seasonal applied irrigation for that grid element and spacing.

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driest parts of all precipitation patterns received at least 80% of ET. The 1996 findings are in contrast to other studies estimating uniformity in solid set sprinklers and require a new assessment of present protocols for evaluating sprinkler irrigation management and uniformity on water and nitrogen fertilizer use efficiency.

The role of pressure, optimal droplet size, nozzle wear, and diurnal and seasonal fluctuations in wind speed and direction are as critical as lateral spacing, as evidenced by results from the 1997 trial. For accurate assessments of seasonal uniformity, the number of catchcans and duration of catch needs to be increased over present production practice.

Further data analysis of soil samples for nitrate and hydraulic properties and plant growth data will be used to field calibrate the computer model. This trial suggests that these factors may have the greatest impact on nitrate leaching under sprinkler irrigation systems with DU's greater than 70%, regardless of lateral spacing. Coupled with the ability to simulate soils with spatially variable properties, the final model should be a powerful tool to extend our findings from this research to other vegetable cropping systems.

EVALUATION OF CONTROLLED RELEASE FERTILIZERS AND FERTIGATION IN STRAWBERRIES AND VEGETABLES

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OBJECTIVES

The primary objective of this project is to explore research, field demonstrations and educational elements for the nutrient management of strawberries and vegetables.

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

STRAWBERRY PROCEDURES

A fertilizer trial was established in a commercial strawberry field southeast of Santa Maria. The field had been planted to strawberries for several years. The trial area received the same fertigation program as the commercial field.

The preplant fertilizer treatments were applied on October 12, 1995 to compare three controlled release fertilizers, a standard fertilizer, and no fertilizer. The controlled release fertilizers were compared at 2 rates, 80 and 160 pounds of nitrogen per acre. The fertilizers were placed 5" below the bed surface and 2" to the side of the plants. Each fertilizer treatment was replicated four times in a randomized block design with each plot 25 feet long and one 64" wide bed.

The variety Camarosa was planted on Oct. 25, 1995. The nursery plants were dug on Oct. 22, 1995 on the high elevation Lassen Canyon McArthur Nursery. Each bed had four rows of strawberries spaced 10" apart. The plants were spaced 16" apart within each row. The soil type is a Sorrento sandy loam. The fertilizer trial received the same irrigation, pest control, and picking schedule as the commercial field.

The spring rains delayed the first harvest until March 17, 1996. During April, May, and June, the trial was harvested on a 3 or 4 day schedule and irrigated after each picking. The last fresh fruit harvest was on July 4, 1996. The trial was harvested for freezer fruit from July 10 to August 8, 1996.

The strawberries were harvested by the growers commercial strawberry pickers. The fresh and freezer yields are based on the high commercial standards for the growers saleable fruit. The yields are the average of the four replications from each of the plots 25' long and 64" wide beds.

The growers fertigation program applied a total of 180 lbs of nitrogen per acre to the commercial field and the trial area. This fertigation program included an average of 0.7 lbs. of nitrogen per day during February and March.

Soil samples were collected on May 20th and July 16, 1996 from a depth of 0"-3", 3"-6", 6"-9", 9"-12" and at 6" increments from 12"-48".

RESULTS

The strawberry yields are shown in Table 1. There are non-significant differences between strawberry yields of the 3 controlled release fertilizers. The controlled release fertilizers with 160 lbs. of nitrogen per acre produced significantly higher strawberry yields than the plots with 80 lbs. of nitrogen. The yields are very high for this area indicting a good production management program.

The standard commercial fertilizer at 160 lbs. of nitrogen produced yields similar to the 80 lbs. per acre rates of controlled release fertilizers.

The plots receiving nitrogen only through the drip tape (no pre-plant N) produced lower yields than the plots receiving preplant sidedress fertilizer applications.

The petiole NO_3-N showed non-significant differences between the fertilizer treatments.

Supplying adequate fertilizer for early crown, root and top growth appears to be an important advantage of the preplant fertilizer practices.

The nitrogen fertigation rate is high, however, not untypical of some strawberry fields fertilized with pre-plant non-controlled release fertilizers

There were non significant differences between fertilizer treatments in NO_3-N and ECe concentration from the soil samples collected in May and July. The samples ranged from 1.1-12.0 ppm - NO_3-N and 1.2 -3.9 ECe of the soil solution.

Table 1. 1996 Strawberry Fruit Yields with Three Fertilizer Rates and Three Control Release Fertilizers in Combination with Fertigation.

	Company	Fertilizer		N Preplant lbs/A	Fruit Yields* Fresh	Freezer	Season Total
1	Viridian Duration	24-8-15	urea	160	71,368 a	9,655 a	81,023 a
2	Scotts Agricote	22-7-11	urea	160	70,259 a	9,295 ab	79,553 a
3	Scotts Agriform	18-8-13	NH4NO3	160	69,744 a	9,172 ab	78,916 a
4	Viridian Duration	24-8-15	urea	80	65,804 b	8,672 ab	4,476 b
5	Scotts Agricote	22-7-11	urea	80	66,072 b	8,227 b	74,299 b
6	Scotts Agriform	18-8-13	NH4NO3	80	64,668 b	8,306 b	72,974 b
7	Growers Commercial	15-15-15		160	63,715 b	9,660 a	73,375 b
8	Control				56,747 c	8,618 ab	65,364 c
				CV%:	2.6%	7.4%	2.4%

*Duncan's multiple range test - Data numbers represented by the same letters are not significantly different at the 5% level.

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Figures 1, 2, and 3 show nitrate concentrations at various depths across the bed. Concentrations of the control treatment (Figure 1) were relatively uniform throughout the profile with values generally less than about 1.5 ppm. For the fertilizer treatments of 80 pounds per acre (Figure 2) and 160 pounds per acre (Figure 3), much higher concentrations were found in some areas of the soil profile. Near the surface, very high concentrations of 40 to 50 ppm occurred where the fertilizer bands were located. The band effect was not evident on the right side of Figure 3 which was the result of the interval used to sample the soil profile. Between 10 and 30 inches deep, relatively low concentrations were found. Values generally were less than about 1.5 ppm. However, below 30 inches, much higher nitrate concentrations occurred with values as high as 4 to 5 ppm.

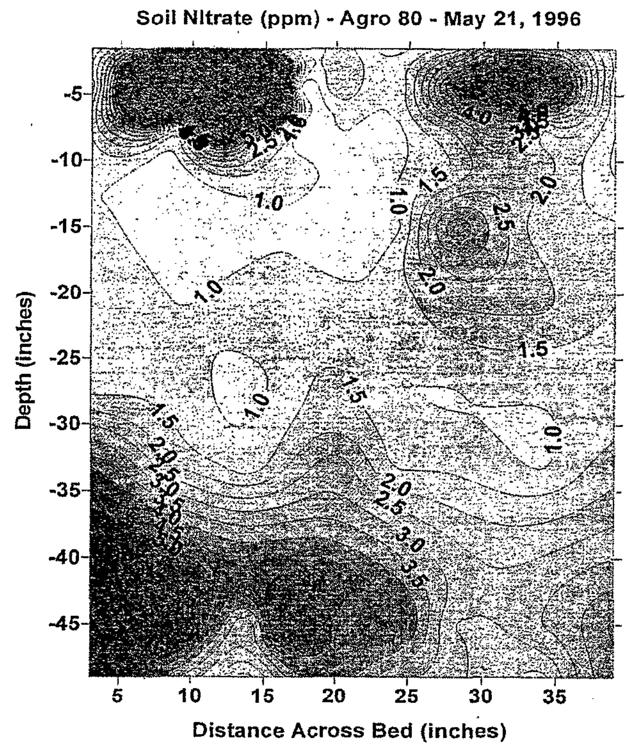

Figure 2. 80 pounds per acre.

CELERY

Santa Maria valley has been targeted as a nitrate sensitive area. Celery is a crop with a potential for high nitrate leaching because it requires relatively high N fertilization rate and frequent irrigations. It also has a shallow root system and is high-value crop.

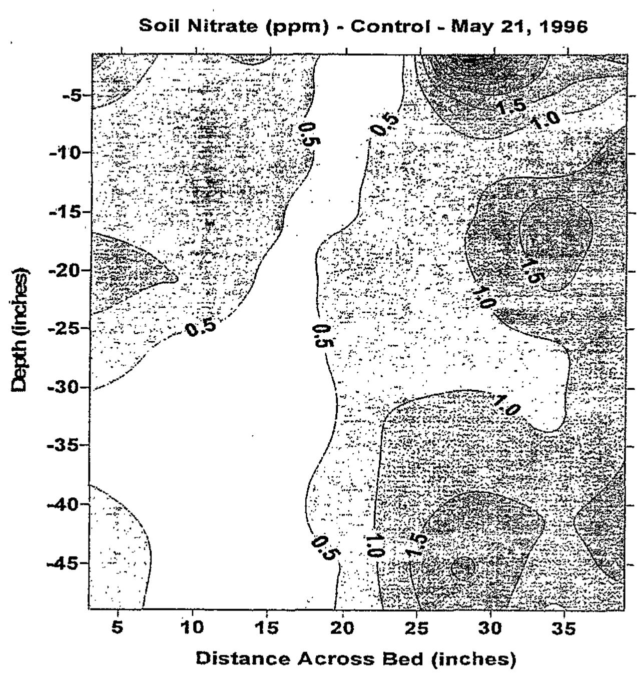

Figure 1. Control treatment.

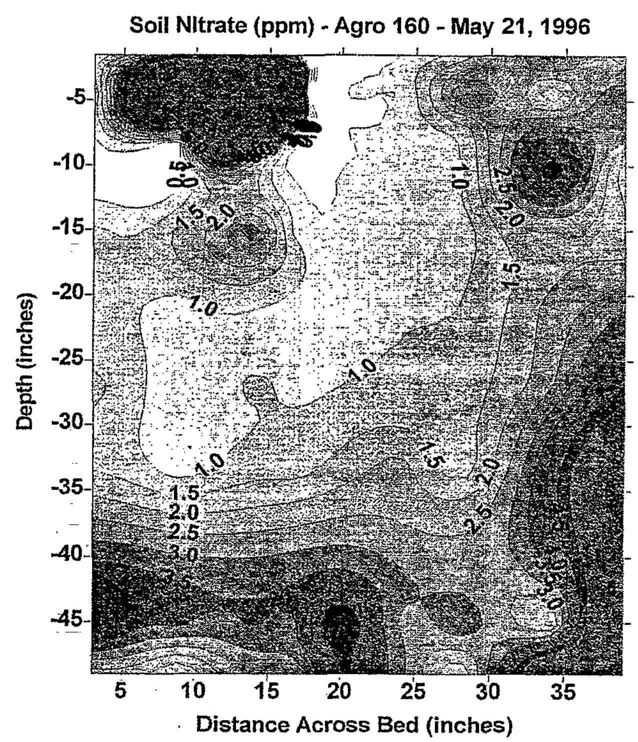

Figure 3. 160 pounds per acre.

