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California Certified Crop Adviser Program

Proceedings edited by Kathy Sole and Margaret Keefer of *WriteSource* and Casey Walsh Cady.

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I. Conference Program

8:00 **REGISTRATION**

8:15– 8:30 **WELCOMING REMARKS**

California Department of Food and Agriculture (CDFA)
California Fertilizer Association

8:30– 8:40 *Fertilizer Research and Education Program (FREP): An Update*
Casey Walsh Cady, Program Coordinator, FREP, CDFA

8:40– 8:50 *Update on CDFA's Facilitated Rulemaking Process for Heavy Metals in Commercial Inorganic Fertilizers*
Steve Wong, Branch Chief, Agricultural Commodities and Regulatory Services, CDFA

9:00– 9:30 *Featured Speaker—The Fact and Fiction of Nutrient Management*
Bryan Hopkins, Servi-Tech Laboratories, Blackfoot, Idaho

9:30– 9:50 *Development of a Nitrogen Fertilizer Recommendation Model for California Almond Orchards*
Qinglong Zhang, Department of Pomology, University of California, Davis

10:00– 10:30 **BREAK**

10:30– 10:50 *Diagnostic Tools for Efficient Nitrogen Management of Vegetables in the Low Desert*
Charles Sanchez, Yuma Agricultural Center, University of Arizona

10:50– 11:10 *Evaluation of Controlled Release Fertilizers and Fertigation in Celery*
Warren Bendixen, UC Cooperative Extension, Santa Barbara County

11:10– 11:30 *Development of Best Management Practices for Broccoli Production in the San Joaquin Valley*
Michelle Le Strange, UC Cooperative Extension, Tulare County

11:30– 11:50 *Effects of Irrigation Nonuniformity on Nitrogen and Water Use Efficiencies in Vegetables*
Blake Sanden, UC Cooperative Extension, Kern County

11:50– 1:00 **LUNCH**

1:00– 2:45 *Crop Production Breakout Session I*
These sessions are designed to provide practical training, up-to-date information and research, and growers' perspectives for these four California cropping systems. Each session will cover important cultural management; including crop quality, stand establishment, harvest timing, variety selection, rotations, seed technology, irrigation, and disease aspects. (Not all of these topics will be covered in each session.)

A) *Garlic/Onions* —Ron Voss, Coordinator
B) *Forages* —Marsha Campbell Matthews, Coordinator
C) *Cotton* —Robert Hutmacher, Coordinator
D) *Processing Tomatoes* —Timothy Hartz, Coordinator

2:45– 3:00 **BREAK**

3:00– 4:45 *Breakout Session II* The sessions listed above will be repeated.

II. Brief Updates

FERTILIZER RESEARCH AND EDUCATION PROGRAM: 1998

Casey Walsh Cady
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 the efficient use of fertilizers. FREP serves a wide audience including growers, agricultural supply and service professionals, extension personnel, public agencies, consultants, and other interested parties.

BACKGROUND

In January 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.

COMPETITIVE GRANTS PROGRAM

In 1990, the Department was authorized to increase the mill tax on fertilizers to conduct research and education projects that advance the environmentally safe and agronomically sound use and handling of fertilizer materials. The program has supported over seventy projects at a projected cost of $3 million, with $2.5 million in matching funds. Of these projects, about forty have been completed. Details about these projects, and the information products available, can be found in these and last year's proceedings, and in our Resource Guide. A comprehensive list of completed projects can be found in Section IV of these proceedings.

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

1998 ACTIVITIES

This year, FREP has been active in a number of issues relative to our mission. We continue to fund new projects, reach a widening audience, and delve into new research areas. Seven new projects were approved for funding in 1998 for a projected multi-year cost of $400,000. Our first rice project will commence in 1999. This project will examine the effect of rice straw management on potassium relations. The issue of air quality as it relates to fertilization practices will be examined through the development of a fertilizer use inventory. Other new projects will focus on developing best management practices for desert agriculture, including avocados, desert sweet corn and vegetables. Cover cropping issues are also being explored in prunes and processing tomatoes.

HEAVY METALS IN INORGANIC FERTILIZERS

In March 1998, CDFA released a report entitled "Development of risk-based concentrations for arsenic, cadmium, and lead in commercial inorganic fertilizers." This risk assessment was funded by FREP and conducted under contract with Dr. Lee Shull of Foster Wheeler Environmental. Upon release of the report, CDFA committed to establish an open, facilitated process to examine potential regulations for heavy metals in commercial inorganic fertilizers (Phase I) and in organic soil amendments such as biosolids and fly ash (Phase II).

CDFA has contracted with a facilitator to develop and implement a process involving various stakeholders. The goal of this process is to address the need for potential regulations in the areas of heavy metals and in inorganic and organic fertilizing materials. The stakeholders include representatives from environmental groups, local and state agencies, the fertilizer industry, California legislative staff, and other agricultural organizations. Representatives from the waste water and cogeneration industries will be included in Phase II.

FREP OUTREACH

CDFA has an excellent web site, which now hosts our program's web site. The site provides information on FREP and how to receive funding, as well as summaries of FREP activities and information. Please visit us at:

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

We are currently working on additional publications that will be released in 1999. These publications 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.

We are also pleased to report that we will 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 sixth consecutive year. The conference is scheduled for January 20-21, 1998, in Visalia.

The Certified Crop Adviser (CCA) program, now in its fifth year of operation, is helping crop production professionals improve their technical proficiency. Hundreds of crop production professionals are benefiting from this program.

ACKNOWLEDGMENTS

I would especially like to acknowledge the members of the Fertilizer Inspection Advisory Board Technical Advisory Subcommittee (TASC); Carl Bruice, Al Ludwick, Steve Purcell, Brock Taylor, Jack Williams, Tom Beardsley, and Jack Wackerman. The TASC members have exhibited dedication, insight, and professionalism and have been invaluable in helping to ensure FREP's success. The members of the Fertilizer Inspection Advisory Board are also hereby acknowledged.

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.

THE FACT AND FICTION OF NUTRIENT MANAGEMENT

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INTRODUCTION

Facts aren't usually as exciting as fiction. Failure is the likely result if we manage our stewardships based on fiction. In the recent past, fiction has often governed nutrient management decisions and regulations. We must be careful that we know the facts, and more importantly, realize what we *don't* know to avoid the pitfalls of absurdity. The purpose of this address is to briefly discuss the facts of major issues affecting nutrient management at this time and in the foreseeable future.

There are four major nutrient management issues affecting agriculture in the United States currently. First, nitrate contamination of drinking water continues to be a concern for those working in agriculture. Second, a more recent issue is the supposed contamination of soil, crops, livestock, and humans by heavy metals in inorganic fertilizers. Third, legislation continues to increase the regulation of manure application to agricultural soils. And finally, the Natural Resources Conservation Service (NRCS, formerly Soil Conservation Service) is planning to require producers participating in federally funded cost share programs to submit written nutrient management plans.

NITRATE IN DRINKING WATER

The issue of nitrate contamination of drinking water has dominated, and continues to dominate, research projects and government regulation and expenditures in agriculture. The result has significantly affected the activities of producers, consultants, and fertilizer dealers with regard to nitrogen management. We know considerably more now than we did fifteen years ago, when this issue was first becoming a concern in agricultural and environmental circles. Research has shown that, indeed, many drinking water supplies have "high" levels of nitrate. We also know, however, that the problem isn't nearly as bad as we were originally led to believe.

Activists concerned about high levels of nitrate in drinking water effectively advertised to the public that this was a widespread and serious problem. The general public and government regulators were persuaded that immediate action should be taken to protect our health and environment. Regulations and guidelines were soon established, in spite of the fact that very little evidence existed that these high levels of nitrates were a substantial health risk.

The initial concern was that high levels of nitrates in the drinking water of infants could cause sickness and even death due to blue baby syndrome. Although very few documented cases of this syndrome have been reported, public hysteria spurred a massive effort to reduce the levels of nitrate in drinking water supplies. Since then, it has also been speculated that high levels of nitrates in drinking water could be carcinogenic, although this concern is still highly theoretical.

Whether the issue of high nitrates in drinking water is a valid concern or not, producers are generally managing their nitrogen inputs more efficiently since they have been made aware of the potential problems. The net effect of this effort will likely result in reduced fertilizer costs, increased yields, and less waste of natural resources in the production of fertilizer. It remains to be seen, however, if this improved management will actually reduce nitrate levels in drinking water over time, and whether or not the considerable expenditure of time and money will result in better health.

HEAVY METALS IN FERTILIZER

A more recent issue that has sparked intense debate among those managing nutrients resulted from a recent court case. A producer in Soap Lake, Washington accused the fertilizer industry of poisoning his family, as well as his livestock, crops, and soil with heavy metals in inorganic fertilizers. The court case was recently dismissed, but the effects are still being felt in the agricultural community. The fertilizer industry organized itself and presented facts to the public and government agencies to alleviate concerns over this issue. However, many legislative and regulatory agencies are still considering mandates that would control heavy metal concentrations in fertilizers. Although the legal aspects of

this issue seem to be stalled, most fertilizer companies continue to investigate methods of reducing and documenting the amounts of heavy metals in fertilizers.

MANURE LOADING LIMITS

Another hot topic in nutrient management is the increasing number of states imposing limits on the amount of manure applied to crop land. Excessive application of manure in states near the Great Lakes and on the eastern coastal plain has generated current and pending legislation governing manure management. The reason for the concern is that nutrient-rich water tends to promote algae blooms, which can result in the death of marine life due to oxygen depletion (eutrophication). The limiting factor for these algae blooms is often phosphorus and/or nitrogen. Soils that are heavily manured tend to have high levels of phosphorus. If these soils are also in areas of heavy rainfall, the phosphorus tends to move to surface waters as a function of soil erosion.

Many states have already passed laws that limit the amount of manure that can be applied to a field in any one year. Most of these state laws also limit the total amount of manure that can ever be applied to a field. Many more states are currently considering similar laws. These laws are similar to those limiting the application of sewage sludge based on heavy metal loading rates. Although some states limit the use of manure based of the concentration of heavy metals, most are limiting application based on phosphorus and/or nitrogen levels.

There are two approaches to using these limits. The first requires that the manure is analyzed, and that the amount applied is regulated based on the most limiting nutrient or metal. The second approach limits the amount of manure to be applied based on soil test values. With this approach there are questions of which soil test to use, how high is too high, and how deep to take the soil sample. The concern with the first approach is that it does not take into account the amount of the nutrients or the metals that are tied up by the soil and/or removed by plants.

Many poultry, cattle, and pork operations are moving out of states with these laws because of the extra labor and associated costs. This approach is probably a temporary solution because many of the states these producers are moving into are also considering manure management regulations. This is in spite of the fact most of the states without current regulations don't have manure management problems. The reason these states don't have problems is because they have less soil erosion (due to less rainfall) and/or low animal to crop land ratios.

A worse case scenario would be the adoption of federal manure management regulations with a "one size fits all" mentality. The concern about this approach is that manure would be regulated similarly to sewage sludge, which would result in a quick reduction of land eligible for manure application. Animal operations would have to move or find alternative ways to dispose of the waste.

NUTRIENT MANAGEMENT PLANS

Another emerging issue is one sponsored by the NRCS to require producers receiving government support payments to file a nutrient management plan. This plan would need to be written by a qualified adviser. Very few details of this program are available at this time. The NRCS will probably enlist the help of a third party vendor, such as the Certified Crop Adviser Program, to provide the expertise in writing the plans, rather than doing it internally. The question remains, however, as to who will pay for this service. There are also many questions and few answers regarding what will be an accepted nutrient management plan.

SUMMARY

It is vital that those with an interest in agriculture work together to make common sense, fact-based decisions regarding the aforementioned issues. We have seen what happens when hysteria and hype drive regulations and public opinion. There is no doubt that we can do a better job of managing nutrients in agriculture. However, our approach, as an industry, needs to be proactive rather than reactive. There may have been fewer questions now about what is a high level of nitrate in drinking water if more of us had become involved when this was an emerging issue. It is almost too late to do anything about the nitrate regulations, other than live by them. We can, however, impact the other issues previously discussed. We must consider world food production, farm profitability, and the environment in all our decisions regarding nutrient management. If we fail to do so, we may experience increased food costs, food shortages, bankrupt producers, and/or environmental contamination.

III. Ongoing Project Summaries

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

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OBJECTIVES

1. Determine the optimum timing and concentration of one or two 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 15N as a tracer
4. Disseminate information to growers about foliar urea using newsletters, meetings, radio, and popular journals

DESCRIPTION

Nitrate leaching into the groundwater is becoming an ever-increasing problem in agricultural areas. Innovative approaches to tree nutrition are needed to reduce soil-applied fertilizers. Foliar nitrogen sprays are one approach that could supply N to the tree and minimize nitrate leaching through the soil.

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 percent 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.

RESULTS AND CONCLUSIONS

Results from the first two years of this study have shown that 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 percent of the labeled urea solution within 48 hours of application in September, October, or early November. However, November applications of urea were not translocated efficiently out of the leaves before extensive leaf senescence occurred. In addition, the N from this November application was not evenly distributed throughout the tree, but remained more in aboveground parts (Table 1). In contrast, the distribution of 15N from a mid-October spray was almost identical to that of control trees. Therefore, we conclude that foliar urea sprays need to be applied in mid-October or earlier to be taken up efficiently and distributed throughout the tree.

To study long-term productivity, an experiment on Early Maycrest peaches was initiated in Fall 1995 at the UC Kearney Agricultural Center. Treatments were set up comparing soil-applied N fertilizer to foliar urea sprays

Table 1-The Distribution Within Peach Trees of ^{15}N from Foliar Urea Applications Made on September 20, October 11, or November 1. (All trees were excavated in January. For comparison, distribution of total N within unsprayed control trees is also shown)

	^{15}N distribution (% of total ^{15}N recovered in perennial parts)		
Application Date	Roots	Scaffolds & Branches	One-year-old Shoots
September 20	38	26	36
October 11	45	27	28
November 1	28	26	46
Unsprayed Control	46	32	22

applied in October. Four treatments were compared:

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

Applying soil and foliar N in the fall (treatment 4) looked very promising (Table 2). First, this treatment had the highest level of stored N in the roots during the dormant season, which contributed to early fruit growth and helped maintain yields and fruit weights equal to the soil fertilized control. In addition, after-harvest leaf N values were somewhat lower in this treatment, which contributed to reduced pruning weights. Therefore, we conclude that a fertilizer treatment split between soil and foliar applications can effectively maintain productivity, while reducing excessive vegetative growth.

In summary, over the past three years, we have demonstrated that N from foliar applications of low biuret urea in early- to mid-October is effectively taken up and distributed throughout peach and nectarine trees. Rates of 50 to100 lb urea/100 gals water/acre supply sufficient N to allow soil-applied fertilizers to be cut back

Table 2-The Effect of Low Biuret Foliar Urea Sprays on Early Maycrest Peaches

	TREATMENTS			
	Unfertilized Control 1	**Soil Fertilized Control 2**	**Split April - Soil Oct. - Foliar 3**	**Split Sept. - Soil Oct. - Foliar 4**
Root N (%)				
1/96	.70 c	1.33 b	.97 c	1.59 a
1/97	1.02 c	1.29 b	1.37 b	1.62 a
Yield (kg/tree)				
5/96	8.4 b	12.8 a	10.7 ab	12.6 a
5/97	10.7 b	15.0 a	15.1 a	15.1 a
Fruit Weight (g)				
5/96	97.7 b	114.8 a	110.3 a	113.5 a
5/97	90.9 b	110.8 a	103.1 a	110.9 a
Leaf N (percent)				
7/96	2.45 b	2.76 a	2.79 a	2.60 ab
7/97	2.56 b	2.72 ab	2.92 a	2.63 b
Summer Pruning (kg/tree)				
7/96	2.4 b	5.9 a	5.0 a	3.5 b
8/97	3.2 c	9.0 a	6.6 b	6.2 b

substantially, thus reducing excessive vegetative growth without hurting productivity. Associated studies have shown that urea can be mixed with zinc sulfate sprays applied at the same time of the year and that urea enhances the uptake of zinc. Therefore, foliar urea is a tool that can not only help reduce nitrate pollution of groundwater, but can also assist a peach grower with other cultural practices.