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PROCEDURES

Two celery fertilizer trials were established in commercial celery fields west of Santa Maria. The fields had been cropped to vegetables for many years.

Each fertilizer treatment was replicated four times in a randomized block design with each plot 50 feet long and four beds wide. The two center beds, 25 feet long, were harvested for yield. Ten plants per plot were collected at random from the harvested boxes to evaluate the nutrients removed by the crop.

Petiole samples were collected during the growing season to compare nitrogen levels between treatments. The trials were harvested, graded for size, and boxed by the commercial harvest crews.

Ranch 2

A celery fertilizer trial was established on January 5, 1996 to compare 7 fertilizer treatments. Three controlled release fertilizers were applied pre-transplant at the rate of 125 and 250 pounds of nitrogen per acre. The plots with 125 pounds of nitrogen received an additional sidedress application of 100 pounds of nitrogen per acre.

The standard commercial fertilizer treatment received a pre-transplant application of 30 pounds of nitrogen per acre (6-20-20) and 3 sidedress applications for a total of 260 pounds of nitrogen per acre. All of the plots received a sprinkler application of 40 pounds of nitrogen per acre 14 days prior to harvest.

Prior to the fertilizer trial at the time the beds were established, all of the plots received 30 pounds of nitrogen and 100 pounds of phosphorous and potassium (3-10-10).

The variety, Conquistador, was transplanted on January 8, 1996. The trial was harvested on April 30, 1996.

Ranch 6

The second celery fertilizer trial was established on February 2, 1996 to compare 5 fertilizer treatments. Two controlled release fertilizers were applied pre-transplant at the rate of 80 and 160 pounds of nitrogen per acre. The plots with 80 pounds of nitrogen received an additional sidedress application of 80 pounds of nitrogen per acre. The standard commercial fertilizer treatment received a pre-transplant application of 30 pounds of nitrogen per acre (6-20-20) and sidedress applications of 8-8-8, for a total of 210 pounds of nitrogen per acre.

Table 2: Celery Yield and Size Distribution, Ranch 2

Fertilizer		Nitrogen Lbs/Acre	Yield Lbs/A	Size Distribution 24	30	30
				% of Stalks		
Duration	27-9-9	250	96,270 A	50.7 AB	47.9	1.4 B
Scotts 25	25-7-11	250	96,332 A	242455.0 A	40.5	4.0 B
Scotts 24	24-7-7	250	95,273 A	53.5 A	41.3	5.3 B
Duration	27-9-9	125	89,323 B	45.9 AB	44.6	9.6 B
Scotts 25	25-7-11	125	88,759 B	45.3 AB	48.4	6.3 B
Scotts 24	24-7-7	125	90,355 B	42.7 AB	47.1	10.2 B
Commercial		300	77,376 C	24.1 C	52.7	23.2 A
					NS	

Duncan Multiple Range Test - Data numbers represented by the same letters are not significantly different at the 5% level.
Size Distribution Data on size 30 values are not significantly different at the 5%

Fertigation applications of 30 pounds of nitrogen per acre were applied on May 1, 14, and 28, through the drip tape on all the plots.

All of the treatments received 2 tons/acre of chicken manure prior to bedding-up. During bedding-up, 21 pounds of nitrogen per acre was applied as 3-10-10. On March 30, 1996, the controlled release fertilizer treatments received a sidedress application of 90 pounds per acre of phosphorus and potassium as 0-8-8.

The variety, Conquistador, was transplanted on February 23, 1996. The trial was harvested on June 11, 1996. The soil type is a Corralitos loamy sand.

RESULTS

Ranch 2

The celery yields were high, ranging from 77,376 to 96,270 pounds per acre. Celery yields and stalk size is shown in Table 2. The celery yields were not significantly different between the three controlled release fertilizers. The three controlled release fertilizer treatments with 250 pounds of nitrogen produced significantly higher celery yields than the plots with 125 pounds of nitrogen. The standard commercial fertilizer plots produced the lowest yield and the smallest size stalks. During the early growth stages, the celery was smaller and a lighter green color in the commercial fertilizer plots.

The celery stalks were graded as 24, 30, and 36 stalks per box. The celery size distribution was the major factor affecting yields.

Nine nutrients were analyzed on the harvested plants. The analysis showed no statistical difference between treatments in the percent of nutrients. The percent nitrogen ranged from 2.725 in the Duration treatment of 250 pounds of nitrogen, to 2.350 percent for the standard commercial fertilizer.

The nine nutrients reported in pounds per acre removed in the harvested crop are shown in Table 4. The celery crop removed 86 to 124 pounds of nitrogen per acre. The pounds of nutrient removed, was affected more by the yield than the percent nutrients in the plant.

Table 6 shows the celery petiole NO_3-N levels for 4 sample dates. There are no significant differences between the various fertilizer treatments. Additional petiole samples collected near harvest on April 25, 1996 ranged from 6755 to 8218 ppm in NO_3-N with no statistical difference between treatments. The low values near harvest shows the plants are using most of the applied nitrogen.

Soil samples collected at harvest showed no significant difference between treatments in NO_3-N values. The NO_3-N values ranged from 9-17 ppm in the 0"-6" depth,

Table 3. Celery Yield and Size Distribution, Ranch 6

Fertilizer		Nitrogen Lbs/Acre	Yield Lbs/A	Size Distribution 18	24	30
				% of Stalks		
Duration	27-9-9	160	115,569 A	41	94	24
Scotts 24	24-7-7	160	114,916 A	36	100	22
Duration	27-9-9	80	108,011 BC	32	98	26
Scotts 24	24-7-7	80	109,049 B	35	87	31
Commercial		300	104,819 C	23	86	45
				NS	NS	NS

Duncan Multiple Range Test - Data numbers represented by the same letters are not significantly different at the 5% level.
Size Distribution Data values are not significantly different at the 5% level.

6-17 ppm in the 6"-12" depth, 6-17 ppm in the 6"-12" depth, 14-20 ppm in the 12"18" depth and 11-21 ppm in the 18"-24" depth.

Ranch 6

The celery yields on ranch 6 were higher than ranch 2. Celery yields and stalk size is shown in table 3. The yields ranged from 104,819 to 115,659 pounds per acre. The celery yields were not significantly different between

Table 4. Celery Nutrients Removed in Harvested Crop, Ranch 2

Fertilizer		N Lbs/A	N	P	K	Ca	Mg	Zn	Mn	Fe	Cu
			Nutrients Pounds/Acre								
Duration	27-9-9	250	124 A	37.5 A	298 A	72.5 A	16.5 A	.112	.294 A	.459 A	.018
Scotts 25	25-7-11	250	107 B	33.0 BC	283 AB	64.6 ABC	15.6 AB	.099	.181 B	.460 A	.017
Scotts 24	24-7-7	250	109 B	32.9 BC	282 AB	63.9 BC	15.1A B	.112	.147 C	.455 A	.017
Duration	27-9-9	125	106 B	31.7 BC	255 CD	60.9 BC	14.6 BC	.101	.153 BC	.426 B	.017
Scotts 25	25-7-11	125	102 B	34.1 AB	277 ABC	69.0 AB	15.2 AB	.101	.142 C	424 B	.018
Scotts 24	24-7-7	125	102 B	2.2 BC	265 BCD	67.0 AB	15.2 AB	.095	.165 BC	.431 B	.016
Commercial		300	86 C	29.3 C	252 D	58.4 C	13.3 C	.100	.017 D	.369 C	.017
								NS			NS

Duncan multiple Range Test - Data numbers represented by the same letter are not significantly different at the 5% level.
Data values for Zn and Cu are not significantly different at the 5% level.

Table 5. Celery Nutrients Removed in Harvested Crop, Ranch 6

Fertilizer		N Lbs/A	N	P	K	Ca	Mg	Zn	Mn	Fe	Cu
			Nutrients Pounds/Acre								
Duration	27-9-9	160	130 A	31.1 A	188 A	34.4	11.6	.306	.075 AB	.157 A	.014
Scotts 24	24-7-7	160	128 A	30.3 AB	184 A	35.6	11.8	.288	.082 A	.156 A	.015
Duration	27-9-9	80	121 AB	29.7 ABC	184 A	36.3	11.5	.360	.068 BC	.147 BC	.013
Scotts 24	24-7-7	80	119 AB	28.1 BC	175 AB	32.6	10.7	.371	.062 C	.148 B	.013
Commercial		300	110 B	27.0 C	166 B	31.0	10.7	.357	.052 D	.42 C	.011
						NS	NS	NS			NS

Duncan multiple Range Test - Data numbers represented by the same letter are not significantly different at the 5% level.
Data values for Ca, Mg, Zn and Cu are not significantly different at the 5% level.

D-040079

the two controlled release fertilizers. The two controlled release fertilizers at 160 pounds per acre produced significantly higher celery yields than the plots with 80 pounds of nitrogen. The standard commercial fertilizer produced the lowest yield. During early growth stages the celery was smaller and a lighter green color in the commercial fertilizer plots.

The stalks were graded into 18, 24, and 30 stalks per box. There was a trend for the higher yielding treatments to produce larger stalks.

Nine nutrients were analyzed on the harvested plants. The analysis showed no statistical difference between treatments in the percent of nutrients. The percent nitrogen ranged from 2.625 for Duration at 160 pounds of nitrogen to 2.450 percent for the standard commercial fertilizer.

Table 5 shows the nine nutrients in pounds per acre removed in the harvested crop. The celery crop removed 110-130 pounds of nitrogen per acre. Celery yields account for the major difference in the pounds of nutrients removed.

The celery petiole NO_3-N values for four sample dates is shown in table 6. The NO_3-N levels are low in the first sample date (4/12/96). The low value of 4,808 ppm NO_3-N for the standard fertilizer treatment is below the deficiency level (5,000 ppm). The downward trend of the petioles NO_3-N from 5/3/96 to 5/6/96 shows the celery is utilizing most of the applied nitrogen.
See Table 2. Celery Yield and Size Distribution

Table 6. Celery Petiole NO_3-N PPM, Ranch 2

Fertilizer		Nitrogen Lbs/A	Petiole NO_3-N PPM 4/3/96	4/9/96	4/17/96	4/29/96
Duration	27-9-9	250	12,625	13,734	10,374	8,109
Scotts 25	25-7-11	250	0,900	11,550	9,825	7,100
Scotts 24	24-7-7	250	9,338	10,898	9,556	6,925
Duration	27-9-9	125	10,470	11,069	9,140	7,128
Scotts 25	25-7-11	125	2,503	11,790	10,064	7,427
Scotts 24	24-7-7	125	10,125	11,033	9,465	8,275
Commercial		300	3,725	14,249	2,033	7,725
			NS	NS	NS	NS

Statistical Analysis showed no significant difference between treatments at the 5% level.

Table 7. Celery Petiole NO_3-N PPM, Ranch 6

Fertilizer		Nitrogen Lbs/A	Petiole NO_3-N PPM 4/12/96	5/6/96	5/28/96	6/3/96
Duration	27-9-9	160	9,465 A	12,115	8,214	5,673
Scotts 24	24-7-7	160	8,495 A	11,878	8,007	5,636
Duration	27-9-9	80	7,268 B	12,356	7,821	5,613
Scotts 24	24-7-7	80	7,652 B	12,738	8,270	5,624
Commercial		300	4,808 C	12,015	7,489	5,673
				NS	NS	NS

Duncan Multiple Range Test - Data numbers represented by the same letter are not significantly different at the 5% level.
Statistical analysis showed no significant difference between treatments at the 5% level ON 5/6/96, 5/28/96 AND 6/3/96.

DEVELOPMENT AND PROMOTION OF NITROGEN QUICK TESTS FOR DETERMINING NITROGEN FERTILIZER NEEDS OF VEGETABLES AND SURVEY OF SOIL RESIDUAL NITRATE-NITROGEN LEVELS IN VEGETABLES

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OBJECTIVE

Conduct a survey of fifteen lettuce/cole crop production fields and plot the course of soil nitrate-N levels in the soil over the season.

DESCRIPTION

A survey of 15 vegetable production fields in the Hollister and Salinas Valley areas was conducted in the summer of 1996. The fields surveyed were double cropped to lettuce-lettuce or cole crop-lettuce. The fields were located on a wide variety of soil types throughout the two vegetable production areas. The purpose of the survey was to examine a number of fields and determine the nitrate-N levels over the season. This information is to be used to determine residual nitrogen levels in the soil and assess the potential for growers to utilize this source of nitrogen for crop production and thereby reduce nitrogen fertilization. Based upon prior work by Tim Hartz, soil nitrate-N levels of 20 g N/g soil or higher are sufficient for adequate crop growth (20 g N/g soil corresponds to approximately 80 lbs. N/ acre in the top foot of soil). The survey data will provide researchers an opportunity to determine the extent to which the soil quick test techniques can be applied to double-cropped vegetable production systems to improve fertilizer use efficiency.

Eight double cropped fields (i.e. lettuce-lettuce; cole crop-lettuce; or lettuce-cole crop) in the Hollister area and seven fields in the Salinas were selected for sampling of soil nitrate-N over the course of the 1996 growing season. Sampling began with the spring crop and continued at two-week intervals through the fall crop. Sampling in Hollister was initiated on April 25th and sampling in Salinas was initiated on May 13th. Each field was split into four quadrants and the soil was sampled for nitrate levels utilizing KCl extracts and two quick test technologies: the nitrate content of 0.01 calcium chloride extract was determined with merquant nitrate strips (utilized on the Salinas sites) or the RQflex reflectometry meter (utilized on the Hollister sites). Correlations between the quick test methods and the KCl extracts were determined.

RESULTS

Hollister: The nitrate-nitrogen levels in the soils vary widely, but in general, for sprinkler irrigated sites, the levels stayed below 20 ppm except for occasional peaks. There is a great deal of variability on some sampling dates for some fields. The high levels of nitrate-N variability is typical of nitrate levels in field soils. One drip irrigated site showed substantial periods above 20 ppm later in the season. Interestingly, this field had the lowest fertilizer application levels. Figure 1 shows the average soil nitrate-N levels in the soil. From this figure it can be seen, that, in general, the soil levels for the seven fields were at moderate levels of soil nitrate-N. Fertilizer applications were typical for the Hollister area with a range of 129 to 249 lbs. N/acre for the first crop and a range of 155 to 203 lbs. N/acre for the second crop. Yields were also typical, except for some low yields due to bolting and reduced cuttings due to market conditions.

Salinas: The nitrate-nitrogen levels in the Salinas soils also varied widely. However, most of the sites had many periods of time with soil nitrate-N levels above 20 ppm. Figure 2 shows the average soil nitrate-N levels in the soil. From this figure it can be seen that in general the soil levels for the six fields surveyed were at elevated levels of soil nitrate-N. Fertilizer application were typical for lettuce and broccoli production in the Salinas Valley with a range of 183 to 245 lbs. N/acre for the first crop and a range of 177 to 245 lbs. N/acre for the second crop. In general more fertilizer was applied than in the Hollister area and yields tended to be higher in the Salinas area.

Testing Methods: The R-square values between the reflectoquant technique that was utilized at all Hollister sites and the laboratory analyses indicate a good overall correlation, 0.85 (Fig. 3). The correlation coefficients varied from 0.68 to 0.93. The Merquant strip data from Salinas was a bit more variable. Overall the correlation was 0.64 (Fig. 4). The correlations varied from 0.48 to 0.90. It appears that the higher values have lower correlations with laboratory data and that the lower values (i.e., less than 25 ppm) gave better correlations.

The data indicate that there were periods of high levels of nitrate-N (i.e., over 20 ppm nitrate-N) in the soil but that nitrate-N varied greatly through the growing season. Careful monitoring of these nitrate-N levels with soil quick tests may provide opportunities to reduce fertilizer applications.

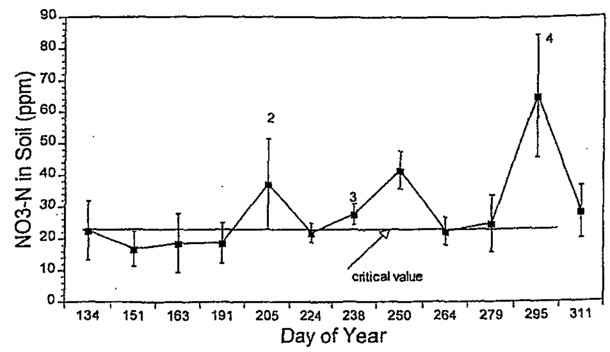

Figure 2. Mean NO_3-N levels in soil over season, Average of all six sites, Salinas, 1996.

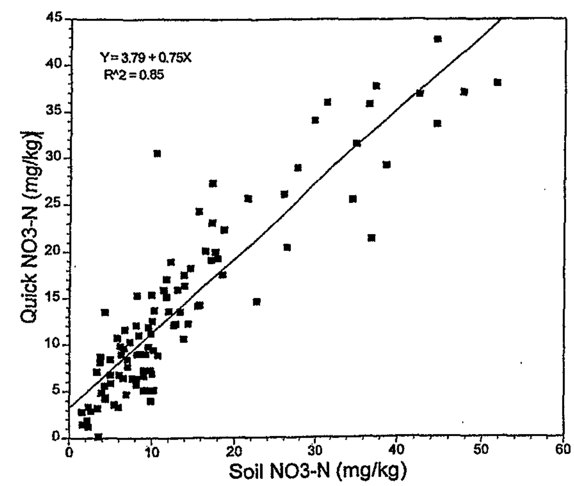

Figure 3. Quick test NO_3-N vs soil NO_3-N, Hollister, 1996

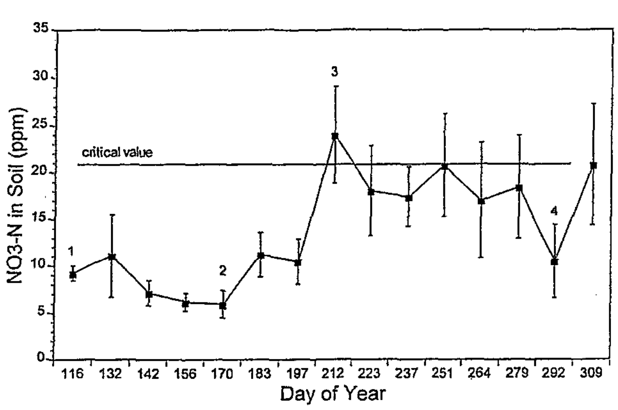

Figure 1. Mean NO_3-N levelsin soil over season, average of all seven sites, Hollister, 1996.

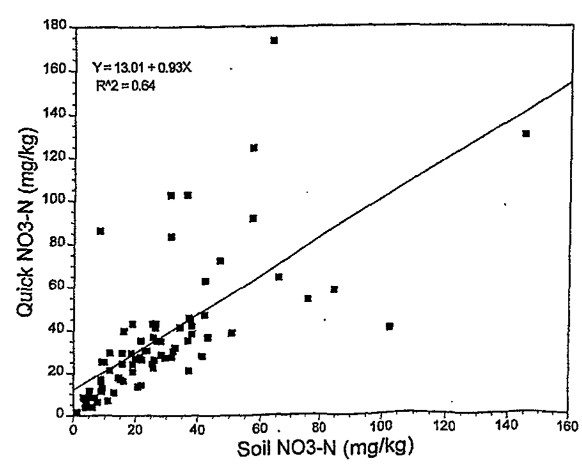

Figure 4. Quick test NO_3-N vs soil NO_3-N, Salinas, 1996

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

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INTRODUCTION

The low desert region of the southwestern United States is a major area of vegetable production during the winter months. Nitrogen is the nutrient most limiting to crop production in the region. Because of rigid produce quality standards enforced by the market, lettuce, cole crops, and other vegetables receive appreciable amounts of N fertilizer for optimal yield and quality. Researchers have found that optimal N management practices for crops in the low desert region consist of a modest preplant application with subsequent sidedress (or water run) applications based on crop monitoring. However, many vegetable growers have been disinclined to adapt N fertilization practices based on tissue monitoring and soil analysis. This project was designed to evaluate several diagnostic approaches as tools to aid in the efficient N management of vegetables produced in the low desert. Approaches include the traditional dry midrib or petiole test, the sap midrib or petiole test using the Cardy meter, absorbance using the chlorophyll meter, and various reflectance technologies including digital analysis of aerial photographs. Because plant tests do not appear to be sensitive indicators of N nutrition during early plant growth stages, a post thinning (and pre-sidedress) soil nitrate-N test was evaluated during the 1996-1997 growing season.