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 trade magazine articles, newsletters, and through presentations at grower meetings

DESCRIPTION

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 the fruit has been graded, packed, and shipped to export markets. At this point, losses result 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.

In the past, ground water contamination with nitrates has been linked to rates of nitrogen application. With the advent of fertigation, the potential for groundwater contamination may be increasing. It is in the best interest of growers to address this issue proactively and to adopt practices that can lead to reduced groundwater contamination. To this end, growers must be made aware of best management practices relative to nitrogen management.

In 1998, an additional demonstration component was added to the project. Its purpose is to serve as a commercial-scale verification of results obtained by the research project and to demonstrate to growers how BMPs can benefit their financial returns by improving fruit quality.

We are now in the second season of differential treatments (See table below). Differential nitrogen treatments commenced in Spring 1997 and are being applied for the second time in 1998. The first harvest following differential nitrogen applications was

completed in March 1998. Soil solution samples have been collected since December 1997. Leaf analyses from all four project sites are presented in this report, as are yield data and results of soil solution analyses from the Griffith Farms site (main plot located in Exeter/ Woodlake).

RESULTS AND CONCLUSIONS

Leaf Analysis

Leaf samples were collected from all treatments at the four nitrogen project sites in Fall 1997. In comparing Griffith Farms results from 1997 with those of 1996, all constituents differed significantly between years. In some cases, contents in 1997 were significantly greater than 1996 contents (N, Mg, S, Mn, Fe, and Cu), and in others, the 1997 contents were significantly lower (P, K, Ca, Cl, Na, B, and Zn). Differences in leaf constituents across treatments were much more prominent in 1997 than in 1996, and it is difficult to account for the differences, except for nitrogen. The differences in nitrogen contents reflect nitrogen treatments. Leaf nitrogen contents (averaged across four replications) for the 25 treatments are plotted as a function of total nitrogen applied (See Table 1). For a given amount of applied nitrogen, foliar application resulted in higher leaf nitrogen contents in every case, as compared to soil-applied nitrogen. With one exception, continuous application to the soil resulted in higher leaf nitrogen contents than did soil application as a single or split application.

The nitrogen content of leaves sampled in 1997 at the three satellite sites also increased compared to leaves sampled in 1996 prior to differential nitrogen application. There was no consistency in trends between years, within sites, for any of the other leafy constituents; some increased from 1996 to 1997, some decreased, and some did not change. Significant differences were also found among the satellite sites for some leaf constituents. While the nitrogen content was higher at Neece (Terra Bella) than at the other two sites, no trends for leaf constituents among the three sites were found.

SOIL SOLUTIONS

Soil solution samplers were installed below the root zone in all plots at the four project sites. Enough data are available from the Griffith Farms site to see trends related to the nitrogen treatments. Solutions collected from the samplers have been analyzed for nitrate nitrogen and chloride. Nitrate nitrogen is the dominant soluble, inorganic form of nitrogen in soils at the field sites. In order to account for differences in leaching volumes, chloride is used as a reference ion.

Soil solutions were collected from the Griffith Farms site five times from December 1997 through April 1998. The NO3-N concentrations leaching below the root zone are dramatically impacted by the nitrogen treatments, especially the soil-applied nitrogen. The NO3-N concentrations increase with increasing nitrogen application. This trend still holds when differences in leaching are accounted for by using chloride in a NO3-N:Cl (chloride) ratio. In every case where comparable foliar and soil applications have been made, foliar applications result in lower NO3-N concentrations in soil solutions leaching below the root zone.

The effect of the winter rains can also be seen in the soil solution data. The chloride concentrations decreased from December to April. Since the chloride concentration of rainwater is less than that of irrigation water, the high Cl concentrations in December are likely from 1997 irrigation. As the rainfall percolated through the soil, the residual chloride was leached out, and the Cl concentrations decreased. During the next few months, the Cl concentrations were expected to again increase as irrigation water reached the samplers.

The few results obtained for the three satellite sites do not yet illustrate clear trends. Solution sampling will continue throughout the coming months, and results for these sites will be provided later this year.

Table 1. Schedule of Experimental Treatments for Nitrogen Management Project for Main Experimental Site near Exeter/Woodlake (Griffith Farms)

Treatment	Soil Applied (lb/tree/yr)	Timing (times/yr)	Foliar (# applications)	Total N (lb/tree/yr)
2	0	-	1	0.25
3	0	-	2	0.50
4	0	-	4	1.0
5	0.5	1	-	0.5
6	0.5	2	-	0.5
7	0.5	C	-	0.5
8	1.0	1	-	1.0
9	1.0	2	-	1.0
10	1.0	C	-	1.0
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		Soil Only	
Applications[z]	Lb N/tree/yr	Lb N/tree/year	Timing[y]
0	0	0	1,2,C
1	0.25	1.0	1,2,C
2	0.50	1.5	1,2,C
4	1.00	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
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

[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 two applications will have an additional application in late winter. Trees receiving four 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.

DEVELOPMENT OF A NITROGEN-FERTILIZER RECOMMENDATION 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, and site-specific N management program

DESCRIPTION

Total leaf-N and nitrate-N levels in leaves were examined throughout the growth season.

Leaf samples of Nonpareil almonds taken from commercially managed orchards in San Joaquin County showed that total leaf-N declined steadily from 5 percent in March to 1.9 percent in December, while leaf nitrate-N increased steadily from 20 ppm in March to about 300 ppm in summer. Nitrate-N in leaves remained at this high level, even after nut harvest, and began to decline after October.

The second aim of this research was to determine the seasonal patterns of N demand in mature almonds. To this end, sequential whole-tree excavations were conducted on 1/21, 3/20, and 5/20 at the Delta College orchard, Manteca, California, and there will be one excavation at harvest and in the spring of the following year. Weight of individual trees excavated ranges from 570 kg to 799 kg dry, with corresponding total N content of 4 to 6 kg N. The highest proportion of total N was present in root and root stock in January and March. Fruit and canopy had the largest proportion of total N in May. Nitrate and total soluble N represented only a small proportion of total N presented in the whole tree. Detailed information will be presented in the final report.

RESULTS AND CONCLUSIONS

Among the field nitrate testing methods used, the portable nitrate meter (Agri-lab) is the best method for measuring tissue extracts of almond, while the portable nitrate meter (HORIBA Inc.) over-estimated the nitrate levels. The semiquantitative method (Merck color indicator strips) provides only limited sensitivity in measuring nitrate level in the tissue extracts.

Leaf total soluble N (including extractable NO_3 and NH_4^+-N) is more responsive to fertilizer application than total N and nitrate-N. Regression analysis in nine commercially managed orchards indicates that meat yield per tree is not a function of leaf total N in late July. Thus, leaf total N was a poor predictor for almond yield. Leaf nitrate-N level in these orchards ranged from 30 to 600 mg/g at a single sampled date and there was no significant correlation between meat yield and leaf nitrate-N level.

Also, almond meat yields were compared to leaf total N, and nitrate-N levels. At two locations where N applications were experimentally manipulated (rates ranged from 0 to 500 lb N/acre), correlation analysis of almond meat yield with leaf total N and nitrate-N, during the growth season, suggests that almond meat yield is highly correlated($r=0.50$ to 0.75) with total N after the May sampling date for all three varieties (Nonpareil, Carmel and Mission). However, almond meat yield was only poorly correlated with leaf nitrate-N level.

The poor correlation between meat yield and leaf nitrate-N level is attributed to the fact that leaf nitrate-N levels changed dramatically during the growth season in response to fertilization and irrigation patterns. Variations of from 10 to 80 mg/g and 10 to 146 mg/g NO3-N were observed during the growth season at Yolo and Colusa County, respectively. Thus, it is concluded that leaf nitrate-N level is not a good predictor for almond meat production. Further correlation analysis between N application levels and leaf N status indicates that leaf total N level is highly correlated with the amount of N applied, especially after May. The relationship between leaf nitrate-N and the amount of N applied varies with different cultivar and time of year. Leaf nitrate-N level is a good indicator of N applied for Mission in May and June only, and it was a poor indicator in July and thereafter. Leaf nitrate-N level was a fair to good indicator of N application rate for most sampling dates during the growth season for Carmel and Nonpareil.

FERTILIZER USE EFFICIENCY AND INFLUENCE OF ROOTSTOCKS ON UPTAKE AND NUTRIENT ACCUMULATION IN WINE GRAPES

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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 (15N) 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

DESCRIPTION

Nitrogen is the fertilizer used most often in California vineyards. Most of the studies conducted on grapevines to determine vine nutritional requirements and vine nutrient status were conducted in vineyards located in the San Joaquin Valley. 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).

Nutritional status of grapevines is usually measured by analyzing nutrients in petioles opposite the cluster at a particular phenological stage (generally bloom or veraison). This technique is also used to determine the efficiency of a fertilizer application in fertilizer experiments. Unfortunately, petiole analysis only gives a 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 of determining vine nutritional status. The only way to definitely determine N fertilization use efficiency in a field situation is to use 15N labeled fertilizer, a non-radioactive isotope of nitrogen. The amount of 15N present in plant tissues can be quantified with the use of a mass spectrometer.

RESULTS AND CONCLUSIONS

This study will use 15N 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). The fertilizer was applied beneath the 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 Carneros district of Napa Valley. To determine the amount of N to apply at berry set, vineyard yield was estimated from previous years' harvests, and total N required for fruit growth was determined. The amount of ammonium nitrate required to replace the

estimated amount of N removed from the crop at harvest in 1997 was applied to six individual vine replicates of each rootstock. This figure amounted to anywhere from 30 to 45 kg per ha (27 to 40 lb/acre). The actual amount of N removed from the fruit at harvest in 1997, averaged across rootstocks at the four sites, was 33, 31, 22, and 21 kg per ha (29.4, 27.6, 19.6, and 18.7 lb/acre). The difference in N applied to actual N at harvest was due to an overestimation of both the final yield and the amount of N removed from the vineyard in one ton of fruit. It was assumed that one metric ton of fruit contained 1.5 kg N (3 lb/ton), while the actual amount of N per unit weight of fruit ranged from 1.58 to 0.98 kg N per ton (3.15 to 1.96 lb/ton) of fruit.

Prior to applying the fertilizer, petioles were sampled to determine vineyard nutrient status using the traditional method of testing for total N in the fruit at harvest, in the leaves as they fell from the vine, and in the pruning wood. This sample included an analysis of petiole nitrate N and total K. Other elements measured on the petioles were phosphorus, zinc, sodium, chloride, boron, calcium, and magnesium. There were large differences in petiole nitrate nitrogen among vineyard locations, and among rootstocks, at a single location. For example, petiole nitrate nitrogen averaged across rootstocks was 59, 664, 815, and 7070 parts per million (ppm) (on a dry weight basis) at the Oakville, Monterey, Carneros, and Paso Robles sites, respectively. At the Paso Robles site, petiole nitrate nitrogen averaged 4042, 6090, 7462, 7878, and 9876 ppm for the 110R, 5C, 140 Ru, 1103P, and Freedom rootstocks, respectively. The percentage of total N in the clusters at harvest, averaged across rootstocks, was 0.426, 0.522, 0.531, and 0.639 (on a dry weight basis) at the Oakville, Monterey, Carneros, and Paso Robles sites, respectively. At the Paso Robles site, percent cluster N averaged 0.565, 0.6, 0.669, 0.684, and 0.677 for the 110R, 5C, 140 Ru, 1103P, and Freedom rootstocks, respectively.

The results would indicate that there does appear to be a relationship between bloom-time petiole analysis and total N found in the fruit at harvest (and also leaf N at leaf fall and cane N at pruning [data not given]). However, there is a certain petiole nitrate level in which a further increase does not result in a further increase in tissue total N levels. This petiole nitrate value probably lies in the range from 1000 to 1500 ppm. It is unknown at this time whether a reduction below the above range would negatively impact vine productivity. Further study is required, and it is anticipated that data collected for this project for the current growing season (1998) and next year (1999) will refine the specific petiole value.

The total amount of N in the vines (i.e., the N found in the vine's clusters, leaves after leaf fall, and canes at pruning) averaged 58.7, 47.2, 43.7, and 44.7 kg per ha (52.3, 42.0, 38.9, and 39.8 lb N/acre) at the Carneros, Monterey, Paso Robles, and Oakville sites, respectively. It is apparent that these values were not related to the petiole nitrate levels recorded at those sites. Many assume that a high value of nitrate in the petiole is associated with a greater uptake of nitrogen. In addition, petiole nitrate levels of individual rootstocks were not associated with total N accumulated by an individual rootstock. For example, at all locations scions on the 5C rootstock had greater petiole nitrate levels than those on 110R. However, Chardonnay scions on 110R accumulated more N in the clusters, leaves, and canes than those on 5C, while Cabernet scions on 110R accumulated less nitrogen than those on 5C.

Fertilizer use efficiency (FUE) (ratio of applied 15N to 15N taken up by the vine) was calculated for all rootstock/scion/location combinations. There were few differences among rootstocks at a given location. This result was anticipated as all rootstocks were culturally treated the same (i.e., vertical trellis system, shoot positioned, hedged at a certain height, and drip irrigated according to best estimates of vine water requirements). All fertilizer applications were such that the nitrogen was applied directly beneath an emitter while irrigating. There were somewhat larger differences in fertilizer use efficiency among locations. Fertilizer use efficiency, when averaged across rootstocks, was 10.3, 3.81, 3.45, and 11.5 percent at the Carneros, Monterey, Paso Robles, and Oakville sites, respectively.

There are several explanations for the differences among sites. The extremely high petiole nitrate levels at the Paso Robles vineyard may indicate an abundance of soil nitrogen at that site, thus diluting the uptake of fertilizer N. At the Monterey site, the cooperator applied an NPK fertilizer without our prior knowledge, again diluting the 15N fertilizer applied at berry set. The higher FUE at the Carneros and Oakville sites may have been due to the fact that neither vineyard had been fertilized since planting,

and the Oakville vineyard had very low petiole nitrate levels when sampled at bloom (an average of 59 ppm).

The above FUEs seem quite low compared to an FUE of approximately 40 percent that the project investigator found on Thompson Seedless grapevines grown in the San Joaquin Valley. It should be pointed out that the FUEs presented in this summary were based upon N found in the fruit, leaves, and prunings, while those on Thompson Seedless also analyzed the root system, trunk, and fruiting wood. Those three organs contained approximately 40 percent of the total 15N labeled fertilizer taken up by the vines in that study. We anticipate that the labeled fertilizer in the trunk, cordons, and root systems of the vines used in this study will be remobilized and found in the clusters, leaves, and pruning when those organs are harvested at the end of the 1998 and 1999 growing seasons. Thus, it is important that this study be conducted for at least three growing seasons. We currently have permission to harvest the entire vine at two of the locations, so I will be able to determine if any residual 15N remains in the trunk, cordon, or root system after three years.

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 and 1997-1998 growing seasons.

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 purpose this season was to evaluate all diagnostic technologies under conditions of sub-optimal, optimal, and supra-optimal levels of N nutrition, correlate diagnostic tools to growth and yield, and correlate the various diagnostic tools to each other. In 1996-1997 and 1997-1998, 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

In 1995-1996 the responses to N were generally curvilinear, which allowed an excellent opportunity for evaluating diagnostic technologies for assessing N nutritional status. The lower portion of the response curve, where yield response is proportional to N rate, indicates N deficiencies. The upper portion of the response curve, the points beyond maximum yield, corresponds to excess N nutrition. Hence, we were able to correlate several diagnostic technologies to growth and yield.