OBJECTIVES

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

DESCRIPTION

Sites were selected in the lower Colorado River Valley, the Imperial Valley, and the Coachella Valley. In 1995-1996 all field experiments included a variable of N rate. Our purposes this season were to evaluate all diagnostic technologies under conditions of sub-optimal, optimal, and supra-optimal levels of N nutrition, correlate diagnostic tool to growth and yield, and correlate the various diagnostic tools to each other. In 1996-1997 all field experiments evaluated the response of lettuce, broccoli, or cauliflower to sidedress N fertilizer application and tested the effectiveness of various diagnostic tests as predictive tools.

RESULTS AND CONCLUSIONS

Yield Response: Results analyzed in 1995-1996 showed lettuce responded to N fertilization in 14 out of 16 sites, cauliflower responded to N in three out of five sites, and broccoli responded to N in two out of four sites. Generally, the responses to N were curvilinear, affording an excellent opportunity for evaluating diagnostic technologies that assess N nutritional status. The lower portion of the response curve, where yield response is proportional to N rate, indicate N deficiencies. The upper portion of the response curve, the points beyond maximum yield, correspond to excess N nutrition. Hence, we can correlate several diagnostic technologies to growth and yield.

Overall, in 1996-1997 we worked in sites less responsive to N than we had previously. Nevertheless, there were responsive sites and non-responsive sites, allowing some testing of the predictive potential of the diagnostic tools.

Dry midrib nitrate-N: Dry midrib nitrate levels increased with N fertilization in most experiments. However, we concluded from results collected during 1995-1996 that the midrib nitrate-N test was not a sensitive indicator during the early crop growth stages. It is our observation that this test is not consistently reliable before eight-leaf to folding stage of growth. This was consistent with our observations during 1996-1997, where the midrib-N test did not successfully predict the need for the first sidedress N fertilization application after thinning. This test did appear to predict the need for N by the second sidedress N application. Overall, the dry midrib nitrate-N test is a suitable diagnostic N test after the earliest growth stages.

Sap nitrate-N: Sap nitrate-N increased with N rate in most experiments. The sap nitrate test is correlated to the dry midrib nitrate-N test, although there is variability. We believe some of the variability is associated with variation in plant water status and interference due to chloride. The dry midrib nitrate-N test is standardized by drying the tissue and chloride interference is minimized through the use of a buffer extracting solution. Despite these limitations, based on data collected to date, we believe the sap nitrate-N test would be a useful test for lettuce, broccoli, and cauliflower after the earliest growth stages. As with the dry midrib nitrate-N test, the sap nitrate-N test did not successfully predict the need for the first sidedress N fertilization after thinning.

Chlorophyll meter readings: There was a general increase in chlorophyll meter readings with N rate. Nevertheless, the values were not a sensitive indicator of N nutritional status. The range in values between low and high chlorophyll meter readings was generally less than 5 units, although yields increased by 80%. There were also frequent reversals in readings among N rates. Furthermore, chlorophyll meter readings varied substantially with cultivar, further limiting its use.

An evaluation of variance components shows extreme variation in readings on different locations on an individual leaf relative to other sources of error. The chlorophyll meter has been successfully used to diagnose N deficiencies on corn in the midwestern United States. Lettuce leaves have more color variation than corn leaves. This variation, in combination with the small sensor size on the SPAD 502, likely confounded readings. Evaluation of the chlorophyll meter as a tool to diagnose N deficiencies in lettuce and cole crops was discontinued.

Canopy reflectance: Canopy reflectance measurements using a spectraradiometer showed sensitivity to N stresses at the 550 nm (green), 650 to 700 nm (red), and 750 to 900 nm (near infrared) regions of the spectrum. Data from a digital analysis of aerial photographs show good relationships between red gray-scale values and relative marketable lettuce yield. Blue and green gray-scale values were generally not sensitive.

Data from a digital analysis of aerial photographs show good relationships between red gray-scale values and relative marketable yield on a given N rate experiment. Blue and green gray-scale values were less sensitive to the N status of lettuce. Because these technologies respond to differences in plant color and plant biomass they are affected by other stresses that impact these responses including insect and disease pressure. Hence, at present, aerial photographs are at best a qualitative tool which can be used to troubleshoot fields. However, the nature of the stress must be verified or determined by data collection on the ground. During the 1996-1997 year, we discontinued our effort in this area and focused on more quantitative diagnostic tools.

Soil nitrate N test: A post-thinning (and pre-sidedress) soil nitrate-N test was evaluated during the 1996-1997 growing season. Results obtained during 1996-1997 are inconclusive because several of our sites were not responsive to N fertilization and some of our results appear confounded or atypical. For example, although soil nitrate-N tested more than 20 ppm in one site, broccoli responded to sidedress N fertilization. Conversely, in another site, although soil nitrate N tested less than 10 ppm, lettuce failed to respond to sidedress N fertilization. Further testing of soil nitrate-N tests are planned during 1997-1998.

D-040084

ON-FARM DEMONSTRATION AND EDUCATION TO IMPROVE FERTILIZER MANAGEMENT

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DESCRIPTION

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, pilot and demonstration, and outreach effort to reduce nitrate leaching through improvements to irrigation efficiency and fertilizer management.

The objective of this project is to bridge the gap between standard grower practices and recently developed best management practices (BMPs) for irrigation and fertility management for head lettuce production. These BMPs are intended to refine irrigation and fertilizer applications to more closely match actual crop needs. Routine monitoring of soil moisture and crop nutrient levels can allow for more precise application of these inputs. However, to begin the project, the growers' standard practices were first evaluated to determine which BMPs have the most potential benefit.

The lettuce fertility demonstration project is being conducted with commercial growers near Salinas. Both sites were sprinkler irrigated for crop establishment. Subsequently, one field was furrow irrigated (conventional) and the other was drip irrigated. Following above average winter rainfall, pre-plant soil nitrate levels in both fields were relatively low (5 to 10 ppm NO_3-N).

The project team decided to gain further confidence in the quick test sufficiency guidelines to better understand the effects of reduced fertilizer applications by conducting variable rate fertilizer trials in both fields. Soil and plant sap nitrate-N levels in all treatments were routinely monitored utilizing the respective quick tests, and irrigations were evaluated for efficiency.

RESULTS

Results of the variable rate fertilizer trials differed in the two fields largely due to water quality and irrigation management. In both fields the crop water requirements were estimated to be about 8". In the conventionally irrigated field, over 18" were applied, resulting in a fairly low irrigation efficiency (below 50 percent) . Seventy percent of the water applied was by furrow irrigation after thinning. Even a slight reduction in fertilizer application to 169 lbs N/acre (still above the crop nitrogen requirement of 150 lbs N/acre) resulted in a yield reduction. This emphasizes the importance of irrigation management in relation to fertility management. Fertilizer applications cannot be fine tuned if excess irrigation leaches nitrate beyond the root zone.

In the drip irrigated field, 12" of water were applied, the majority (70%) by early season sprinkler irrigations. Non-uniform water application by the sprinkler system compounded by grower uncertainty regarding early season water needs resulted in the majority of the water being applied when crop needs were the lowest. Germination irrigations applying more water than daily evaporation resulted in significant deep percolation beyond the future crop root zone. Once these germination irrigations were shortened, to more closely match soil evaporation, this deep percolation was reduced. In this field, reductions in fertilizer applications did not result in yield reductions, even with applications less than the estimated crop nitrogen requirement. The main reason for this was the additional nitrogen contribution from high nitrate well water. The two wells used had respective nitrate concentrations of 92 and 104 ppm, providing the equivalent of 56 to 63 pounds of nitrate nitrogen per acre foot of water. Considering the efficiency of the irrigations, the contribution of the high nitrate well water is significant (perhaps in the range of 40 lbs N/acre), and needs to be considered when determining fertilizer needs.

Although there were no significant yield differences in this field, the low fertility rate produced lettuce with noticeably less green color.

At the field days conducted at each site, concepts regarding the inter-relationships between irrigation and fertility management were discussed. Monitoring tools and methods including methodology for soil sampling, performing the soil nitrate quick test, tissue sampling, and soil moisture monitoring were also demonstrated to growers and fertilizer dealers.

The demonstration sites are being continued with the same growers for the second crop. The emphasis is now on the implementation of the best management practices on a field scale level.

DEVELOPING SITE-SPECIFIC INFORMATION FOR CROPPING SYSTEMS IN CALIFORNIA

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OBJECTIVES

1. In commercial fields, measure the variability of yield of irrigated wheat (1996) and processing tomatoes (1997).
2. Within individual fields, determine the relationship of crop yield to soil and plant characteristics as observed in aerial photographs and plant and soil samples.
3. Assess the potential for site–specific farming in a Sacramento Valley tomato–field crop rotation and communicate with growers and allied businesses.

DESCRIPTION

We are monitoring the performance of crops in three commercial fields of 77, 78, and 108 acres in the lower Sacramento Valley. The soil textures are mainly clay loam, silty clay loam, and silty clay, and the fields generally are difficult to irrigate uniformly. The fields were cropped to wheat in 1995–96 and to tomatoes in 1997. Wheat yield was measured continuously with an Ag Leader™ yield monitor/GPS combination retrofitted on the grower's harvester. Tomato yields were measured in July–August 1997 using a prototype load cell/GPS yield monitor mounted on one of the grower's harvesters. Yields were calculated by weighing fruit at frequent time intervals on a section of the conveyor belt that discharges into the trailer. Distance traveled during each interval was determined by GPS. Color infrared aerial photographs were taken in each year, once when the soil was bare and three times during the cropping period. Soil and plant samples were collected on a 200' x 200' grid, or approximately one sample per acre. Digitized aerial images, plant tissue and soil data, and yield monitor data from the wheat crop were compiled in an ArcView® file. Tomato yield data analysis is in progress.

RESULTS

Two examples of whole–field variability are presented here. The first example shows that in one field, wheat grain yield and leaf N content at the early jointing stage were correlated (Fig. 1).

In this field, the grain yield of 2,940 lbs/acre was about half the county average; however, some areas of the field yielded above 6,000 lbs/acre.

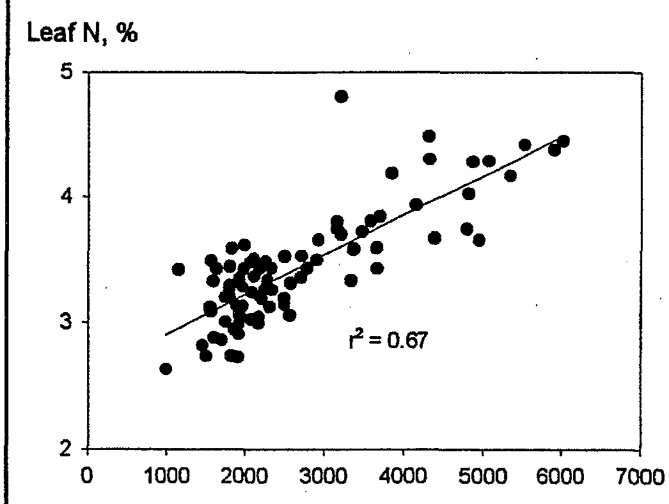

Figure 1. Wheat leaf total N content versus yield in 77-acre field. Yields are averages for the 25 x 25-ft² area nearest each leaf sample location. Various researchers in other states suggest a sufficiency value at early jointing of 3.0 - 3.5% N.

The main reason for low yield was the effect of heavy rains during the 1995–96 winter on the aeration status of the slow draining Capay silty clay—the predominant soil in the northern two–thirds of the field. In the higher yielding part of the field, the predominant soils (Brentwood and Yolo) have a similar surface texture but lack the impervious subsoil of the Capay. In the areas with Capay soil, plants were small and poorly tillered.

It is likely that wheat in the areas with saturated soil was not able to obtain sufficient N due to a smaller root system and a greater loss of N from the soil. An aerial application of urea on February 25 resulted in green–up that was visible in a May color infrared aerial photo as streaks running perpendicular to the beds. However, we did not observe any pattern in the yield monitor data that corresponded to these streaks.

One management scenario would be to use plant N analysis (or chlorophyll meter readings) to identify the most N–deficient areas of the field, then apply a fluid fertilizer such as urea or urea–ammonium nitrate solutions only to the area needing treatment instead of to the entire field.

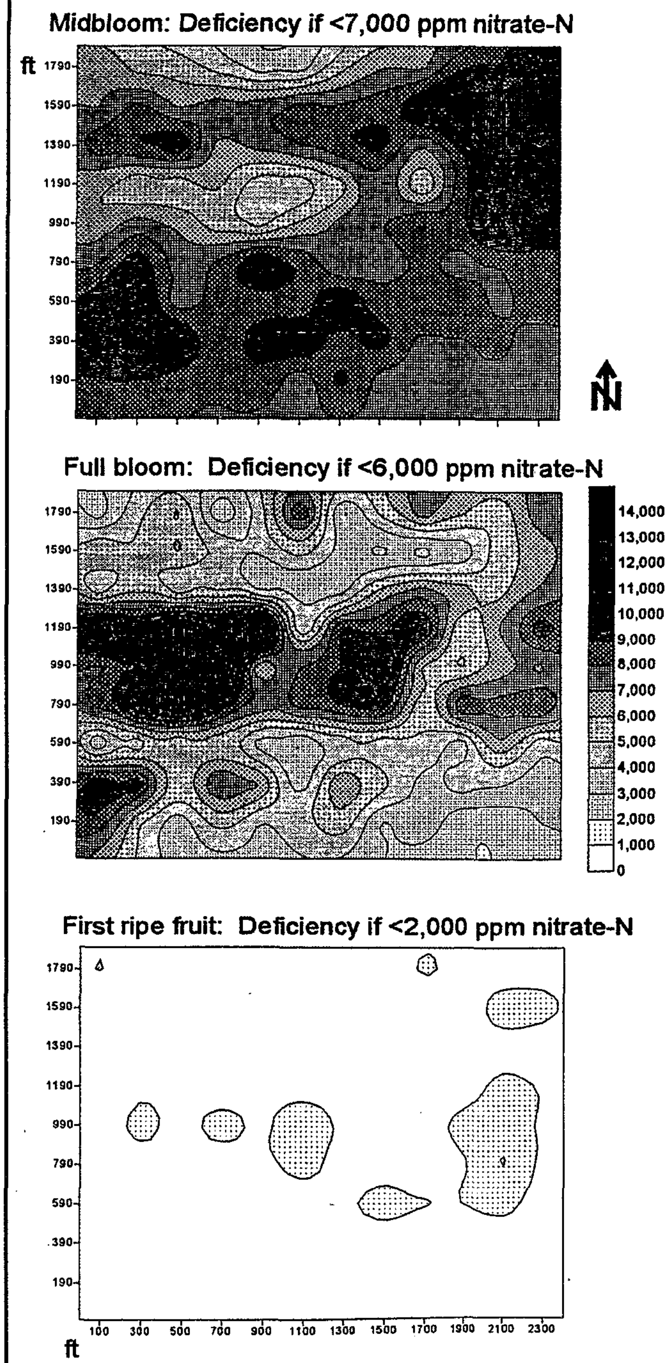

Figure 2. Temporal and spatial variability of processing tomato petiole nitrate at three growth stages in a 106–acre field in Yolo Co. (contour lines based on 108 samples at each date). N fertilizer was applied between the first and second sampling. Beds and furrows run in an east–west direction.

A second example from a different field in the same study shows that tomato petiole nitrate content varied within a large (106 acre) field, but the pattern changed during the season, presumably in response to N fertilizer sidedressing and irrigation (Fig. 2). At all three growth stages, there were significant areas of the field with petioles both above and below the UC–recommended deficiency level. At mid–bloom, samples from a large area in the west–central part of the field and another smaller area on the north end of the field were very low in nitrate. Eighteen days later (following N fertilizer sidedressing and several irrigations), the area in the west–central part of the field had the highest petiole nitrate, but the rest of the field was somewhat deficient. At neither sampling date did the patterns of petiole nitrate match the soil texture map of this field.

It is relatively costly and time–consuming to collect and analyze so many plant samples. We are exploring use of aerial photography to assess nutrient status. One strategy proposed is to use aerial photography to divide the field into a few relatively uniform areas from which a small number (1–3) plant samples would be collected.

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

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DESCRIPTION

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

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

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

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

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

RESULTS AND DISCUSSION

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

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

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

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

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

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

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

Table 1: Barley Dry matter Production and P Uptake at Late Tillering and Anthesis for selected treatments

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

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

Location Key:

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

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

D-040091

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

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

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

D-040092

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

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INTRODUCTION

Large quantities of N fertilizers are used annually in the production of sudangrass hay for low desert regions, at rates varying from 150 to over 800 lbs. N/acre. Interest in sudangrass hay has increased due to increased export demand and a deficit of forages for California's dairy and beef industries. We initiated experiments to better characterize the N needs of sudangrass, and to make recommendations about N fertilization practices in sudangrass for hay.

OBJECTIVES

To determine the response of sudangrass (yield and forage quality) to varying levels of N fertilizers in the low desert environment, quantify the effects of N application rates on the potential for groundwater contamination, and develop rapid diagnostic tests to monitor N content and nitrates in the forage.

DESCRIPTION

In 1997, we established three field trials at two locations in the low desert of California. One trial was established in April at the Desert Research and Extension Center, El Centro, CA, which is in the Imperial Valley, and two on farmer's fields in Blythe, CA, which is in the Palo Verde Valley. Of the two Blythe trials, one will be intensively sampled, and the other will be sampled only for yield. The experimental design was a randomized complete block design, with N treatments as: 0, 35, 70, 105, 140, and 210 lbs. N/acre per harvest. We plan to harvest these plots 4 times. Hence, treatments for N application rates over the season were: 0, 140, 280, 420, 560, and 840 lbs. N/acre. Dry matter yields have been measured at each site. Measurements using a Cardy meter for nitrate content were taken at each plot from a large number of representative plants. Chlorophyll readings were also taken. Samples were taken for forage quality (ADF, NDF, CP), and nitrate analysis, which are currently being analyzed. Soil samples were taken at the start of the experiment and after the first harvest from each plot, to measure the impact of fertilization treatments on soil N and nitrate levels.

We are continuing to harvest these trials, and to analyze samples and data, so detailed results are not currently available. However, a few general observations can be made. In general, visual differences due to N fertilization treatment were much more apparent at the Blythe site than at the El Centro site, where results are more variable. A yield response to N fertilization is likely to have occurred at Blythe, whereas it is less likely that yields were significantly affected by N fertilizers at El Centro, at least in the first two cuttings.

The soils at Blythe are sandier, and perhaps prone to greater leaching than those at El Centro, and the experimental site may have been less variable than the site at El Centro. Although full sample and data measurements remain to be analyzed, samples taken with a Cardy meter indicated nitrate readings which were in approximate agreement with the fertilizer treatments which we imposed.

Ongoing work will characterize the yield and quality response of sudangrass to N, as well as the likelihood for nitrate poisoning, or nitrate contamination of groundwater, due to N fertilization practices in sudangrass. The prospects for using either the Cardy Meter or a chlorophyll meter for monitoring N needs or for assessing potential for nitrate problems will be evaluated.

ESTABLISHING UPDATED GUIDELINES FOR COTTON NUTRITION

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INTRODUCTION

This project has completed a 4 year effort to update potassium guidelines for cotton. Revised guidelines for K fertilization have been established and are in Table 1 below. Guidelines for N fertilization are being developed.

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

RESULTS

The revised guidelines for K fertilization appear in Table 1. For a more detailed discussion of the project

Table 1. Revised Guidelines for Potassium Fertilization for Cotton

Improved K fertilization predictions are [illegible] soil samples taken at a depth of 6-18 inches (15-45 cm)

If soil level is 110-120 ppm:	Apply 100 pounds K2O/acre
If soil level is 80-110 ppm:	Apply 200 pounds K2O/acre
If soil level is less than 80 ppm or if K fixation is > than 60%:	Apply 400 pounds K2O/acre
Threshold petiole K levels for achieving 90% or greater potential yield are:	a) first flower: 3.5% b) 2 weeks after first flower: 2.75% c) 10 days after cutout: 1.5%

Supplemental K can be added by foliar application after first bloom. Water run applications may be less effective.

Implementing these fertility guidelines can improve economic returns.

D—040095

D-040095

results including a discussion of deficiency symtoms and soil and petiole sampling, please see DANR publication 21562, *Cotton: K fertility guidelines for the San Joaquin Valley of California.*

This publication is available from the University of California Division of Agriculture and Natural Resources, Communications Services Publications: 800-994-8849.

Guidelines for Nitrogen Fertilization
Data for nitrogen fertilizer guidelines is still being gathered. It is expected that recommendations will be available after two more research seasons.
Survey of Changes in Irrigation Methods and Fertilizer Management Practices in California

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

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DESCRIPTION

This survey was undertaken to describe transitions in irrigation and nitrogen fertilization management techniques in California over the last ten years. Quantitative, current, and geographically extensive data is not available. This survey differs from others conducted in the past because it directly asked the growers about two distinct points in time to characterize real changes in management techniques and to relate the changes to each other.