In 1996-1997 and 1997-1998 we worked in sites that were responsive to N fertilization, as well as sites that were non-responsive to N fertilization. This allowed testing of the predictive potential of the diagnostic tools evaluated.

Chlorophyll Meter Readings

There was a general increase in chlorophyll meter readings to 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 percent. There were also frequent reversals in readings among N rates. An evaluation of variance components showed extreme variation in readings on different locations on an individual leaf, relative to other sources of error. We believe this variation in color on lettuce leaves, combined with the small sensor size on the SPAD 502, likely confounded readings. Furthermore, chlorophyll meter readings varied substantially with cultivar, further limiting its use. Evaluation of the chlorophyll meter as a tool to diagnose N deficiencies was discontinued after 1995-1996.

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 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, qualitative tools that 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.

Dry Midrib or Petiole Nitrate-N Test

Dry midrib and petiole nitrate levels increased to N fertilization in most experiments. However, we concluded from results collected during 1995-1996 that the dry 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 and 1997-1998, where the midrib-N test did not successfully predict the need for the first sidedress N fertilization application after thinning. The dry petiole test generally predicted the need for N by the second sidedress and third sidedress N application for broccoli and cauliflower. For lettuce, the relatively high frequency (31 percent) with which a positive response was predicted but did not occur, suggests that some revision of critical midrib nitrate-N values is needed. We suspect that lettuce cultivars planted during the early planting season (September-October) may have a different critical level than those seeded later in the season. We are optimistic that we will be in a position to identify more appropriate critical values for lettuce as we complete analysis of our 1997-1998 database.

Sap Nitrate-N

Sap nitrate-N increased with N rate in most experiments. In 1995-1996, we reported that the sap nitrate test was correlated to the dry midrib nitrate-N test, although there was variability. The impact of this variability became apparent in the 1996-1997 and 1997-1998 seasons, where the frequency of inaccurate diagnosis was high, compared to the dry midrib or petiole nitrate-N tests. We believe this 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. The sap test might be used as an adjunct to the dry tissue testing program; it might be used for more frequent analysis and allow for more rapid turnaround time.

However, because of this variability, we do not endorse the sap test as a substitute for the dry midrib or petiole tissue test.

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. A correlation between a standard laboratory nitrate-N test and a quick test using the Cardy meter showed substantial variation. Because the Cardy meter readings are potentiometric determinations, they are susceptible to interference from salinity (chloride). Salinity variation in soil samples is undoubtedly more pronounced than in plants, because plants have physiological exclusion mechanisms. We suspect variation in salinity across low desert soils will limit the utility of the Cardy meter as a tool for quick nitrate soil tests. During 1997-1998, we used nitrate sensitive colorimetric test papers, which are less sensitive to salinity-induced variation than the Cardy meter. Preliminary results look promising. We will make final conclusions concerning these colorimetric test strips as we complete analysis of data collected during the 1997-1998 season.

EVALUATION OF CONTROLLED RELEASE FERTILIZERS AND FERTIGATION IN STRAWBERRIES

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OBJECTIVES

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, through workshops, field days, and research reports, the advantage of best management practices

DESCRIPTION

Strawberry and vegetable crops are the most valuable crops and represent the highest acreage (over 30,000 acres) in Santa Maria Valley. These crops are grown all year and require large amounts of nitrogen and other fertilizer nutrients for economic production. Grower acceptance of new nutrient management programs will be based on cost-effective practices that produce crops with good quality and high yields. Santa Maria is designated as a high priority area for the protection of the ground water. Previous research has indicated Santa Maria Valley has the potential for the leaching of nitrates into the ground water. The use of controlled release fertilizers can significantly reduce the nitrogen leaching hazard, especially during winter months. The advantage of control release fertilizers is that the nutrient release pattern is based on temperature and time. The amount and frequence of water application has little effect on nutrient releases.

Strawberries
Three fertilizer trials were established on strawberries during 1996-98. All of the trials were located east of Santa Maria. The trials received the same fertigation, irrigation, pest control, and picking schedule as the commercial fields.

The strawberries were harvested by the growers' commercial strawberry pickers. Fresh and freezer yields were based on the growers' high standard for fruit quality.

The preplant fertilizer treatments were applied in October to compare three controlled release fertilizers, a standard fertilizer, and no preplant fertilizer. The controlled release fertilizers were compared at 2 rates, 80 and 160 pounds of nitrogen per acre. The fertilizers were placed 5 inches below the bed surface and 2 inches to the side of the plants. Each fertilizer treatment was replicated four times in a randomized block design. The plots were 1 bed (64 inches) wide. The 1996 and 1997 plots were 25 ft long, and the 1998 plots were 30 ft long.

Celery
Santa Maria Valley has been targeted as a nitrate-sensitive area. 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 ft long and four beds wide. The two center beds, 25 ft 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.

RESULTS

Strawberry yields were tested over three years, and celery yields were tested at two ranches.

Strawberries, 1996

The strawberry yields are shown in Table 1. The strawberry yields were not significantly different between the three controlled release fertilizers. The controlled release fertilizers with 160 pounds of nitrogen per acre produced significantly higher strawberry yields than the plots with 80 pounds of nitrogen. The yields were very high for this area, indicating a good production management program.

The standard commercial fertilizer, at 160 pounds of nitrogen, produced yields similar to the 80 pounds per acre rate of the controlled release fertilizers. The treatment with no preplant fertilizer produced significantly lower yields than the other seven treatments.

Soil samples collected in May and June showed non-significant differences between fertilizer treatments in NO3-N and ECe concentrations. The samples ranged from 1.1-12.0 ppm - NO3-N and 1.2 -3.9 ECe of the soil solution.

Strawberries, 1997

The strawberry yields are shown in Table 2. The fertilizer trial showed the advantage of a preplant fertilizer application. The three controlled release fertilizers showed non-significant difference in strawberry yield. The three controlled release fertilizers with 160 pounds of nitrogen per acre produced significantly higher strawberry yields than the treatments with 80 pounds of nitrogen.

The standard commercial fertilizer at 160 pounds of nitrogen produced yields similar to the 80 pounds per acre of controlled release fertilizer. The plots receiving no preplant fertilizer produced the lowest strawberry yields.

Soil samples showed non-significant differences between treatments for N03-N. The soil N03-N ranged from 1.0-8.0 ppm. The surface area had relatively low concentrations. The N03-N at the deeper depths had a wider range with 2-8 ppm.

Strawberries, 1998

The strawberry yields are shown in Table 3. The yield shows the control treatment was significantly lower than all the other treatments receiving preplant fertilizer.

Celery, Ranch 2

The celery yields at ranch 2 were high, ranging from 77,376 to 96,270 lb/acre. Celery yields and stalk size are shown in Table 4. The celery yields were not significantly different among 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 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.

Celery, Ranch 6

The celery yields on ranch 6 were higher than on ranch 2. Celery yields and stalk size are shown in Table 5. The yields ranged from 104,819 to 115,659 lb/acre. The celery yields were not significantly different between the two controlled release fertilizers. The two controlled release fertilizers, at 160 lb/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 compared to the controlled release fertilizer treatments.

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.

CONCLUSIONS

Both strawberries and celery showed increased yields, as discussed below.

Strawberries
The three fertilizer trials clearly show the response to preplant nitrogen applications in addition to the nitrogen applied by fertigation through the drip system.

Two of the three trials showed a yield response to the 160 lb/acre controlled release fertilizer over the 80-pound application.

Celery
Celery yields may be increased through the use of controlled release fertilizers during years with heavy winter rainfall.

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

Fertilizer		N Preplant		Fruit Yields*		
				Fresh	Freezer	Season Total
			lb/acre			
1 Duration	24-8-15	urea	160	71,368 a	9,655 a	81,023 a
2 Agricote	22-7-11	urea	160	70,259 a	9,295 ab	79,553 a
3 Agriform	18-8-13	NH_4NO_3	160	69,744 a	9,172 ab	78,916 a
4 Duration	24-8-15	urea	80	65,804 b	8,672 ab	74,476 b
5 Agricote	22-7-11	urea	80	66,072 b	8,227 b	74,299 b
6 Agriform	18-8-13	NH_4NO_3	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%

Table 2-1997 Strawberry Fruit Yields with Two Fertilizer Rates and Three Controlled Release Fertilizers in Combination with Fertigation

Fertilizer			Nitrogen Preplant lb/acre	Fruit Yield*		
				Fresh	Freezer	Season Total
1. Duration	24-8-15	urea	160	46,802b	40,275a	87077a
2. Helena	20-7-15	urea	160	46,823b	39,544ab	86,366a
3. Agriform	18-8-13	NH_4N0_3	160	48,166a	38,368bc	86,534a
4. Duration	24-8-15	urea	80	42,563c	36,443de	79,006b
5. Helena	20-7-15	urea	80	42,920c	35,409de	78,329b
6. Agriform	18-8-13	NH_4N0_3	80	44,666bc	35,132e	79,798b
7. Commercial	15-15-15		160	43,843bc	37,168cd	81,011b
8. Control	-	-	-	34,765d	32,561f	67,326c

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

Table 3-1998 Strawberry Fruit Yields with Two Fertilizer Rates and Three Controlled Release Fertilizers in Combination with Fertigation

Fertilizer			Nitrogen Preplant Lb/Acre	Season total yield*
1. Duration	24-8-15	urea	160	67890a
2. Helena	20-7-15	urea	160	66279a
3. Agriform	18-8-13	NH_4NO_3	160	67429a
4. Duration	24-8-17	urea	80	69417a
5. Helena	20-7-15	urea	80	65879a
6. Agriform	18-8-13	NH_4NO_3	80	66581a

Table 4-Celery Yield and Size Distribution (Ranch 2)

Fertilizer		Nitrogen Lb/Acre	Yield Lb/Acre	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	55.0 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	52.7	23.2 A
					NS	

Ranch 2
Size distribution data on size 30 values are not significantly different at the 5 percent level.

Table 5-Celery Yield and Size Distribution (Ranch 6)

Fertilizer		Nitrogen Lb/Acre	Yield Lbs/A	Size Distribution 18	24	30
				% of Stalks		
Duration	27-9-9	160	115,659 A	41	92	24
Scotts 25	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

Ranch 6
Size distribution data values are not significantly different at the 5 percent level.

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

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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

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 1,000 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 the weather is extremely variable during head formation, when nitrogen demand is high.

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.

(An updated summary for this project was not received in time to be included in this publication. Please contact the CDFA/FREP office for a copy of the latest report.)

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-ft lengths of pipe with 2-ft sprinkler risers set up in laterals with 40- to 48-ft 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 percent. 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 ft could boost DU to 80 to 90 percent, 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 and producing irrigation uniformity, and reducing nitrate leaching.

OBJECTIVES

The objective is to evaluate the effectiveness of standard and alternative sprinkler lateral spacing in solid-set sprinkler irrigation systems on water and N fertilizer use efficiencies, in commercial carrot production systems, in the Southern San Joaquin Valley by:

1. Characterizing in-field irrigation distribution uniformities and their relation to soil N distribution and leaching and the impact on crop N distribution, yield, and quality
2. Using computer modeling to simulate these alternative management strategies, given the soil hydraulic properties

DESCRIPTION

Seven different sprinkler lateral spacings of 33.3 to 48 ft over three different carrot plantings were tested. The same field was used for the Spring 1996 and Fall 1997 trials, with subsampling from nearly identical locations for both years. The age of sprinklers used each season were new (Spring 1996), two years old (Spring 1997), and greater than three years old (Fall 1997). The first trial was planted on 40-inch beds, with the last two on 36-inch beds. Irrigation duration was scheduled in an attempt to apply the same depth of water (about two inches for established carrots) to all spacings.

One intensively sampled grid with each node, consisting of two beds wide by five feet 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 48 sample points, depending on lateral spacing. In addition to these grids, four replicated sites measuring yield, soil water content, precipitation, and nitrate leaching were established at three to four locations in each lateral

spacing, in an attempt to sample the spots of high, medium, and low precipitation. Anion exchange resin bags (25 sq.cm. with five dry grams of BIO-RAD AG 1-X8 resin) were installed at three feet and retrieved three times during the season to monitor nitrate leaching. Soil solution access tubes (SSAT) were installed in the final two trials as a spot comparison with resin bags.

Soil samples were taken at planting and after harvest to a depth of four feet, to correspond with the location of resin bags. Plant samples were also collected during the season.

Undisturbed soil cores were taken from the 100-acre field to determine soil hydraulic characteristics to calibrate and develop a computer model. Model components include irrigation and fertilization; water and N cycling in the rootzone; along with uptake, yield, and leaching. The model also accounts for field spatial variability.

The final component of this project is regional, solid-set sprinkler evaluations testing various ages of sprinklers in comparison to new nozzles and new sprinklers, to determine the impact of sprinkler age on uniformity. Hydraulic properties of soil cores from a potato, onion, and garlic field will also be used to calibrate the model for estimating nitrate leaching from these fields.

RESULTS

Distribution Uniformity

Irrigation System Distribution Uniformity (DU), as measured with periodic catchcan evaluations, varied from a mean low of 71.8 percent for a 45-ft spacing with the 3+ year-old sprinklers to a high of 86.0 percent for the 46.7-ft spacing with new sprinklers. The 40-ft and 42-ft spacings were the most consistent, regardless of age, at 77.4 to 82.0 percent. All of these values exceed the 65 to 70 percent mean DU reported for most hand-move solid-set aluminum pipe in California. The age of sprinklers and nozzles made the biggest difference; with a mean evaluation DU of 81.6, 79.1, and 74.8 percent for the new, two-year, and 3+ year-old sprinklers, respectively. Leaching and applied water is always greatest near sprinklers when nozzles and spoons are more than two years old.

A "mean normalized sprinkler DU" was calculated to estimate the uniformity of precipitation for the whole season. This value accounts for shifts in wind pattern from one sprinkler evaluation to another and provides a more "plant based" viewpoint of seasonal precipitation uniformity. The result is a general increase of four to eight percent in seasonal DU over the straight mean DU. These DU's (from a low of 81.6 to a high of 90.8 percent) are more consistent with the uniformity of total root system yield, as discussed below. Natural rainfall greatly increased the seasonal uniformity of the Fall 1997 trial (Table 1).

Yield

Total root yield and quality was not statistically different for any of the spacings for sampling over the entire field, although a consistent trend of two to six percent increased yield for the closest spacing was observed for each trial. Total root yield for the 42-ft intensively monitored grid in the Spring 1997 trial was significantly greater than the grid from the 48-ft spacing by 6.2 ton/acre (Table 1), but this difference was reduced to 1.5 ton/acre for overall field sampling (Table 3). Total root yield DU ranged from 81.5 to 89.3 percent, with no significant differences from lateral spacing. Total precipitation in monitored grids ranged from 75 to 160 percent of evapotranspiration (ET) for the season, depending on location relative to sprinklers. There was no correlation with yield and applied water at these levels (Figures 1 and 2) for any spacing, suggesting that carrots are capable of maximum yield even under some deficit irrigation.

Leaching

Nitrate leaching, as estimated by anion-exchange resin bags, was found to be 7 to 12 percent (19.2 to 30.5 lb/

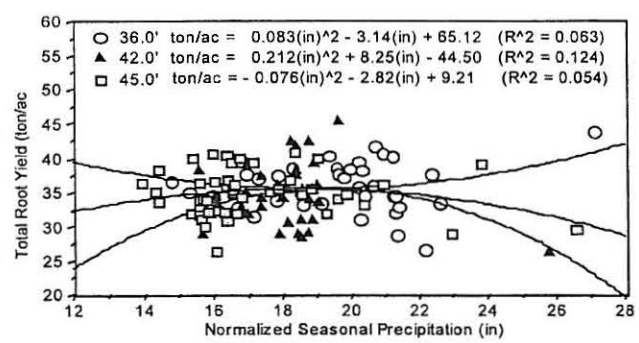

Figure 1—Second Order Polynomial Regression of Total Root Yield and Normalized Seasonal Applied Water for Intensively Monitored Grids, for All Spacings, for the Fall 1997 Trial (Same field, and approximately same sites, as Spring 1996 trial)

Table 1—Typical Irrigation Set Times, Sprinkler, And Root Yield Distribution Uniformity (DU) Characteristics Of In Intensively Sampled Grids Under Varying Sprinkler Lateral Spacings

Lateral Spacing (ft)	Typical Irrigation Set Time (hrs)	Applied Water Per Set (in)	[1]Total irrigation for season (in)	Mean Root Yield for Gridded Plots (ton/ac)	[2]Mean Normalized Sprinkler DU (%)	Yield DU (%)	[3]R^2 for Normalized Sprinkler and Yield DU	Mean Evaluation DU (%)
Spring 1996								
33.3	8.5	2.21	25.65	35.95	84.1	84.3	0.047	*80.6 ab
40.0	10	2.16	25.63	37.35	81.6	81.5	0.114	78.1 a
46.7	12	2.23	26.08	36.03	89.9	85.4	0.073	86.0 b
Spring 1997								
42.0	10	2.41	30.94	*38.80 a	87.6	89.3	0.054	82.0
48.0	12	**2.64	34.32	32.48 b	84.2	85.2	0.042	76.2
Fall 1997								
36.0	9.5	**2.67	19.64	35.91	84.2	87.2	0.063	75.2
42.0	11	2.35	17.96	34.58	90.8	85.6	0.124	77.4
45.0	12	2.40	17.27	34.81	87.6	88.0	0.054	71.8

[1] Rainfall negligible for Fall 1996 and Spring 1997. Fall 1997 includes 5.19ĩ rainfall.

[2] Normalized precipitation for each grid element was computed as a percent of the average of each evaluation. The mean normal value for each element of all sprinkler evaluation times total precipitation for the season is used to compute mean normalized sprinkler DU.

[3] R^2 values are for a second order polynomial regression of yield and normalized precipitation by grid element and spacing.

[4] Equals the mean of the computed DU values from individual evaluations. Does not include rainfall events.

* Numbers with different letters are significantly different at the 0.05 level.

** Pressure excessive due to cooperator error when changing sets.

Table 2—Nitrate-N Leaching as Estimated by Anion-Exchange Resin Bags for Spring 1996 Trial by Lateral Spacing

Lateral Spacing (ft)	Resin Bag NO3-N (lb/ac)	Coefficient of Variation	Adjusted Leaching @ 85% Recovery	Estimated NO3-N Leached (%)	Total Yield (ton/ac)
33.3	25.9 a	0.54	30.5	12.2%	43.66
40.0	16.3 b	0.55	19.2	7.7%	41.16
46.7	21.3 a	0.31	25.1	10.0%	41.09

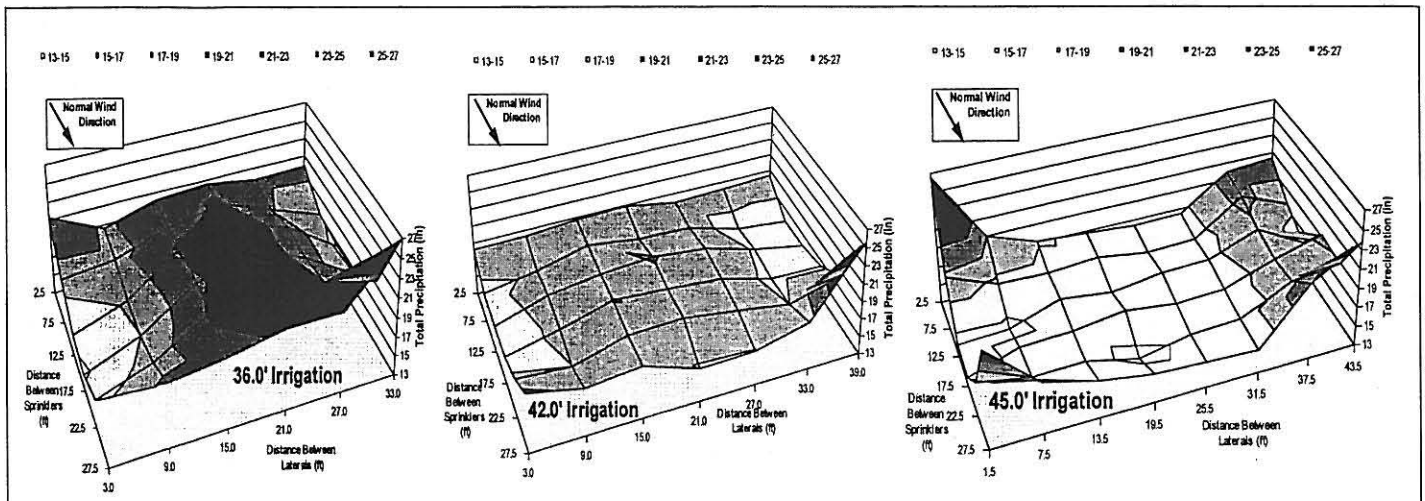

Figure 2—Surface Plot Of Applied Water For The Entire Season (Total Inches) For All Lateral Spacings, For Fall 1997 Planting (Total applied water for each 5' by 6' (2 beds) grid element determined by normalized applied water from 5 to 7 sprinkler evaluations. Precipitation includes 5.19 inches of rainfall)

Table 3—Nitrate-N Leaching as Estimated by Anion-Exchange Resin Bags, Total Precipitation, Leaching and Total Root Yield for Spring 1997 Trial by Lateral

Lateral Spacing (ft)	Resin Bag NO3-N (lb/ac) 3/14-4/16	4/16-6/27	Season Total	Total Precip (in)	Total Leaching (in)	Total Yield (ton/ac)
42.0	28.0	37.9	65.9 a	24.15	3.51 a	36.20
48.0	24.7	23.4	48.1 b	26.56	5.92 b	34.72

Table 4—Nitrate-N Leaching as Estimated by Anion-Exchange Resin Bags, Total Precipitation, Leaching and Total Root Yield for Spring 1997 Trial by Location Relative

Lateral Spacing (ft)	Resin Bag NO3-N (lb/ac) 3/14-4/16	4/16-6/27	Season Total	Total Precip (in)	Total Leaching (in)	Total Yield (ton/ac)
Lateral	24.8	35.7 a	60.5	24.12	3.48	36.44
Middle	32.2	35.5 a	67.7	25.77	5.13	35.07
Mid Sprink	22.0	24.9 b	46.9	26.17	5.53	34.87

Table 5—Nitrate-N Leaching as Estimated by Anion-Exchange Resin Bags, Total Precipitation, Leaching and Total Root Yield for Fall 1997 Trial by Lateral Spacing

Lateral Spacing (ft)	Resin Bag NO3-N (lb/ac) 9/1-10/27	10/27-12/4	12/4-2/10	Total	SSAT NO3-N (ppm) 9/19/93	10/27/93	Total Precip (in)	Total Leaching (in)	Total Yield (ton/ac)
36.0	187.4 a	78.4 a	46.9	331.0 a	333.4	236.1	17.83 a	6.44	36.43
42.0	80.8 ab	54.2 ab	37.4	165.9 ab	512.1	179.7	17.45 b	6.06	34.42
45.0	133.2 b	48.5 b	50.8	232.1 b	411.8	284.3	16.05 b	4.67	34.33

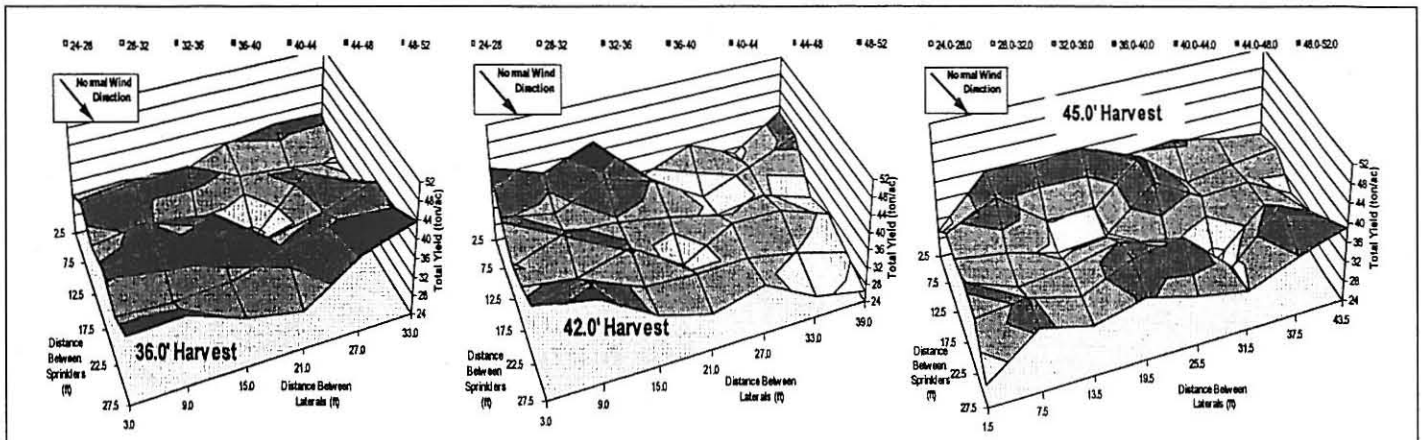

Figure 3—Surface Plot Of Total Root Yield (Tons/Acre) From Intensively Sampled Grids Corresponding To Mean Applied Water Shown In Figure #5, For Fall 1997 Planting

acre) of applied N in the Spring 1996 trial (Table 2). The 40.0-ft lateral spacing leached significantly less nitrate than the 33.3-ft or 46.7-ft spacings, even though the 46.7-ft spacing proved to have the highest mean DU. An 85 percent efficiency of nitrate recovery was established for these bags, using soil columns prepared from soils used in these trials. Use of these resin bags to accumulate total leached nitrate seemed highly promising after the first season. Intercepted nitrate in the Spring 1997 trial jumped to 18 to 27 percent of applied N (Tables 3 and 4). Resin bag results from the Fall 1997 trials, however, showed impossibly high levels of nitrate leaching from 66 to 132 percent of applied nitrogen (in excess of 300 lb/acre NO3-N, Tables 5 and 6). NO3-N concentrations in soil solution access tubes (SSAT) were also unrealistically high. Further confounding these results is the fact that intercepted resin bag nitrate decreased as leaching of irrigation water increased. This is not supposed to happen. Appropriate lab procedures appear to have been followed, and control bags showed zero nitrate contamination. Soil analyses data for Fall 1997 have not yet been collated and summarized, but these may help provide a reason for this anomaly.

Examining the degree of leaching by "Location Relative to Sprinklers"' (Table 6) reveals a much greater differential than seen between different lateral spacings. However, intercepted resin bag nitrate decreased as leaching of irrigation water increased. After seeing elevated levels of nitrate leaching in the Spring 1997 trial, we had some concerns about passive diffusion of soil nitrate into the resin bags, which represents part of the background soil N pool that is not necessarily being leached out of the profile. A few bags were installed in the Fall 1997 trial that were exposed to the soil at the three-ft depth but protected from any leaching of water from above. These bags showed 30 to 50 ppm accumulated NO3-N, which translates to 35 to 65 lb/acre NO3-N that did not actually "leach" through these bags but was absorbed from nitrate resident at that depth. Values of leached nitrate reported in Tables 5 and 6 have not been discounted by these amounts, as the "diffusion bags" were placed at four locations only. An average "diffusion value discount" would have caused some monitoring sites to have negative NO3-N. More benchtop studies using these resin bags are needed to resolve this issue.

Modeling

Computer modeling simulations have revealed that even modest heterogeneity of the soil hydraulic characteristics becomes more important than the irrigation system DU. Total nitrate leaching had no significant correlation to lateral spacing for carrots with a 2 1/2 to 3-ft root. The minor differences in nitrate leaching between different lateral spacings must be attributed to the variability of soil hydraulic properties at the sampling sites within treatments.

Saturated hydraulic conductivity (K_s) values for the field used in the Spring 1996 and Fall 1997 trials ranged from a high of 3.35 in/hr in the top foot of soil to 0.94 in/hr for the four-ft depth, with coefficients of variation (CV) for these values of 31 to 120 percent, respectively. Nitrate leaching proved to be significantly correlated only with K_s

at the four foot depth ($R^2_{simulated}$ = 0.863 and R^2_{actual} = 0.712). Simulated values agreed very well with the actual data from this field. Our simulation model reveals that nonuniform leaching will happen in a spatially variable soil, even though the irrigation DU is 100 percent.

Knowledge of the soil hydraulic properties at the levels of DU encountered in this study appear to be more important for determining total leaching than minor variations in irrigation uniformity. There is undoubtedly some threshold at which the irrigation system DU would become the dominant factor. This model is not capable, at this time, of determining this threshold, but it is safe to say that it is almost certainly less than a DU of 75 percent for deeper-rooted vegetable crops like carrots.

CONCLUSIONS

Substantial differences in irrigation uniformity for varying sprinkler lateral spacings were verified in the field. The 1996 trial revealed the widest spacing (46.7-ft) to be the most uniform, while the Spring 1997 trial showed a 48.0-ft lateral spacing to have the worst uniformity. The Fall 1997 trial showed the 42-ft spacing to be most uniform. Of all lateral spacings, a 40- to 42-ft spacing provided the most consistent performance (DU's of 78 to 85 percent). This spacing also produced a slightly lower estimate of leached nitrate. However, total yield or quality was found to be unaffected by spacing, as the driest parts of all precipitation patterns received at least 80 percent of ET.

The role of pressure, optimal droplet size, nozzle wear, and diurnal and seasonal fluctuations in wind speed and direction are equally 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 need to be increased over present production practice. Preliminary results from 1998 evaluations in shorter set durations in onions and potatoes reveal generally lower DU's than those reported above.

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 percent, 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.

Table 6—Nitrate-N Leaching as Estimated by Anion-Exchange Resin Bags, Total Precipitation, Leaching and Total Root Yield for Fall 1997 Trial by Location Relative to Sprinklers

Location Relative to Sprinkling	Resin Bag NO_3-N (lb/ac) 9/1-10/27	10/27-12/4	12/4-2/10	Total	SSAT NO_3-N (ppm) 9/19/93	10/27/93	Total Precip (in)	Total Leaching (in)	Total Yield (ton/ac)
Lateral	133.8	82.6 a	65.3 a	268.1	533.1 a	372.2 a	14.17 a	2.77 a	32.32 a
Middle	123.9	63.2 ab	52.4 ab	267.4	512.8 a	225.4 ab	16.63 b	5.25 b	34.77 ab
Mid Sprink	120.7	59.4 ab	38.7 ab	236.4	450.2 a	258.0 ab	16.03 b	4.64 b	37.71 c
Sprinkler	165.6	36.4 b	26.9 b	217.1	137.4 b	94.7 b	21.61 c	10.22 c	35.37 bc

DRIP IRRIGATION AND FERTIGATION SCHEDULING FOR CELERY PRODUCTION

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OBJECTIVES

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

DESCRIPTION

A substantial portion of California celery production is now grown using drip irrigation, predominately by surface systems. Drip irrigation and N fertigation management practices vary widely among growers, and there is virtually no relevant research on drip management of celery under field conditions representative of the commercial industry. In this project, field trials have been, or are being, conducted in six drip-irrigated commercial fields during 1998, one in Ventura County, two in Monterey County, and three in Santa Barbara County. In each field, the drip system was installed several weeks after transplant establishment. After system installation, replicated plots of drip tapes of different flow rates were patched into the field system. Two flow rates greater than and two rates less than the field system were installed (three replicate plots per flow rate) with in-line water meters to document water volume applied. As the grower managed the field system, graduated amounts of water (and fertigated N) were applied in the various plots, from approximately 40 percent less than to 30-60 percent more than the field system. Tensiometers were installed to monitor soil moisture. Plant growth and N status were monitored by biweekly sampling. At harvest, plants were trimmed and sized by experienced harvest crews. Mean trimmed weight and degree of pithiness of the petioles were also recorded.