We asked farmers to identify, by crop, the acreage in 1986 and 1996 under four classes of irrigation methods; micro-irrigation, surface, sprinkler, and a combination of these techniques. We then asked them to answer a series of questions about their nitrogen fertilization techniques for the same crops. The following questions were asked:

1. Times that commercial N fertilizer was surface applied? (0 to more than 5)
2. Number of foliar N applications? (0 to more than 5)
3. Fertilize through a water system? (yes/no)
4. Cover crops during the off season? (yes/no/not applicable)
5. Soil test for nitrogen? (yes/no)
6. Plant tissue analysis for nitrogen? (yes/no)
7. Organic amendments (e.g., manures, compost, manure water, biosolids)? (yes/no)
8. Total lbs. commercial actual N/acre applied?

With much cooperation from the individual University of California Cooperative Extension regional and county directors and farm advisors, 42 of 58 of California's counties were chosen to be surveyed. Due to the Cooperative Extension system's method of cross-listing farm advisors in several counties or delegating responsibility for two counties to one office, the participating counties were eventually examined as 34 separate units (Table 1).

Our target audience was growers of irrigated field, vegetable, tree, and vine crops. Nurseries, confined animal production facilities, rice farmers and some other forms of agriculture were not targeted in the survey because these facets of agriculture either do not fertilize, can not change their techniques (e.g., rice and flood irrigation) or do not occupy a large amount of acreage in the state-wide picture.

RESULTS AND ANALYSIS

In all, 7800 surveys were mailed to the 34 different county units. After eliminating all of the surveys which were returned to us for incorrect addresses or for other reasons, the total mailing was 7635 surveys. 833 surveys were returned for a response rate of 11%. This response rate was disappointingly low, but it was in line with the predictions of most of the farm advisors we collaborated with on the project.

The data were organized by crop and by region. Crop categories were taken from the 1996 California Agricultural Resource Directory produced by the California Department of Food and Agriculture's Office of External Affairs. The following categories are used in the analysis: nut crops, citrus fruits, non-citrus fruits, grapes, vegetables and field crops.

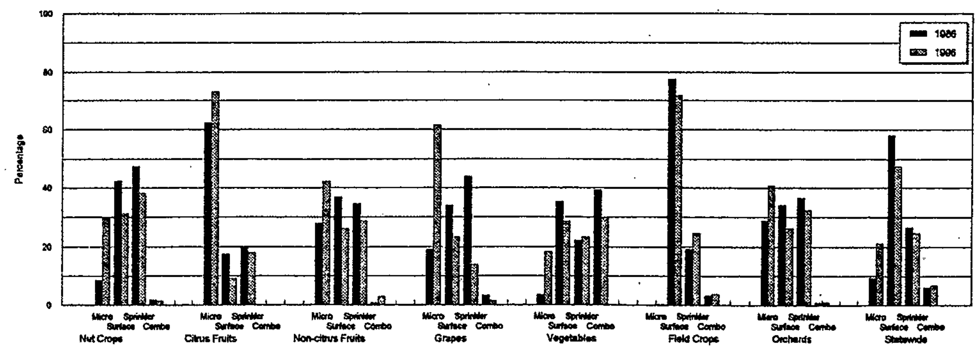

Figure 1. Irrigation method changes by Ccrop

Regional categories were created from DWR Bulletin 113-4 of April 1986 "Crop Water Use in California" using Appendix F (Index to Agroclimate Stations pg. 66-67) and Appendix G (Evaporation Pan Data pg. 69-73). Counties are placed into one of the categories based upon their classification in the agroclimate station map and then a comparison of their evaporation pan data during the summer months (Table 1).

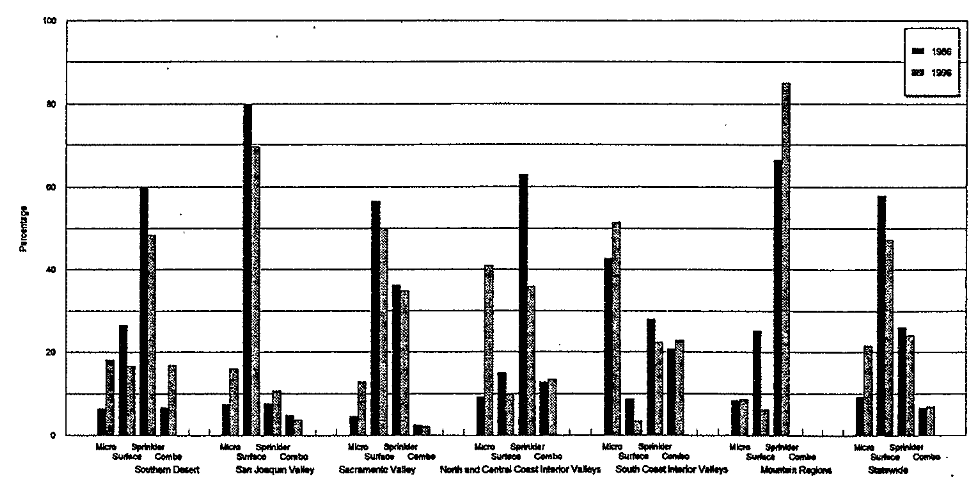

Figure 2. Irrigation method changes by region.

Acreage was summed by region and by crop type for the analyses. Answers to the nutrient management questions were also summed with the question "Times that commercial N fertilizer was surface applied ?" being calculated as a Likert scale with 0 = 0 applications and 6 = more than 5 applications. Percentages were calculated for each question both by crop type and region as well as the overall statewide numbers.

Irrigation methods have changed in nearly all categories of analysis both by crop and by region (Figs. 1 and 2). There was a decrease in reported percent acreage irrigated by surface methods and an increase in percent acreage irrigated by micro systems for all regions and crop types except field crops which are not irrigated by micro systems. There was a decrease in percent acreage irrigated by sprinklers in all regions except the San Joaquin Valley and Mountain Regions. The San Joaquin Valley reported large acreage in field crops such as cotton and the mountain areas reported large amounts of irrigated pasture and alfalfa. All changes were tested for statistical significance. Differences were shown to be significant at the 99%, level except for citrus fruits under the combination method as well as the micro-irrigation and combination methods for the mountain regions. These changes did not test to a minimum significance level of 90%.

The trends from the nutrient management answers of the survey are more complicated. At the statewide level, a strong trend away from only one surface application was found. Significant increases in the acreage managed without a surface application or with multiple (and presumably smaller) applications were found (Fig. 3). This corresponds with the observed trends towards adopting other methods of supplying nitrogen to the crops. A significant increase in the percentage of farmers who managed their crops with foliar N applications,

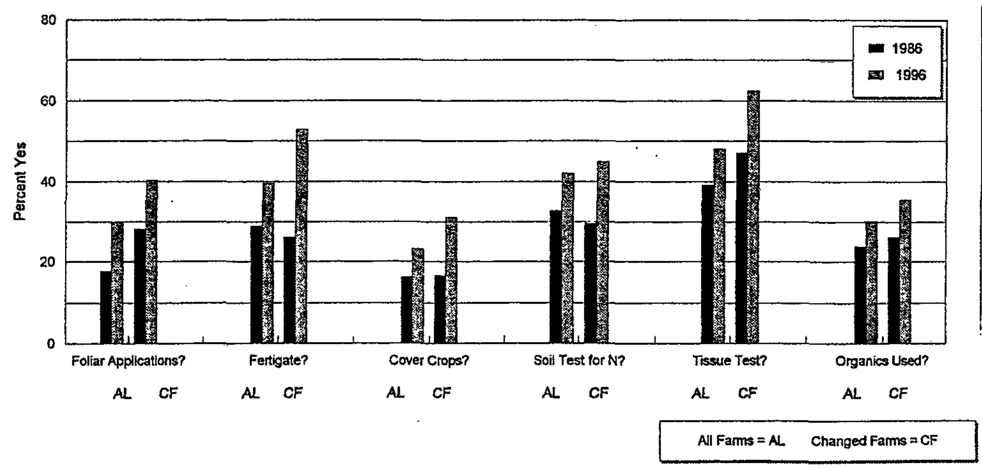

Figure 3. Surface applications of N - statewide.

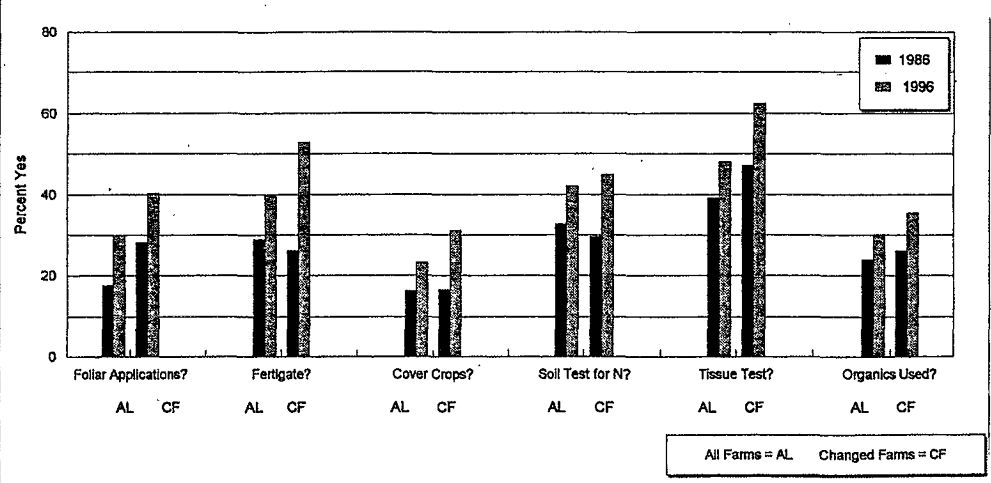

Figure 4. Statewide statistics for all farms vs. farms which changed irrigation method; N management techniques.

fertigation, soil and plant tissue testing or using cover crops and organic amendments was found (Fig. 4). We separately examined these nitrogen management questions for farms which reported a change in their irrigation method and they are identified as "CF" in Fig. 4. All of the differences at the statewide level tested to be statistically significant at the 99% confidence level. The adoption of these methods was most prominent in the North and Central Coast Interior Valleys, the San Joaquin Valley and for nut, grape and vegetable crops. (These data have been summarized and graphed by individual category, but are not being presented here. Those interested in receiving copies of the data should contact our Riverside office.)