RESULTS AND CONCLUSIONS

At the time of preparation of this report, only two trials had been completed, one in Guadalupe and one in Chualar. The Guadalupe trial was installed May 21 and harvested July 8. Reference evapotranspiration over that period was 8.2 inches. (See table below.) The grower applied approximately 11.8 inches, including 2 inches by furrow irrigation on June 13 (a standard practice for this grower). Plots receiving less than the field rate were clearly water stressed, as evidenced by high tensiometer readings (frequently >50 cb) and smaller average plant weight; water application in excess of the field rate did not improve the crop. The grower irrigated on average only once every 5-6 days. Although the total volume of water applied to the field was sufficient, such low frequency irrigation resulted in even the field rate plots experiencing greater than ideal transient water stress. The absence of pithiness in all water treatments was surprising, since water stress tends to induce pithiness.

The Chualar trial was installed on July 2 and harvested on August 25; seasonal potential evapotranspiration (Et_o) was 10.6 inches. The grower applied 12.9 inches, or about 120 percent of Eto. Irrigation frequency was approximately every three days, except when the need to dry the field to allow pesticide application by ground rig delayed irrigation. In those instances, the field plots encountered transient water stress. Plots receiving less than the field rate of water had much smaller plants, and very high rates of pithiness. (See table below.) There was a trend toward larger plants and less pithiness in plots

receiving more water than the field rate. The plant response noted in this field was clearly related to water relations rather than N nutrition.

In neither trial did the grower specifically adjust water application for the growth stage of the plant, instead applying approximately the same percentage of Eto throughout the season. Since the crop canopy cover ranged from less than 25 percent to >80 percent as the crop developed, early season applications undoubtedly resulted in substantial leaching. The plant growth differences among plots of varying drip flow rates became evident only in the second half of the season, after substantial plant canopy developed. Also, individual applications in the Guadalupe trial were often >1.5 inches. Such large applications from a line source (the drip tape) undoubtedly resulted in a significant degree of leaching, reducing the amount of applied water that a shallow-rooted crop like celery could utilize.

Table 1. Response of Celery to Varying Drip Irrigation and Fertigation Regimes

Site	Seasonal Et_o (inches)	Irrigation treatment	Seasonal water application (inches)[z]	Mean plant weight (lb)	Pithiness[y] (% of plants)
Guadalupe	8.2	60% of field rate	7.8	1.69	0
		80% of field rate	9.5	1.94	0
		field rate	11.8	2.07	0
		120% of field rate	13.5	2.16	0
		160% of field rate	18.2	2.11	0
Chualar	10.6	60% of field rate	7.3	1.41	76
		70% of field rate	8.7	1.60	53
		field rate	12.9	2.27	12
		115% of field rate	15.0	2.28	5
		130% of field rate	16.8	2.47	2

[z] applied after the installation of the drip system
[y] % of plants with two or more petioles showing pithiness

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

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OBJECTIVES

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

DESCRIPTION

California produces more than 80 percent of the United States garlic crop, and nitrogen fertilization practices of garlic growers vary tremendously. Rates of N are, however, usually in excess of those generally recommended. Timing and amounts 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. This is especially true for "virus-free" garlic, which has a much higher yield potential.

A three-year project was initiated at Westside Research and Extension Center, University of California (Five Points, California) in September 1996, with industry funding, to assess the relationships among fertilizer management, water management, and yield. Our three-year Fertilizer Research and Education Program funded project began in 1997, permitting evaluations of leaf tissue analyses, soil nitrogen movement, and postharvest quality.

RESULTS AND CONCLUSIONS

Results of irrigation treatments from 1997 and 1998 follow.

1997 Garlic Research: Focus on Yield and Quality Components at Harvest

Four irrigation treatments and four nitrogen fertilizer treatments were used in the same plots in 1997. The irrigation treatments consisted of: one week between irrigations with the last irrigation on May 9 (T1), one week between irrigations with the last irrigation on May 16 (T2), irrigations every 1.5 weeks with the last irrigation on May 9 (T3), and irrigations every two weeks with the last irrigation on May 16 (T4). For each plot, applied water, soil moisture content, bulb count, and yield (pounds per plot) were measured.

Results of the irrigation treatments showed no statistical differences between the irrigation treatments for the bulb count (Table 1 and Figures 1 and 2). Statistical differences occurred in yield, with the treatments with highest yields for the irrigation at one-week intervals and the lowest for the 1.5 and two-week intervals.

Results of the N fertilizer treatments showed statistically significant differences in bulb count between F4 and the other fertilization treatments (Table 2 and Figures 1 and 2). Statistical differences occurred in yield, with the largest yields occurring in plots with the longest intervals between irrigations. Interactions between irrigation treatments and N fertilizer treatments were not significant. In summary, the 1997 results indicate that irrigation intervals exceeding one week and late irrigations (beyond the first part of May) can cause a yield loss. Seasonal nitrogen applications should be about 300 lb/acre to maximize yield.

Total percent N and nitrate -N in garlic leaf tissue increased with increasing N fertilization treatment (Figure 3 and Figure 4). Total percent N was not significantly different between the two highest fertilization treatments. Irrigation regime made little difference to total percent N and nitrate -N concentrations (Figure 3 and Figure 4).

Postharvest quality evaluations showed that dry irrigation treatments significantly reduced clove weight, increased pungency, and increased yellow color in comparison to results from the wet irrigation treatments (Table 3). The percent dry weight and percent soluble solids were significantly affected by N fertilization. In the 1997 trial, 18 to 35 percent of the cloves had green tips, with a higher percent green tips in the dry irrigation treatments. At harvest, internal sprout development was very low, but was significantly higher in some of the wet treatments.

1998 Garlic Research: Focus on Yield and Quality Components at Harvest

Initially, irrigation treatments consisted of water applications equal to 85 percent (T1), 100 percent (T2), 115 percent (T3), and 130 percent (T4) of the potential evapotranspiration. Measurements of soil moisture content of T2 were to be the basis for estimating the amount of water to be applied. Weekly irrigations were to occur, based on the 1997 results. However, because of rainfall during the winter and spring, the irrigation treatments could not be applied. Instead, the effect of the timing of the irrigation cutoff was investigated, with a cutoff date of May 12 for T1, a cutoff of May 19 for T2, a cutoff of May 25 for T3, and a cutoff of June 1 for T4.

Table 1-Results of the 1997 Irrigation Treatments*

Treatment	Time between irrigations	Date last irrigation	Applied water (inches)	Bulb Count	Yield (lb/ plot)
T1	1 week	May 9	13.8	340a	29.0a
T2	1 week	May 16	17.2	342a	31.1b
T3	1.5 weeks	May 9	11.8	327a	26.1c
T4	2 weeks	May 16	14.3	334a	26.2c

* Averaged across N fertilization treatments

Table 2-N Fertilizer Treatments and Yield Data for 1997*

Treatment	Preplant	Sidedress	Water-run**	Total lb N/acre	Bulb Count	Yield (lb/plot)
F1	70	30	0	100	332a	25.6a
F2	70	90	40	200	332a	28.1b
F3	70	170	60	300	334a	29.2c
F4	70	250	80	400	344b	29.4c

* Averaged across irrigation treatments
** Applied in four applications

Results of the irrigation treatments (Table 4) showed decreasing bulb count and bulb weight with time of the last irrigation, while the piece weight yields increased with time. Irrigation treatments had no effect on the percent soluble solids. Shattering of the bulbs caused the decrease in bulb weight with time.

Results of the 1998 N fertilizer treatments showed a decreasing bulb count and bulb weight with increasing N applications (Table 5). At the same time, the piece weight yield increased with increasing N applications. Soluble solids percentage decreased with increasing N applications.

Table 3-Quality Characteristics of Peeled Garlic Cloves from Selected 1997 Irrigation and Fertilization Treatments (Analyses were done after field and laboratory curing [about 4 weeks])

Irrigation-[1] Fert Trt.	Wt/clove (g)	% cloves[2] green tips	Dry weight (%)	Sprout Dev.[3]	Soluble solids (%)	Pungency[4]	Firmness[5]	L* Color values	Chroma[6]
DRY (T3)									
100 lb N/A	3.6	27	43.2	0.008	43.0	23.3	1677	69.0	12.6
200	4.0	22	41.2	0.005	40.5	22.1	1868	68.2	12.1
300	4.1	35	39.9	0.003	41.0	24.5	1654	68.5	14.5
400	3.9	36	41.2	0.005	41.3	25.6	1650	68.3	12.3
Average	*3.9*	*30*	*41.3*	*0.005*	*41.5*	*23.9*	*1714*	*68.5*	*12.9*
WET (T2)									
100 lb N/A	4.1	18	41.5	0.007	42.5	25.4	1686	68.0	11.6
200	4.5	27	41.3	0.007	41.8	21.7	1664	67.7	11.5
300	4.5	19	40.8	0.005	42.6	19.4	1686	67.5	11.5
400	4.8	25	39.2	0.013	41.2	20.8	1682	67.5	11.4
Average	*4.4*	*22*	*40.7*	*0.008*	*42.0*	*21.8*	*1682*	*67.7*	*11.5*
LSD.05	0.4	9	0.7	0.002	1.2	1.0	ns	0.3	1.2

1 Dry is treatment T3; wet is treatment T2 (see Tables 1 and 2.)
2 Any presence of chlorophyll on peeled clove, data based on 90 cloves per treatment
3 Cloves were sectioned longitudinally, and the length of the sprout was estimated as a fraction of full clove length; data from 30 cloves per treatment.
4 Pungency estimated as µmole pyruvate/g fresh weight; data is average of three composite samples per treatment.
5 Firmness estimated as g-force to penetrate with a 0.3 mm probe; data based on 90 cloves per treatment.

Table 4—Irrigation Treatments Applied in 1998 (Data are averages of six field replications)

Treatment	Date last irrigation	Bulb count	Bulb weight*	Piece weight*	Total yield*	Solids (%)
T1	May 12	615a	36.0a	2.8a	38.7a	37.2a
T2	May 19	545b	31.4b	6.6b	38.0a	36.8a
T3	May 25	447c	24.9c	8.9c	33.8b	36.1a
T4	June 1	390d	21.9c	9.5c	31.4b	36.1a

* Weights are pounds per plot
** Data averaged across fertilization treatments

Table 5-Nitrogen Fertilizer Treatments Applied in 1998 (All plots received 70 lb N/acre pre-plant. Data are averages of six field replications)

Treatment	Side-dress*	Water-run*	Total*	Bulb count	Bulb weight*	Piece weight*	Total yield*	Solids (%)
F1	30	0	100	565a	31.3a	2.9a	34.3b	38.1a
F2	65	40	175	527ab	30.9a	5.9b	36.8a	37.2ab
F3	140	40	250	486bc	28.4b	7.2c	35.7ab	36.6bc
F4	175	80	325	465c	26.9bc	9.1d	36.0ab	35.5c
F5	250	80	400	451c	25.1c	9.4d	34.5b	35.3c

* Pounds per plot

Table 6-Quality Characteristics of Garlic from Selected 1998 Irrigation and Fertilization Treatments (See Tables 4 and 5 for treatments and Table 6 for explanations. Garlic was analyzed after field and laboratory curing [about four weeks]. Data are averages from six field replications).

Irrigation	Fertiliz-ation	Wt/bulb (g)	% Decay	% Dry wt	% Soluble Solids	L* color value	Chroma	Pungency µm/g dw
Dry T1	1	37.8	8	39.6	39.6	58.8	9.3	22.3
	3	33.9	27	36.7	37.4	58.1	8.8	25.2
	5	32.4	6	36.8	37.8	58.7	8.5	26.7
Average		*31.4*	*13*	*37.7*	*38.3*	*58.5*	*8.9*	*24.7*
Wet T4	1	34.7	12	36.8	38.4	58.2	8.9	27.7
	3	38.2	13	35.0	35.9	58.8	8.8	33.0
	5	35.5	7	33.4	35.0	60.4	9.4	31.9
Average		*36.1*	*11*	*35.0*	*36.4*	*59.1*	*9.0*	*30.8*
LSD.05		4.9	10	1.0	0.9	0.4	ns	2.3

Based on the 1998 results, late irrigations beyond the first part of May can reduce bulb count and bulb yields. Piece weight yields increased for the later irrigations. The N fertilizer treatments showed decreasing bulb count and total weight with increasing N applications. Little yield difference occurred between the middle three N fertilizer applications with the smallest total yields for the smallest and largest N applications. These results are not entirely consistent with the 1997 results. Additional plots of NPK fertilizer treatments were installed in 1998, but data are not yet summarized.

Garlic bulbs from the 1998 dry treatments (T1) had an average 14 percent lower weight than bulbs from the wet (T4) treatments (Table 6). With higher irrigation levels, N fertilization did not significantly affect bulb weight; however, with low irrigation level, higher fertilization levels reduced bulb size. Because of the wet spring, there were notable levels of decay and waxy breakdown on the bulbs at harvest after field curing, with an average of 12 percent of the bulbs affected.

Dry weight percent was significantly higher under dry irrigation regimes; higher N fertilization reduced percent dry weight. The percent soluble solids followed a similar trend to the percent dry weight analyses in relation to the field treatments, and are closely correlated (Figure 5). The percent soluble solids and percent dry weight of the cloves from the 1998 harvest were substantially lower than values for the 1997 garlic (Table 3). There were minor differences in whiteness of the cloves (L* color value) and no significant differences in coloration

(chroma value) at harvest after curing (Table 6).

In 1998, we used an assay for pungency which is more specific to garlic. The bulbs from the dry irrigation treatment were less pungent than those from the wet irrigation treatments (Table 6). Pungency was lower for the lowest fertilization level. Pungency may be correlated to percent dry weight (Figure 6).