In the final nitrogen fertilizer management question, we asked the grower to identify the total pounds of commercial actual N/acre they applied to the crop. We then took the usable responses and classified them as either 1) increased the amount, 2) decreased the amount, or 3) no change in the amount. The results of this analysis are presented by crop in Fig. 5 and by region in Fig. 6. In the majority of cases (57% statewide) the total amount of N being applied remained the same. The percentage of growers who increased the total amount applied (24% statewide) was higher in all categories except for the Southern Desert region, citrus crops and non-citrus fruit crops which reported a decrease in the total amount of nitrogen applied (19% statewide). The Mountain regions and grape growers reported an equal number of farmers who increased and decreased their total applications.

CONCLUSIONS

The trends in shifting irrigation away from surface systems to pressurized micro irrigation or sprinklers is consistent with the results of other surveys. Pressurized irrigation systems provide the farmer with greater control on the amount of applied water and, for properly designed and managed systems, better uniformity of irrigation than surface systems. The irrigation results must be considered to be positive.

The trend toward adoption of fertilization management factors such as soil testing, plant tissue testing, multiple fertilizer applications, etc. that are considered to be good management practices is also a positive finding. However, adoption of better irrigation systems and improved nitrogen management practices have not translated into overall reduced nitrogen application amounts.

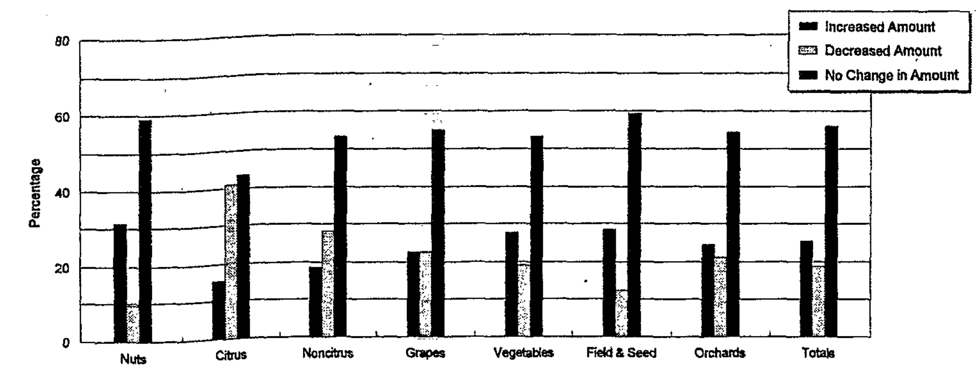

Figure 5. Total lbs commercial actual N/ac applied by crop.

We can only speculate on the reason(s) that overall nitrogen application amounts have balanced out to be about the same for 1986 and 1996. Possible explanation includes the following considerations. Improved irrigation can lead to increased yield which would require higher nitrogen inputs to meet crop needs. One farmer growing a nut crop specified that the increase in N application between 1986 and 1996 was because the trees had grown and required more N.

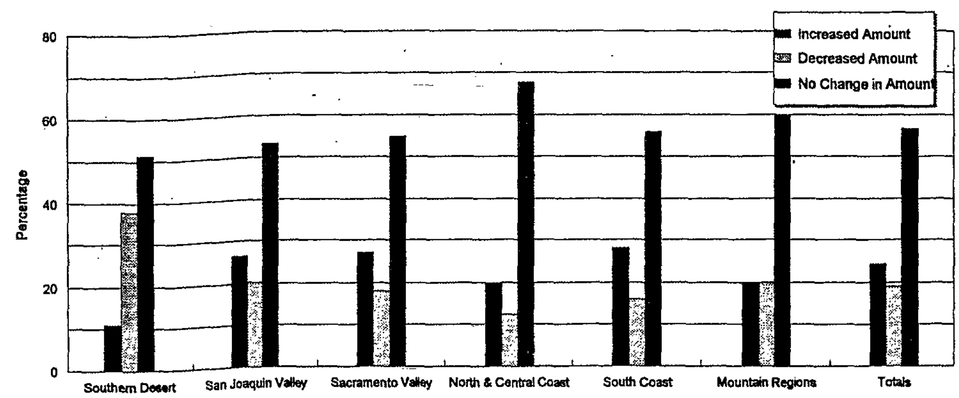

Figure 5. Total lbs commercial actual N/ac applied by region.

Research and Extension activities which address shifts in fertilizer application which should accompany a shift in irrigation technique may be lacking. In other words, in the absence of new information, the farmer relies on previous fertilizer application guidelines even though there has been a shift in irrigation systems.

The survey instrument allowed farmers to provide a message they would like the nonfarming community to understand. The most common message was that they were well aware of and concerned about environmental quality. They pointed out that water and fertilizer are costly and that it would be economically unsound for them to apply more than necessary to get a good yield. The results of this survey suggests that they are taking a number of steps to improve management, however, the apparent stability in nitrogen application amounts requires further investigation before it can properly be interpreted.

Table 1. Listing of Participating Counties and their Regional Classification

North and Central Coast Interior Valleys

Contra Costa and Alameda Counties
Lake County
Napa County
Monterey County
San Benito County
San Luis Obispo County
Santa Clara County
Santa Cruz County
Shasta and Trinity Counties
Siskiyou County
Sonoma County

Southern California Desert

Imperial County
Inyo and Mono Counties
San Bernardino and Riverside Counties

San Joaquin Valley

Fresno County
Kern County
Kings County
Madera County
Merced County
San Joaquin County
Stanislaus County
Tulare County

South Coast Interior Valleys

San Diego County
Santa Barbara County
Ventura County

Sacramento Valley

Butte County
Colusa County
Glenn and Tehama Counties
Sacramento County
Solano and Yolo Counties
Sutter and Yuba Counties

Mountain Counties

El Dorado County
Lassen County
Placer and Nevada Counties

Nonparticipating Counties

Alpine County
Amador County
Calaveras County
Del Norte County
Humboldt County
Los Angeles County
Marin County
Mariposa County
Mendocino County
Modoc County
Orange County
Plumas County
Interior Valleys
Mountain Counties
San Francisco County
San Mateo County
Sierra County
Tuolumne County

PRACTICAL IRRIGATION MANAGEMENT AND EQUIPMENT MAINTENANCE WORKSHOPS

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Monterey County

The objective of this two-year project is to develop and conduct a series of irrigation and fertigation workshops throughout the Salinas Valley. The 2-3 hour workshops will address technical issues geared towards growers and other agricultural professionals, as well as less technical issues geared towards the irrigators and irrigation foremen. At least nine workshops will be held per year (6 on practical sprinkler irrigation management, two on fertigation, and one on drip irrigation filter maintenance). The workshops will include a professional evaluation.

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

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

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

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

IRRIGATION AND NUTRIENT MANAGEMENT CONFERENCE AND TRADE FAIR

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

The fifth Irrigation and Nutrient Management Conference and Trade Fair was held in Salinas on February 28, 1996.

The conference is the result of coordinated effort between the following cosponsors: Fertilizer Research and Education Program, Monterey County Water Resources Agency, Irrigation Training and Research Center at Cal Poly, University of California Cooperative Extension, and University Extension, UC Davis.

The goal of this project is to conduct an annual conference in Salinas to transfer practical knowledge to area growers about the issues and practices of irrigation and fertility management. The conference focuses on practical information and new technologies designed to efficiently manage water and fertilizer inputs. In addition to university researchers presenting recent research findings, the conference also draws on the experience of key industry personnel.

The conference is targeted specifically towards growers in the Salinas Valley and other coastal vegetable producing regions. In 1997, 78 percent of all attendees came from the coastal areas of California. The majority of attendees (44%) were growers from the central coast region. Representatives from farming related businesses such as seed and fertilizer companies and crop consultants made up the second largest group (32%), followed by Cal Poly students (13%) and representatives from public agencies (9%).

Returns from the conference evaluation survey represented a slightly different segment of attendees, with fewer growers completing the survey. However, 80% of the respondents indicated that the conference enhanced their knowledge, and that they expected to use the information in their work.

The main session conference topics included: using pre-sidedress soil nitrate levels to determine sidedress nitrogen requirements for cool season vegetables, field performance of drip irrigation systems in the Salinas Valley, and a moderated industry panel discussion regarding chemical water treatment products for drip irrigation system maintenance.

Concurrent session topics included: irrigation management for wine grapes, fertility management of vegetable crops, soil organic matter management, and water treatment for drip irrigation.

Next year's conference will be held in late February, 1998.

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IV. Completed Projects

The following is a list of projects completed prior to October 1996. Summaries of these projects appear in the 1996 FREP Conference Proceedings, final reports are available by calling FREP or ordering through FREP's Resource Guide.

Fruit, Nut and Vine Crops

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

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

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

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

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EDUCATIONAL VIDEOS

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

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

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

Best Management Practices for Tree Fruits and Nuts Production: A Video
Thomas Doerge and Lawrence J. Klaas

New Projects

DRIP IRRIGATION AND FERTIGATION SCHEDULING FOR CELERY PRODUCTION

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Approximately 25,000 acres of celery are produced annually in California, mostly along the central coast. To reach yield goals of more than 1000 cartons per acre, growers have traditionally applied more than 300 lbs. N and 24 inches of water per acre, considerably in excess of actual crop usage. With future constraints on agricultural water resources likely, and with increasing concern over nitrate pollution of groundwater, more efficient celery production practices must be developed and implemented. Celery growers have already begun to modify their management practices, most notably by converting to drip irrigation. Currently more than 20% of celery acreage is produced under drip; by 1998 at least 30% of celery acreage will be drip irrigated. There is virtually no relevant research on water or N fertility management of celery under drip irrigation. This project proposes to begin to fill that void by developing practical guidelines for optimizing drip irrigation and N fertigation management. The information developed will be disseminated through presentations at grower meetings and trade journal articles; additionally, the results of this research will be summarized in a layman's guide to drip irrigation management of celery. The objectives of the proposed project are to:

- Develop appropriate guidelines for water and N application to drip irrigated celery under varying soil and environmental conditions.
- Disseminate this information to growers, PCAs and consultants involved in celery production.

SOIL TESTING TO OPTIMIZE NITROGEN MANAGEMENT FOR PROCESSING TOMATOES

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Don May
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Processing tomatoes are a major vegetable crop grown throughout California's Central Valley. Mounting evidence suggests that excessive rates of nitrogen fertilizers may be commonly applied to processing tomato crops as insurance so as to safeguard against deficiencies, regardless of residual soil nitrogen levels. Such insurance applications have the potential to negatively impact both the profitability of producers and the groundwater quality of tomato producing regions. The objectives of the proposed project are to:

- Develop and extend information on pre–sidedress soil testing as a means for optimizing nitrogen management for processing tomatoes.
- Evaluate the effectiveness and utility of fresh petiole sap testing for decision making in tomato nitrogen management
- Investigate relationships between fresh sap nitrogen testing, dry tissue testing and current sufficiency levels being used by commercial testing labs for N fertilizer recommendation.
- Evaluate and present the potential of a quick soil nitrogen test as a means for establishing soil nitrogen levels during the season, in conjunction with fresh sap testing.