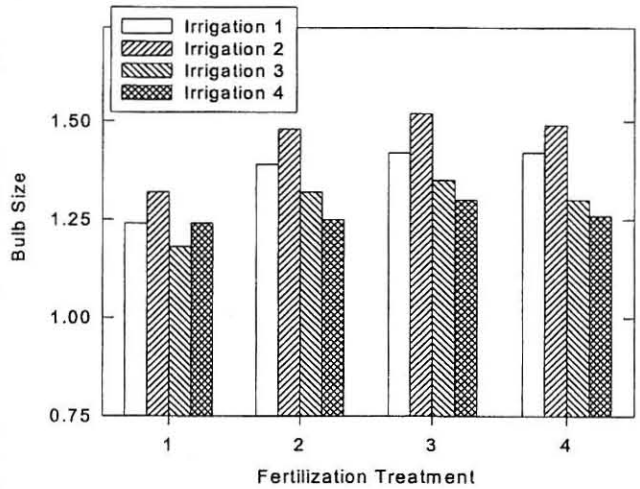

Figure 1—Bulb Size in Relation to 1997 Irrigation and Fertilization Treatments (See Tables 1 and 2 for Treatments)

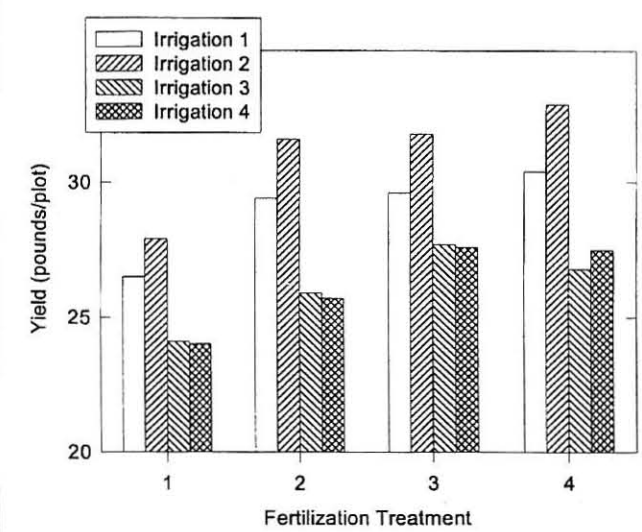

Figure 2—Yield of 1997 Garlic Plots in Relation to Irrigation and Fertilization Treatments (See Tables 1 and 2 for Treatments)

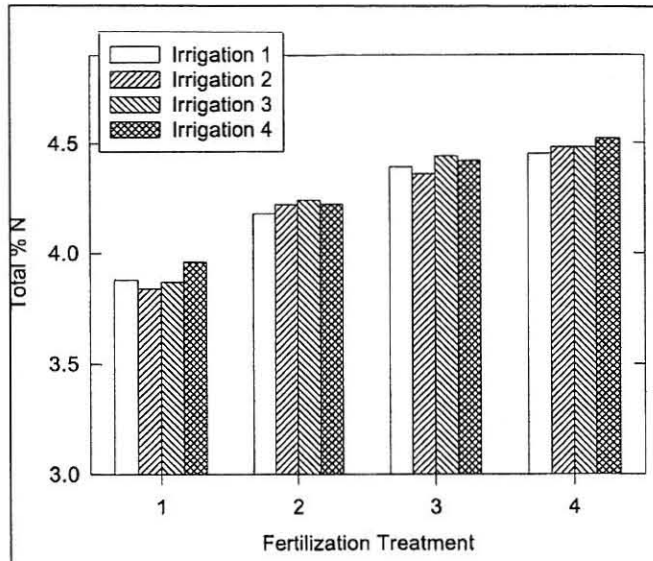

Figure 3—Total Percent Nitrogen in Leaf Samples from 1997 Garlic Plots in Relation to Irrigation and Fertilization Treatments (See Tables 1 and 2 for Treatments)

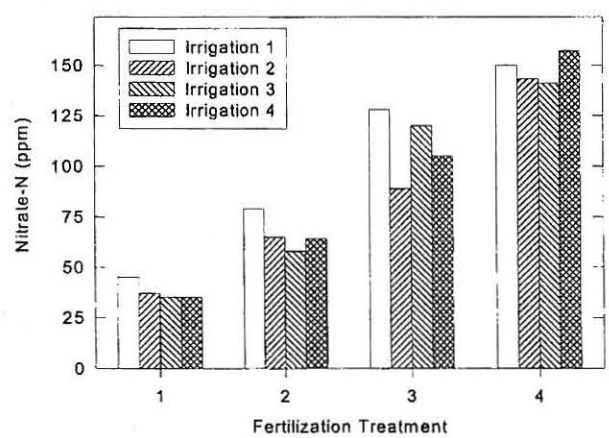

Figure 4—Total Nitrate Nitrogen in Leaf Samples from 1997 Garlic Plots in Relation to Irrigation and Fertilization Treatments (See Tables 1 and 2 for Treatments)

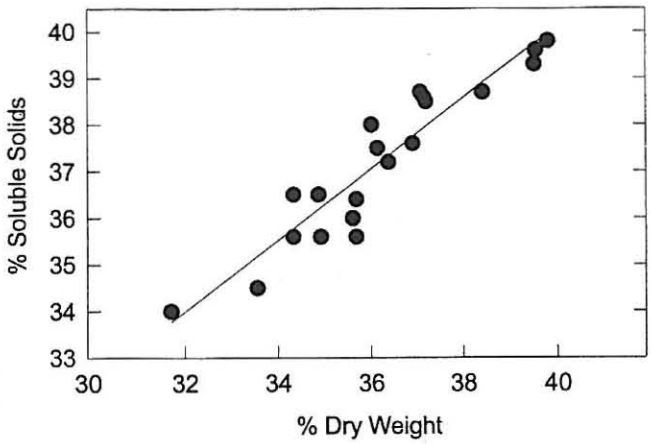

Figure 5—Relationship Between 1998 Average Dry Weight and Soluble Solids Data

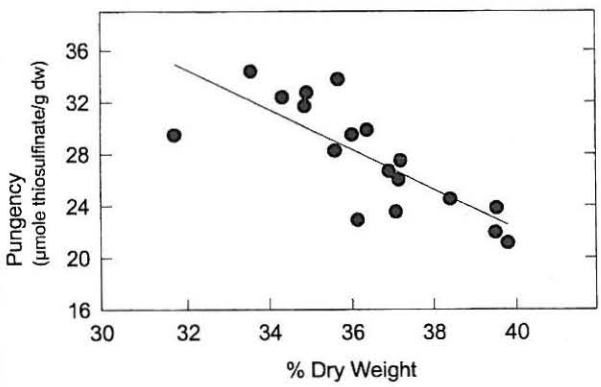

Figure 6—Relationship Between 1998 Average Dry Weight and Pungency of Garlic

SOIL TESTING TO OPTIMIZE NITROGEN MANAGEMENT FOR PROCESSING TOMATOES

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OBJECTIVES

This project is developing a protocol for recommending tomato fertilizer application rates based primarily on early-season soil testing. This testing system is based on the correlation between NO_3 -N of the surface foot of soil and other N pools in the surface two feet of soil, at early plant growth stages. Similar protocols have been successfully developed for corn in the Northeast and Midwest, and recently have been successful in broccoli and cauliflower production in California's coastal cole crop production regions. Similar work has not been done, however, for processing tomatoes.

Additional correlations are being sought, as part of this project, between fresh petiole sap testing, dry plant tissue testing, and N fertilizer management practices. Specific objectives of the project are as follows:

1. Develop and extend information on pre-sidedress soil testing as a means for optimizing nitrogen management for processing tomatoes
2. Evaluate the effectiveness and utility of fresh petiole sap testing using the Cardy Meter for decision making in tomato nitrogen management
3. Investigate relationships between fresh sap nitrogen testing, dry tissue testing, and current sufficiency levels being used by commercial testing labs for nitrogen fertilizer recommendations
4. 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

DESCRIPTION

California produces approximately 90 percent of the nation's processing tomato crop. Processing tomatoes are the most widely grown vegetable crop in the state, with over 300,000 acres in annual production. Major production areas are the San Joaquin and Sacramento Valleys.

Due to the generally high economic value of processing tomatoes, production practices typically rely on relatively large inputs of nitrogen fertilizers. Additionally, there is mounting evidence suggesting that "insurance" may be built into recommended fertilizer application rates to guard against deficiencies, thereby leading to excessive applications of N fertilizers. For example, repeated experiments at the University of California's West Side Research and Extension Center (WSREC) in Five Points, California, during the past decade have demonstrated that maximum yield responses result from application of 100 to 150 lb of nitrogen per acre, depending on residual soil N levels. Yet processing tomato growers in the region routinely apply 200 to 300 lb of nitrogen per acre, based on current fertilizer recommendation systems.

The case for developing new and better systems for making N fertilizer recommendations for processing tomatoes can be made on two fronts. First, there is widespread concern that NO_3 contamination of surface

and groundwater may occur through leaching losses associated with over-application of N fertilizers. Development of better systems for making N fertilizer recommendations has been identified as a major goal in reducing nitrate pollution of groundwater. Second, past, and perhaps future, N fertilizer price increases make development of a better method for estimating fertilizer N application rates a critical economic concern to growers of processing tomatoes. Reductions of N applications by 50–100 lb/acre can result in per acre savings of $20 to $40.

RESULTS AND CONCLUSIONS

During the 1998 growing season, the project conducted six on-farm experimental sites in the West Side region of the San Joaquin Valley and one experimental site at the WSREC. The six on-farm project sites each received N fertilizer sidedress applications of between 0 to 300 lb/acre in increments of 50 lb/acre. Seven different application rates were used at each site, with six replications per site. The experimental site at the WSREC received 15 different N fertilizer applications ranging from 0 to 300 lb/acre with four replications.

Soil samples collected from each field prior to N sidedress applications have been and/or are in the process of being tested for total N (Total Kjeldahl Nitrogen, TKN) and potentially mineralizable nitrogen (PMN). Leaf petiole samples were collected at three plant growth stages: first bloom, fruit set, and fruit color/bulking. Petiole samples were used to determine fresh sap nitrate using the Cardy Meter, and testing for dry petiole nitrate levels is being conducted at the UC Division of Agriculture and Natural Resources Analytical Lab. In-field plot yields and quality determinations of processing tomatoes are being done by machine harvesting each strip plot. Electronic scales mounted to gondola weigh wagons are being used to determine in-field plot yields. Five-gallon subsamples of unsorted fruit on the harvester are being collected from each plot for in-field determinations of fruit maturity and percent defects and State Grading Station determinations of soluble solids, pH, and color.

Data from 1998 trials are being analyzed and presented in two ways. First, correlations will be done between pre-sidedress soil nitrogen concentrations and a formula that integrates TKN, NO_3 -N and PMN determinations and relative yields (i.e., yields at a site expressed as percentages of the highest yield that can be attained by adding fertilizer at that site). Second, the Cate-Nelson graphical technique will be used to analyze the relationship between soil test N and relative yield. This statistical procedure partitions data into one population that has a high probability of response to added fertilizer, and another that has a low probability of response to added fertilizer.

Harvesting of processing tomatoes in the West Side region of the San Joaquin Valley had not been completed at the time of this report's submission, therefore the compilation and analysis of data from the project is still ongoing. Very preliminary data from the project indicate poor correlations between processing tomato harvest yield and fruit quality and the amount of N fertilizer applied. If this data holds after further analysis, revision, and testing, it could lend support to previous evidence of "insurance" being built into recommended fertilizer application rates to guard against deficiencies, thereby leading to excessive applications of N fertilizers. However, it needs to be emphasized that this data is very preliminary, and no such conclusions can yet be reached or substantiated.

WINTER COVER CROPS BEFORE LATE-SEASON PROCESSING TOMATOES FOR SOIL QUALITY AND PRODUCTION BENEFITS

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OBJECTIVES

1. Document the contribution of a winter leguminous cover crop to plant nutrition in processing tomatoes on a field scale
2. Document the impact of a winter cover crop on soil permeability and winter runoff vis-à-vis fallow, pre-bedded ground on a field scale
3. Observe the weed suppressive qualities of a cover crop as well as any hindrances it might pose to winter weed control on a field scale
4. Educate other growers and support industry about trial results and cover cropping technique

DESCRIPTION

Winter cover cropping was once a more common practice for nutrient management in annual cropping systems. In current conventional practices, processing tomato fields are pre-bedded and fallowed in winter months, foregoing the possible nutrient benefits of winter cover and increasing the amount of runoff and silt transported into local streams during winter rains. In addition, comparative research from the UC Davis Sustainable Agriculture Farming Systems (SAFS) Project demonstrates that conventional two-year processing tomato rotations without cover crops cause a gradual decline in soil permeability and tilth, as compared with cover cropped fields. Additional effects on soil biology leave plants more susceptible to soil-borne pathogens. Such small-scale trials need to be extended to a larger scale on farms outside of university and field station research plots. Reintroducing winter cover crops to annual row crop rotations has the potential to provide multiple benefits of plant nutrition, winter soil stabilization, wildlife forage and refuge, and improved soil tilth, permeability, and organic matter.

During the winter of 1997-1998 the Yolo County UC Cooperative Extension (UCCE) office and the Yolo County Resource Conservation District (RCD) cooperated on a trial using a winter cover crop ahead of a processing tomato crop on five acres of a Yolo County grower's 37-acre field. The trial featured a mix of Common vetch and Dundale pea, in replicated plots three rows wide (15 ft) by 100 ft long. Four levels of additional fertilizer were sidedressed at layby on fallowed and cover cropped treatments. Treatments were sampled for tissue and soil N before cover crop planting (soil only), before cover crop turn in, and at three stages of tomato crop development. Tomato yield and fruit quality were also assessed at harvest. The RCD compared water infiltration rates from the treatments and assessed weed pressure in all treatments.

Interim project findings have been shared with local growers and industry through a field day and individual tours. A final paper and presentation at the 1999 Lower Sacramento Valley Tomato Production Meeting will communicate the project results.

RESULTS AND CONCLUSIONS

The tomato crop was harvested by the grower cooperator on August 8, 1998. Yields were measured and categorized into marketable fruit as well as sorted into categories of culls, which included pink, green, sun-damage and mold. Soil samples were collected to the three-ft depth to compare residual N levels in cover cropped and fallowed bed treatments. Although the analysis of variance evaluations are yet to be completed, we are encouraged that average yields were increased with the cover crop as compared to the conventional, fallow-bed system.

Our observations of water infiltration yielded no significant differences between cover cropped and fallowed treatments, although we acknowledge that such changes are not typically observable after only one year of treatment. Soil samples have been taken and submitted for aggregate stability analysis. We were unable to perform the runoff comparison during the winter due to the field's lack of a tail drain. Weed pressure in the field was equally slight in both fallowed and cover-cropped treatments. We intend to undertake a similar project on a different field during the winter of 1998-99.

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

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OBJECTIVES

Previous research has shown that in coastal vegetable production, high levels of residual soil nitrate-N (NO3-N) are common. In-season soil NO3-N testing could identify fields in which sidedress N application could be delayed or reduced. This approach has been researched extensively in the Midwest for corn production; called the presidedressing soil nitrate test (PSNT), it is now in widespread commercial use. This project sought to adapt the PSNT technique to coastal vegetable production. The specific objectives were:

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 NO3-N determination.
3. Survey commercial vegetable fields in the Salinas and Santa Maria Valleys to determine the range of soil NO3-N concentrations common at the time of first sidedressing.

DESCRIPTION

A total of 22 field trials were conducted in commercial vegetable fields in the 1996 and 1997 seasons. Fields were located in Oxnard, Santa Maria, King City, Soledad, and Salinas; eleven were planted in head lettuce, five in celery, four in cauliflower and two in broccoli. Soil texture varied from sandy loam to clay loam. All fields were conventionally irrigated, generally sprinkled to establish the crop, then switched to furrow irrigation to complete the season. All test fields chosen had soil NO3-N at or above 20 ppm immediately prior to the first sidedress N application.

The N fertilization program in each field was determined solely by the participating growers. In each field, two levels of reduced N application were established, usually by entirely skipping one or more sidedress N applications; in several fields a sidedress N application was reduced rather than eliminated. One plot of each reduced N treatment was established in each quadrant of the field to allow statistical comparison of crop yield to the grower's full N program.

Periodic plant and soil sampling was done to document N status throughout the season. Soil samples (2-12 inches) were collected prior to each sidedressing, and at harvest, and analyzed for NO3-N concentration. 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 NO3-N concentration and the whole plant samples for total biomass and total N content. Plots were harvested within two days of the scheduled commercial harvest, where possible, by experienced personnel from commercial crews. Harvested plants were evaluated for size and condition based on established market standards.

A survey of commercial vegetable fields was conducted to determine the range of soil NO3-N concentration present at the time of first sidedress application. Thirty-five fields in the Salinas, Santa Maria, and Oxnard areas were sampled from May through September, in each case immediately prior to the first scheduled sidedress N

application. The accuracy of the soil NO3-N "quick test" was compared to conventional laboratory analysis using a set of 40 soil samples collected during the PSNT trials.

RESULTS AND CONCLUSIONS

In all 22 fields, plots in which the first sidedress N application was eliminated or reduced had equivalent yield and the same product quality with those receiving the full grower N program. In only three of the fields did the lowest rate of seasonal N application, achieved by reducing or eliminating two sidedress applications, have a detrimental effect on yield or quality. The average reduction in seasonal N application was 88 and 162 lb N/acre for the two reduced N treatments.

High productivity was maintained with low N application rates because considerable N was available from other sources. Soil NO3-N concentration of 25 ppm represents approximately 100 lb N/acre in the top foot. Net N mineralization rates of 1.0-1.5 lb 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 lb of available N/acre. Given the NO3-N concentration common in irrigation water, between 15-30 lb N/acre could be added during a cropping season. Clearly, a crop such as lettuce, which normally contains only 100-120 lb 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.

These trials clearly demonstrate that PSNT can identify fields in which significant reduction in N application can be achieved, through postponing or reducing sidedress applications, with no loss of crop yield or quality. The survey of coastal vegetable fields, conducted from May to September, found that the majority had soil NO3-N prior to first sidedressing high enough (> 20 ppm) to delay additional N application. The soil NO3-N "quick test" proved to be reasonably accurate across a wide range of soil NO3-N concentration, making it a viable on-farm monitoring technique.

MANAGEMENT OF NITROGEN FERTILIZATION IN SUDANGRASS

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OBJECTIVES

1. Determine the response of sudangrass (yield and forage quality) to varying levels of N fertilizers in the low desert environment
2. Quantify the effects of N application rates on the potential for groundwater contamination
3. Develop rapid diagnostic tests to monitor N content and nitrates in the forage

DESCRIPTION

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 lb 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.

(An updated summary for this project was not received in time to be included in this publication. Please contact the CDFA/FREP office for a copy of the latest report.)

NITROGEN BUDGET IN CALIFORNIA COTTON CROPPING SYSTEMS

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OBJECTIVES

1. 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
2. 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
3. Conduct an outreach program including extension publication and oral presentations

DESCRIPTION

Fertilization practices for cotton in California call for nitrogen applications of 150-200 lb/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, two-year experiment with Cotton Incorporated, field trials showed only four of sixteen sites 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.

RESULTS AND CONCLUSIONS

This spring we labeled two of the fertilizer trials with ^{15}N. The ^{15}N plots were established within the main plots of the N fertilizer trials. The ^{15}N label will allow evaluation of the rate of mineralization of soil organic matter and release of available nitrogen. Partitioning of various fractions of nitrogen will be followed over time. The dilution of the 15N label by the indigenous soil N pool provides an indication about the N supply power of the indigenous soil N pool.

DEVELOPING SITE-SPECIFIC FARMING INFORMATION FOR CROPPING SYSTEMS IN CALIFORNIA

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University of California, Davis

OBJECTIVES

1. Measure the variability of yield within fields in a processing tomato-based rotation
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 crop yields in three irrigated fields in Yolo County, in the southern Sacramento Valley, over a four- to five-year period. Data have been analyzed for the first two years (wheat in 1996 and processing tomatoes in 1997), and data have been collected from sunflower and bean fields during 1998. The three fields are 77, 78, and 108 acres in size; soil textures are mainly clay loam, silty clay loam, and silty clay; and the fields generally are difficult to irrigate uniformly. The largest of the three fields was rotated into alfalfa in the fall of 1997 following tomato harvest and has been dropped from the project due to a lack of the resources needed to map alfalfa yields. Tomato yields were measured in 1997 using a prototype 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 global positioning system (GPS). The tomato yield monitor was developed by S.K. Upadhyaya and M. Pelletier with financial support from the California Tomato Research Institute. Yields for crops other than tomatoes are being mapped with an Ag Leader™ yield monitor/GPS combination retrofitted on the grower's harvester.

Color infrared aerial photographs were taken of bare soil and at several crop growth stages. Soil and plant samples and other field observations were collected on a 200-ft x 200-ft grid, approximately one sample per acre. Digitized aerial images, plant tissue and soil data, and yield monitor data have been compiled with ArcView® software.

RESULTS AND CONCLUSIONS

Tomato and Wheat Yield Variability

Tomato mean yields for the three fields ranged from 27 to 33 tons/acre. Yield distributions in the fields were remarkably similar (Figure 1). The least productive quarter of each field yielded 71-75 percent of the field average and 55-57 percent of the most productive quarter. These figures are based on yield values for 900-ft2 grid cells interpolated from the yield monitor data points. Based on a price paid to growers of $50/ton, the lowest and highest yielding quarters of an 80-acre field would produce gross incomes of $21,700 and $38,000, respectively.

Low average yields in these fields were probably a result of poor early-season vigor, related to the heavy texture of the soil combined with wet conditions. The causes of yield variability, as distinct from low average yield, were not apparent in two of the fields. Weeds were well-controlled, and while some disease was present, it did not appear to be severe. Variability of the crop in color infrared aerial photos (specifically, the normalized difference vegetation index) from early bloom through the first ripe fruit stage was not related to the yield patterns in each field. It is possible that late-season variation in timing of canopy senescence played a role. We can speculate that both inadequate and excessive irrigation led to early senescence of vines in some parts of each field.

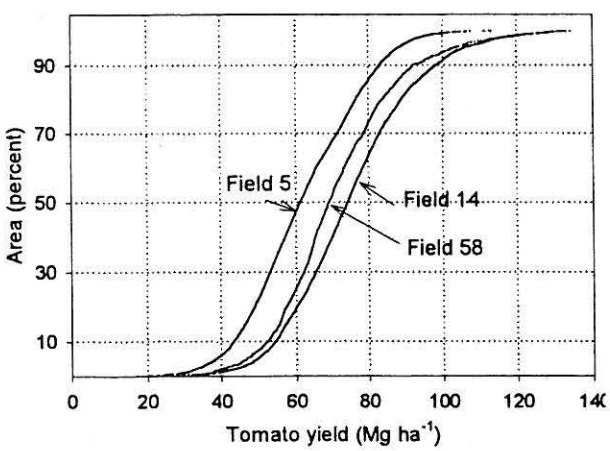

Figure 1—Processing Tomato Yield Distribution in Three Fields in Yolo County

(ton/acre = 0.45 Mg/ha)

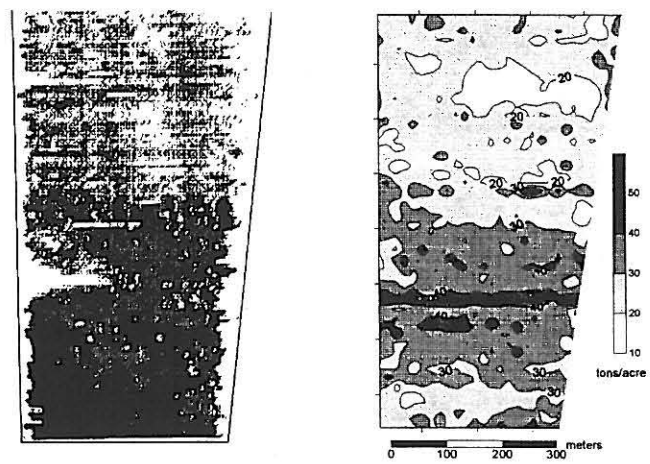

Figure 2—Yield of 'Express' Wheat in 1996 (left) and Processing Tomatoes in 1997 (right) in a 78-Acre Field. Both yielded low in northern (upper) half of field where poorly drained Capay silty clay soil is located. However, best yielding area for wheat (SW corner) gave lower yield of tomato, possibly due to under-irrigation on Yolo loam soil.

In one of the fields, designated Field 5, the relationship of yield to soil physical properties and irrigation management provides a possible explanation for yield variation. In 1996, wheat yield in Field 5 was very low in the northern half of the field due to the combination of characteristic slow soil drainage and wet weather during the 1995-96 winter (Figure 2, left). Wheat yield was best in an area of Class I soil (Yolo silt loam) in the southwest corner of the field (Figure 2, left and Figure 3). The next year, tomato yield was also lowest in the northern half of the field, again probably due to the tendency of the soil to stay saturated longer following irrigation (Figure 2, right). However, in the "best" soil in the southwest corner of the field, tomato yield was lower than in an area to the north where soil was somewhat intermediate in texture and drainage.

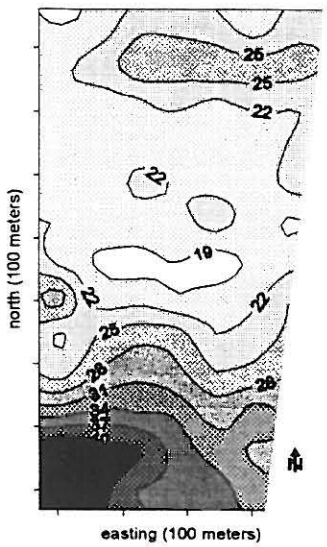

Figure 3—Sand Content of Field 5, 0-6 Inch Depth

Wheat and tomato yields are compared in Figure 4. Grassy weeds reduced wheat yield in some locations in Field 5, and we excluded from this analysis locations with high or very high weed ratings in 1996. The resulting graph shows a curvilinear relation between wheat and tomato yield, with high wheat yield and low tomato yield occurring in areas with the coarsest textured soil.

The grower's explanation for lower tomato yields on the better-drained soil in the southwest corner of Field 5 was that irrigation timing was optimized for the less-well drained Capay silty clay soil occupying more than half of the field. In the areas with better-drained soil, there was more deep percolation loss and lateral movement of water to bed centers. This likely resulted in under-irrigation of the crop in those areas. If irrigation frequency had been increased to accommodate the sandier areas, the crop would have suffered from a saturated root zone in the poorer-drained areas. "Precision farming" solutions to the soil variability might involve spatially varying within a single field one or more of the following factors: irrigation frequency, furrow spacing, double- vs. single-row tomatoes, or bed height. These solutions would require significant, immediate expenses for more intense management, extra land grading, seed, etc., in return for the possibility of increased yields of unknown size on an unknown portion of the whole field.

In 1998, the grower used another, time-honored precision farming technique on Field 5: he split off the best 10 acres at the south end of the field and is growing a seed crop with a higher value than the dry beans being produced on the rest of the field.

Soil Nutrient Level Variability

Although nutrient limitations have not played a major role in crop yield variability in the project fields, we have gained some insight regarding soil sampling for variable rate fertilization (VRF). A major barrier to VRF is the high cost of grid soil sampling. Variable rate applicators usually have a differential global positioning system (DGPS) and a computer linked to a controller that can change the fertilizer rate without any attention required by the driver during application. The variable rate instructions in the computer are usually based, at least in part, on soil nutrient levels. Sampling intensities of one to four acres per sample are usually recommended. At the highest sampling intensity, costs of laboratory analysis and collection can rival or exceed fertilizer material expenses.

A lower-cost approach is to use "directed sampling." Instead of the field being sampled on a uniform grid pattern, it is divided into perhaps three to six sampling areas based on expected similarity of nutrient response within each area. A sampling block could be an area with a single soil type (texture, depth to clay pan, etc.), a uniform position on the landscape, a consistently low- or

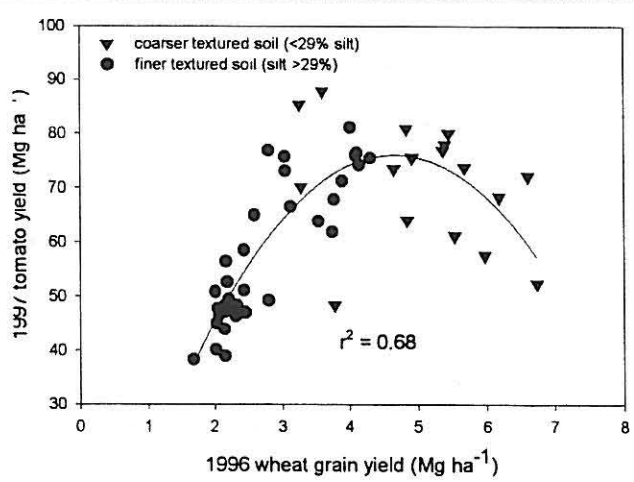

Figure 4—Wheat vs. tomato yield in Field 5. Individual data points are for 30 x 30 ft areas on a 200 x 200 ft grid spacing. Several yield points with high or very high weed ratings in the wheat crop were excluded. Ton/acre = 0.45 x Mg/ha.

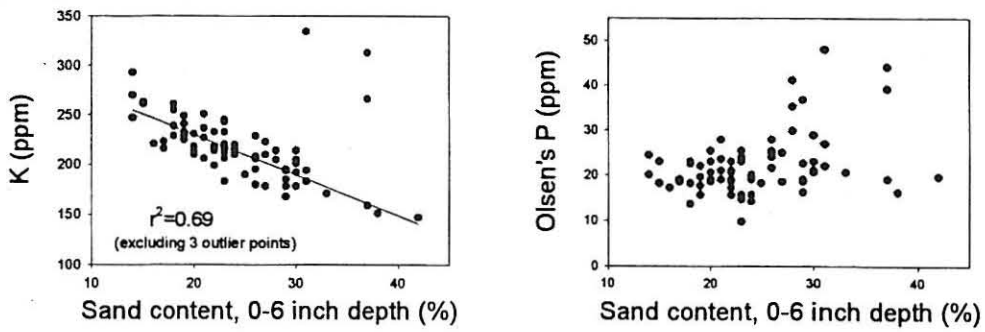

Figure 5—Soil test K and P versus sand content in a 78-acre sunflower field (Field 58, 5/11/98).

high-yield history, or a uniform appearance in an aerial photograph. In two of our project fields, there was a fairly close, inverse relationship between sand content and K soil test. Results for Field 58 are shown in Figure 5. Knowing of this relationship, in the future we will need fewer samples to determine whether the K soil availability has declined to the point that some areas need K fertilization. Of course, for this approach to work, a one-time expense of mapping the soil texture is involved.

Soil P availability in these fields was not related to sand content, so the lower intensity sample collection for K may be inadequate for assessment of P (Figure 5, right). The expense of laboratory analysis is a greater barrier to intensive soil sampling than the cost of collection.

We have also observed that during a 26-month period, the soil test K level—both the average value and the values at individual grid points—changed very little (Figure 6). Change in soil test P level was somewhat more spatially variable (Figure 6, right), although the average barely changed. Both K and P fertilizers were applied (60 lb K_2O and 52 lb P_2O_5/acre) by the grower to the tomato crop eight months after the initial soil sampling. These results suggest that the often-recommended three-year interval for checking soil P and K levels is also adequate for the more spatially intensive sampling needed for variable rate fertilization programs.

Future plans for this project include a fertilizer strip trial in Field 5, in which soil test P levels are below the critical value in a large part of the field.

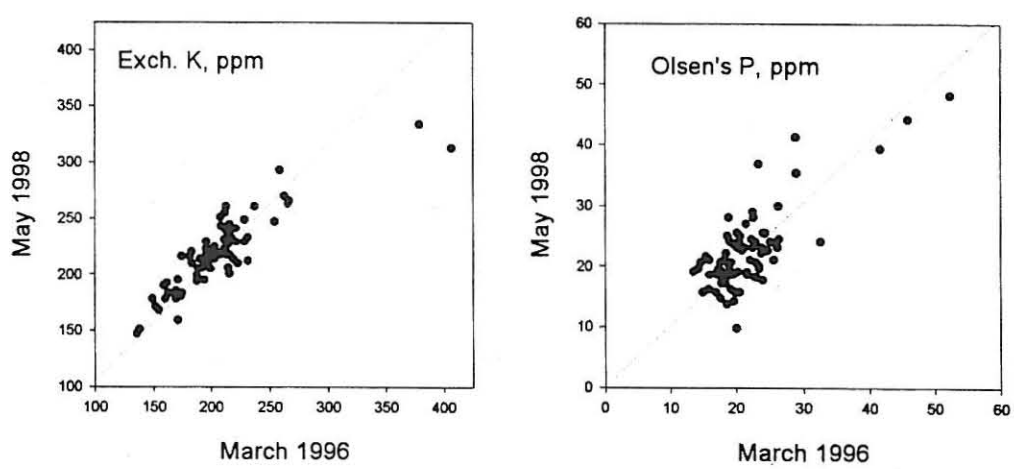

Figure 6—Comparison of soil test K and P values in Field 588 for samples taken 26 months apart in a wheat tomato sunflower crop sequence. Samples were collected on a 200 ft x 200 ft grid. P and K fertilizers were applied to tomatoes 8 months after first sampling date.