LONG-TERM NITRATE LEACHING BELOW THE ROOTZONE IN CALIFORNIA TREE FRUIT ORCHARDS

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Nitrate–nitrogen is the most widespread contaminant in groundwater, causing as much as ten times as many well closures in the State of California as all other industrial contamination combined. While a large amount of research has focused on nitrogen cycling in the root zone (to depths of 6'–10'), little is known about the fate of nitrogen between the root zone and the ground water table. Unlike other agricultural regions of the United States, groundwater levels in many areas of Central and Southern California are from 30 feet to over 100 feet deep. Therefore, the deep vadose zone is a critical link between agricultural sources and groundwater. Few studies have surveyed nitrogen levels or denitrification rates at such depths or monitored leaching of nitrogen to a deep water table. Field–scale spatial variability of nitrate levels due to natural variability of soils and vadose zone sediments also remains unaccounted for in most work on groundwater quality impacts of agricultural nitrogen management. The objectives of the proposed research are:

- To investigate the fate of nitrogen throughout the entire deep vadose zone at a well controlled, long–term research orchard with a stratigraphy typical of many areas on the east side of the San Joaquin Valley and Southern California and with management practices representative for orchards and vineyards.
- To develop and validate an appropriate modeling tool to assess the fate of nitrogen in deep (more than 30 feet), heterogeneous vadose zones.

SITE-SPECIFIC FARMING INFORMATION SYSTEMS IN A SACRAMENTO VALLEY TOMATO ROTATION AND A SAN JOAQUIN VALLEY COTTON ROTATION

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The potential for site-specific farming systems to increase profit and resource use efficiency has not been determined for California's diverse surface-irrigated cropping rotations. This project focuses on site–specific farming and monitors two commercial fields in the Sacramento Valley. The rotation being followed is wheat–tomatoes–corn–sunflower. Our main objective is to determine the extent of yield and quality variability within fields and the causes of that variability. Also, we will publish a technical manual with a large number of examples used from this research. As in 1996 and 1997, aerial photographs, yield maps, and soil and plant analyses will be placed in a geographic information system to generate maps and data sets for study of the relationships among variables. A small additional component will be the analysis of airborne images of cotton fields in Fresno County.

Specific issues to be addressed by our research are: (1) whether the required number and position of plant and soil samples (e.g. for nutrient assessment) are stable within a field over the four–year rotation; (2) the usefulness of electromagnetic induction methods for monitoring soil water content after irrigation; (3) whether simple linear regression or multiple regression can detect relationships of soil and plant data to crop yield and quality or whether non-parametric, non-linear methods are required; and (4) development of a site-specific farming outreach program suited to a California field and vegetable crop industry.

DEVELOPMENT AND TESTING OF APPLICATION SYSTEMS FOR PRECISION VARIABLE RATE FERTILIZATION

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Precision or "site-specific" management of agricultural production involves the application of fertilizer, pesticides, water and other inputs on spatial scales smaller than previously used. The concept is simple: by using accurate navigation and positioning, crop yield, soil properties and other factors can be used to develop maps or databases of crop response and geographic variation. Significant research is underway to determine the validity and utility of the concept to California agriculture. Crop response to fertilization practices, variability in soil properties, potential for reduced adverse environmental effects and improved economic returns are being investigated.

This project will address an essential physical component in the implementation of precision farming, namely, a rapid system for varying the application rate of liquid and gaseous fertilizer under the real-world demands of high vehicle speeds, a wide range of rate control, simplicity and dependability.

A unique spray control system has been developed and patented at UC Davis which can control pesticide application rates over an 8:1 range and respond within 0.3 seconds and often within 0.1 second. Performance and durability of the system has been proven by commercial use. The project will investigate the use of the control technique for application of liquid fertilizers and anhydrous ammonia. Accuracy of the system will be determined, as will suitability for GPS or manually-directed application. Performance of the system will be compared to conventional fertilizer application equipment.

AGRICULTURE AND FERTILIZER EDUCATION FOR GRADES K - 12

Mark Linder, Rich Engel, Pamela Emery
California Foundation for Agriculture in the Classroom

California is the leading agricultural producer in the United States for both domestic and foreign consumption. Increasingly, farmers and ranchers are challenged to produce more food on less land for more people. The lack of concise knowledge about the role of agriculture and the important use of fertilizer is repeatedly apparent in society and, in particular, in the print and electronic media. Inaccurate information is frequently transmitted to the general population.

Children are part of our present consumer population and will be our leaders and decision-makers in the years ahead. Educating them about agriculture's role in their lives and fertilizer's role in agriculture will enable them to make informed decisions in the future.

The California Foundation for Agriculture in the Classroom will address these issues in 1997–98 in the following ways: 1) develop, print, promote and distribute Fact/Classroom Activity Sheets which focus on the three primary nutrients; 2) reprint, promote and distribute the previously produced FREP educational units for grades K–12; 3) develop and place advertisements promoting the previously–produced units in educational and agribusiness publications; and 4) promote these units at educational conferences, teacher workshops, and school in-services.

THE DEVELOPMENT OF IRRIGATION AND NITROGEN FERTILIZATION PROGRAMS ON TURFGRASS TO IMPROVE IRRIGATION AND FERTILIZER USE EFFICIENCY

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This project involves the study and development of best management practices (BMPs) for landscape water conservation and N fertility efficiency on tall fescue, currently the most widely-planted turfgrass species in California. Water use is one of the top environmental issues in California. The objectives of the project are to:

- Investigate irrigation treatments that are designed to test irrigating tall fescue at 80% historical reference evapotranspiration plus rainfall, with increased irrigation during the warm season to improve grass performance and proportional adjustments downward in the cool-season.
- Investigate N fertilizer treatments designed to test optimal annual N rates for tall fescue performance in terms of visual quality and drought stress tolerance, growth (clipping yields), and N uptake. We will also determine the influence of irrigation and N fertilizer treatments on soil water content and soil N status.
- Conduct an outreach program including trade journal publications and oral presentations.

DEMONSTRATION PROJECT FOR NITROGEN MANAGEMENT IN CITRUS UNDER LOW-VOLUME IRRIGATION

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Fruit quality problems in recent years have adversely affected the movement of California citrus into the fresh market and severely hurt grower returns. Postharvest rind breakdown and pitting of navels have been particularly critical. These disorders usually do not appear until after fruit have been graded, packed and shipped to export markets where they then result in losses due to repacking charges, price allowances and loss of consumer confidence.

Nitrogen fertilization has been identified as playing a role in several citrus fruit quality issues. With the adoption of pressurized irrigation practices and the inclusion of nitrogen fertilizers in irrigation water, it appears from leaf nitrogen levels that there has been an increase in the total amount of nitrogen applied to citrus over the past ten to fifteen years. This project is designed to complement a research project by the same title currently underway and funded in part by FREP. The objectives of the project are:

- To serve as a commercial-scale verification of results obtained by the research project, i.e., identify the role that current nitrogen fertilization practices play in both fruit quality and groundwater quality in San Joaquin Valley navel orchards.
- To serve as demonstration sites for growers of how best management practices that minimize ground water contamination also can benefit their financial returns by improving fruit quality.

UNIFORMITY OF CHEMIGATION IN MICRO-IRRIGATED PERMANENT CROPS

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Chemigation, the injection of chemicals through an irrigation system, is becoming common among permanent crop growers (tree and vine) using micro–irrigation systems. Advantages to chemigation include: (1) flexibility in timing fertilizer applications, (2) reducing the labor required for applying chemicals, and (3) the potential increase in the efficiency of chemical use, thus reducing the cost of chemical use. Some chemicals (e.g. chlorine) and some fertilizers (e.g. numerous nitrogen sources) readily dissolve in water and are injected via venturi or positive displacement pump injectors. Other chemicals seeing recent chemigation use (e.g. gypsum, potassium sulfate), are not readily soluble and are being injected using "solutionizer" machines.

The proposed project will develop information on the water and chemical travel times and on application uniformity of both readily soluble products (e.g. liquid nitrogen fertilizers) and of low solubility materials (e.g. potassium sulfate) injected via solutionizer machines, (2) develop recommendations in the form of best management practices for chemigation in order to attain uniform application of chemicals, and (3) conduct a series of workshops on chemigation of micro–irrigation systems.

NITROGEN BUDGET IN CALIFORNIA COTTON CROPPING SYSTEMS

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Fertilization practices for cotton in California call for nitrogen applications of 150-200 lbs/acre. These recommendations were developed over 30 years ago for different cotton varieties and different cultural practices. The last fifteen years of cotton production systems have seen the introduction of more determinant cotton varieties with narrower row spacing. In an ongoing experiment with Cotton Incorporated, field trials showed only one of eight trials had a positive response to N. This suggests that there may be adequate N in the soil and fertilization is in excess of crop needs. This research project will evaluate the rate of mineralization of soil organic matter and release of available nitrogen. Representative plots will be labeled with ^{15}N and the partitioning of various fractions of nitrogen will be followed over time The dilution of the ^{15}N label by the indigenous soil N pool provides an indication about the N supply power of the indigenous soil N pool. The objectives of the project are to:

- Determine the rate of mineralization of organic matter and release of N from the pool of labile soil N at the previously established experimental sites.
- Determine the contribution of the labile pool of N to the subsequent cotton crop and determine the N supplying power of the soil at selected sites.
- Conduct an outreach program including extension publication and oral presentations.

WATER AND FERTILIZER MANAGEMENT FOR GARLIC: PRODUCTIVITY, NUTRIENT AND WATER USE, EFFICIENCY, AND POSTHARVEST QUALITY

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Nitrogen fertilization practices by California garlic growers vary tremendously. Rates of N are, however, usually in excess of those indicated from studies conducted by UC Cooperative Extension personnel in the 1980's. Commercial yields are considerably higher now, due largely to the wide-spread use of "virus-free" seed garlic. Timing and amount of irrigation, and the relationships among fertility/water management/yield, fertility/water management/nitrogen leaching potential, and particularly among fertility/water management/harvest and postharvest qualities are all areas with very little information. The specific objectives of our proposal are to:

- Relate fertilizer and irrigation management to yield, and efficiency of water and fertilizer use
- Determine leaf tissue concentrations of nitrogen in relation to fertilizer and irrigation practices
- Relate leaf tissue analyses to quality at harvest
- Relate the postharvest quality of intact and fresh–peeled garlic to different fertilization and irrigation practices.

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