DEVELOPMENT AND TESTING OF APPLICATION SYSTEMS FOR PRECISION VARIABLE-RATE FERTILIZATION

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OBJECTIVES

Our goal in this project is to address the practical question, "If results of current research show that site-specific crop management and variable-rate fertilizer application is environmentally sound and economically valuable, and if crop models, yield monitors, and soil sensors exist in order to create accurate fertilizer rate prescriptions, then how can the desired rate changes be practically achieved with existing application equipment in the commercial environment?" Further, we want to know, "Can uniformity and accuracy of fertilizer application rates be improved with better, precision-application equipment?"

We are developing an application control system that uses pulsed valves to change the flowrate, while leaving the system pressure unchanged. By keeping pressure constant, uniform patterns from spray nozzles can be maintained.

Our specific objectives are:

1. Determine if our control valves are suitable for use with typical fertilizer liquids at typical application flow rates and supply pressures
2. Install the control system on a liquid fertilizer applicator and document accuracy and uniformity in application rate and speed of response to changes in application rates in a field setting. Compare the results to a commercial system
3. Determine if the control system can be modified for use with anhydrous ammonia in order to improve uniformity of application, reduce vapor formation in supply lines, and allow a wide range of rate control

DESCRIPTION

The concept of "precision agriculture" is simple: by using accurate navigation and positioning, crop yield, soil properties, and other sensors can be used to develop maps or databases of crop response and geographic variation. From the collected information and an understanding of crop development, the inputs supplied to the crop can be refined and implemented on small "specific" areas, and the overall economic return or environmental effects of production can be optimized.

This project will address the essential physical component of precision farming, namely, a rapid system for varying the application rate of fertilizer under the real-world demands of high vehicle speeds, a wide range of rate control, simplicity, and dependability. When a vehicle is traveling at eight mph, one yard is covered in approximately 0.25 seconds. If fertilizer rate changes are desired in, for example, a two-yard distance, the application system must respond in 0.5 seconds. Most application equipment, even that with electronic rate control, cannot respond quickly enough. Moreover, the range and resolution of rate control are often limited.

The most practical method to adjust application rate of a liquid fertilizer is to adjust the flow rate of material being discharged. The range of required adjustment can be significant. If an applicator wanted to control rates over a three-fold range (for example, from 100 to 300 lb/acre) and be able to compensate for vehicle speed changes over a three-fold range (for example, from three to nine mph), a flow control range of 9:1 would be required.

Existing systems have three problems. The first is the range of rate control. When orifice-metering plates or spray nozzles are used at the fertilizer discharge point, the flow from each line is proportional to the square root of the pressure supplied by the system pump. Therefore, to double the flow rate, the pressure would have to increase by a factor of 4. So, wide control rates, for example the 9:1 range discussed above, would require an 81:1 pressure range or from, for example, 5 psi to 405 psi. Such a wide range is not practically possible.

The second problem is speed of response. Speed measurement and flow measurement can be done in a fraction of a second; however, the control loop requires more time to process the data. The greatest delay is in the actuation, or adjustment, of the regulating valve. Delay times of 2-15 seconds are common with the commercial systems, and delays increase errors when ground speed changes quickly or briefly. For example, if a tractor slows down by 20 percent for a five-second period and then returns to the original speed, a slow-responding system would allow an over-application during the slow period. Then, as it was reducing flow for the slow speed and the tractor was returning to the original speed, it would cause an under-application to occur.

The third problem is uniformity of distribution across a boom or manifold or spray pattern. When a pressure regulator is adjusted to control flow rate, the pressure distribution in a plumbing system is altered, and uniformity of flow in the system can be distorted, particularly over the wide pressure ranges necessary for adequate flow control. The problem is especially acute when spray nozzles are used to distribute the liquid. The spray distribution pattern is significantly affected by the liquid pressure.

RESULTS AND CONCLUSIONS

This project is testing the concept of pulsed-spray application for rate control with liquid fertilizer. With the pulsed-spray valves, the liquid pressure can be maintained at a constant value and the flow rate changed by the characteristics of the pulsing. The valves are coupled to standard spray nozzles, and we are pulsing at frequencies of 5, 10 and 15 cycles per second. The length of each pulse is controlled over a range of 5 percent to 100 percent open. For example, a 10-cycle-per-second rate means that there is 1/10 of a second between pulses. If the valve is open 50 percent of the time, each pulse lasts 1/20 of a second. If the valve is open for 5 percent, then each pulse lasts 1/200 of a second.

The valves have been tested with three standard fan nozzles. The nozzles were TeeJet, 8008, 11015, and TF-10 tips, which were selected to cover a range of flowrates and spray angles. Fertilizer solutions of UN 32 and UN 20 were used. Spray pressures of 10, 20, and 40 psi were used.

Example data for a UN 32 flowing through an FT-10 nozzle is shown below (Figure 1.). Trends and results for the other tests were very similar. A wide range of flow control was possible—from 0.09 gpm to 2.8, or a 30 to 1 range of control. This is far beyond any practical control range that might be needed for variable-rate fertilizer application. This results indicates that the control technique will work well for fertilizer application. The other important result was that the relationship between the flow rate (gpm) and the valve open time (%) was linear and consistent. This result will likely make the control system stable and accurate.

Since the valve pulse rate can be quite rapid, 5–15 times / sec., the speed of response of the application system is likely to also be very fast. Current testing is examining the speed of response for a test system that uses the valves. Constant pressure operation will improve uniformity of application.

The control valve materials are stainless steel and Viton, seals. There have been no problems with corrosion or plugging of the valves from the UN 32 or UN 20 solutions.

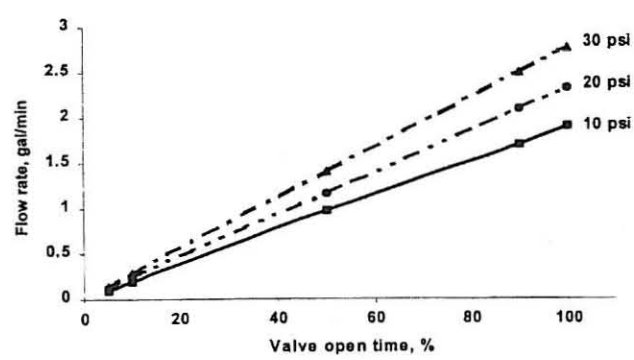

Figure 1—Flow Rate vs. Valve Open Time for TF-10 Nozzle

WESTERN STATES AGRICULTURAL LABORATORY PROFICIENCY TESTING PROGRAM

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Robert O. Miller
Soil and Crop Sciences Department
Colorado State University

OBJECTIVES

The Western States Agricultural Laboratory Sample Exchange program was initiated in 1994 with the prime objective of developing an external quality control program for the agricultural laboratory industry. The program is based on the quarterly exchange of soil and plant materials, on which standard agricultural analysis is conducted using standard methods.

DESCRIPTION

The 1998 Western States Program merged with five other programs from across the United States and Canada to form the North American Proficiency Testing Program for Agricultural Laboratories (NAPT). The number of soils utilized was increased from three to six per quarter to accommodate the greater range of soil properties. Laboratories enrolled in the program can choose from a list of 75 soil analyses. Soil and plant materials utilized in the program were collected from across the United States, of which four were collected from California. For the 2nd quarter of the 1998 NAPT Program, 165 laboratories have enrolled, of which thirty-five provide analytical services in California.

The 1999 NAPT Program will become an organized activity of the Soil Science Society of America. The program will be coordinated by Robert O. Miller, Soil Scientist at Colorado State University, and sample materials will be prepared by Janice Kotuby-Amacher, Analytical Laboratory Director of Utah State University. Two laboratory analytical workshops will be conducted to provide the laboratory with information on analytical methods and quality control.

RESULTS AND CONCLUSIONS

The program has been well received by the industry, and results have been published in the popular press and in scientific proceedings.

For the first two quarters of 1998, approximately 50% of the soil labs provided more than 90% of their values within established warning limits. For plant analyses, approximately 65% of the labs reported more than 90% of the values within established warning limits. Of the soil methods evaluated: soil extractable sulfur; hot-water extractable boron; sand, silt and clay and Soil EC (1:2) method have precision problems across the laboratory industry. Of the plant methods under consideration, both extractable nitrate and sodium have precision problems. Two laboratory workshops have been organized to address laboratory analytical problems. Annual results from the 1996 and 1997 program are available from the project leaders.

Two manuals describing the analytical methods used are available. Plant, Soil and Water Reference Methods for the Western Region is available from:

Ray Gavlak
Palmer Research Center
533 E. Fireweed Ave.
Palmer, AK 99645
(907) 746-9467

Western States Agricultural Laboratory Exchange Program: Suggested Soil and Plant Analytical Methods, Version 4.10, is available from:

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

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INTRODUCTION

The number of Southeast (SE) Asian "small farmers" in Fresno County is 745, according to the most recent figures available. (A small farm is defined as one grossing less than $100,000 and "family operated and/or owned.") This is almost 25 percent of the total number of all small farmers in the county. Many of the SE Asian farmers are refugees from Laos, Cambodia, and Thailand and have been in the United States for less than 20 years, some for as few as two years. About 92 percent are of Hmong and Lao descent-more Hmong and Lao farmers than in any other county in the United States.

SE Asian Vegetable Small Farmer Ethnicity–1992	
62.0%	Hmong
30.0%	Lao
3.4%	Chinese
1.5%	Mien
1.3%	Vietnamese
9%	Cambodian

Farmers in Laos practice a very simple type of agriculture, and many of the first generation farmers have little to no formal educational training. Laotian farmers typically use "slash and burn" methods for crop production. Fertilizers and pesticides are rarely used. Learning and using the American agricultural practices has been a difficult challenge for the Laotians, especially since they are also learning a new language.

OBJECTIVES

The goal of this two-year project is to provide culturally appropriate field trainings and demonstrations to help educate Hmong and Lao farmers in plant nutrition and fertilizer practices. Pre- and post-test surveys will be used as one measure of training effectiveness.

DESCRIPTION

A pre-test questionnaire was given to 20 Hmong/Lao farmers and used to ascertain their level of understanding in plant nutrition, fertilizers, integrated pest management, and pesticide safety. Other pertinent data will also be collected such as years of schooling, ethnicity, languages read and spoken, age, acreage, crops grown, etc. A Hmong field assistant, fluent in Hmong and Lao, was used to gather information for the questionnaires.

A series of six separate mini trainings/workshops was subsequently given to this same group of farmers over a period of time. General and basic information in the four areas of plant nutrition, fertilizers, IPM, and pesticide safety was provided, with an emphasis on hands-on training.

At the end of the mini-workshops, the same questionaire will again be given (post-test) to provide a measure of any learning improvement as a result of the trainings.

RESULTS AND CONCLUSIONS

We traveled to individual farm sites and asked farmers to participate in the questionnaire and trainings. All agreed initially, and we had 21 questionnaires completed by Spring 1998.

The researchers soon realized that getting this group of farmers to attend six mini-workshops was going to be very difficult. We tried meetings in the UC Cooperative Extension office, in the field at the farm site, and both small group and/or individual meetings. Sometimes the farmers would be present, but often they would not. It should be noted that it is very difficult to contact these farmers, even by phone. They are frequently gone, either to their own or to relatives' farms.

Preliminary results for this initial survey are provided below.

A different strategy was developed in Summer 1998, to encourage better farmer participation. A seven-week mini, short course was developed with an emphasis on "Certificates of Completion," farmer Cooperative Extension hours they could use for restricted permit renewals, hands-on, and free door prizes/gifts. The classes started August 6 with 18 participants and ended on September 17 with a graduation ceremony. The same initial questionnaire was used, and the post-tests were administered at the last class. Average attendance has been quite good (16 participants) since farmers had to attend five of the seven classes to receive a certificate.

The pre-test and post-test results are not yet available. However, several observations should be noted here concerning Hmong and Lao small farmers in this survey.

1. Hmong and Lao small farmers are extremely busy, working many hours on their farms (and on relatives' farms), and have difficulty attending a series of training meetings.

2. Incentives are extremely valuable in encouraging participation-particularly:
   - Certificates of Completion

Preliminary Results of the Initial Survey of 21 Respondents	
Country of Origin:	Laos, via Thailand refugee camps
Languages Spoken:	Primarily Hmong and Lao; some Mien, a little French
Languages Read:	Hmong, but less than 50 percent are literate
Educational Background:	Most have received from four to seven years of schooling
Crops Grown:	Strawberries, cherry tomatoes, green beans, bittermelon, sugarcane, sinqua, moqua, chili peppers, oriental eggplant, lemongrass, opo, squash
Acreage Farmed:	2-14 acres
Plant Nutrition:	Practically no understanding of plant nutrition—only a very basic understanding that a fertilizer is needed; and someone told them they should use XXX fertilizer. Minimal understanding of the importance of nutrients needed, soil tests, fertilizer analysis, timing, or rates. Even less understanding about minor nutrient deficiencies/toxicities, soil texture, or different nitrogen forms
Insect Knowledge:	Very limited knowledge—most could not identify harmful or beneficial insects shown on visual aids
Weed Knowledge:	Very limited ability to identify weed speciesæof all pest problems, probably the weakest area of knowledge. Those surveyed were somewhat able to separate broadleafs from grasses

- CE hours for renewing restricted materials permits (new California Department of Pesticide Regulation policy, 1998)

A short, seven-week training may give some indications of the effectiveness of training; however, a long-term study would be much more useful. These two groups (initial 21 pre-test farmers and the second group, which went though the seven trainings) will be evaluated and compared again in two years. The second group will continue to receive monthly trainings (via mail and periodic workshops) and other meeting notices.

CALIFORNIA CERTIFIED CROP ADVISER PROGRAM

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California Certified Crop Adviser Administrative Team
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INTRODUCTION

Public agencies are increasingly concerned about the relationship between crop recommendations and environmental management. Pressure is being placed on growers to evaluate the impact of soil and water contamination. The Certified Crop Adviser (CCA) Program complements and extends recognition beyond the state licensure of pest control advisers on a voluntary basis, while addressing fertilizer needs. Additionally, the program recognizes the need to minimize paperwork and streamline the tracking among programs and among states. It can provide the competitive edge in conducting business.

The program began in 1994 through the American Society of Agronomy and has grown to nearly 10,000 certified participants throughout the United States. California continues to grow, with 520 CCA's, through the support of the California Department of Food and Agriculture Fertilizer Research and Education Program. This past year, the administration of the program was moved to Phoenix, and has established improved tracking and monitoring for participants.

The certified CCA has passed both a state and national exam, signed a code of ethics, and maintains ongoing continuing education units (CEU's) to stay current in the field. It is the only certification program within fertilizer and pest management recognized throughout the country.

OBJECTIVES

The CCA Program administration has embraced a wide variety of tasks. Beginning in May 1997, a greater focus was placed on effective methods of tracking continuing education units (CEU's) and expanded communication directly and indirectly to CCA's. In the initial phase, the administrative team developed a database that allowed flexibility in sorting and creating reports desired by the CCA Program and the national office. During the course of the year, nearly 4,400 individual entries were recaptured into the database to reflect past course histories. In this manner, CCA's were able to search their own information in meeting certification and maintenance requirements.

RESULTS AND CONCLUSIONS

The administrative team reviewed other websites and investigated design issues and linkages. The domain address (www.cacca.org) was selected and registered based on ease in finding. Due to the large volume of inquiries, three years of course history were originally placed on the website to allow anyone missing hours for renewal to become current. We now list CEUs by period-to-date, however, the database exists to reconstruct previously sponsored courses, at any time, by calling the Phoenix office. Whenever a sponsored course is approved, the information is updated on the Internet within a few weeks. The count at the bottom of the webpage represents the number of "hits" to the site since we reset it in April. For the first year of operation, we had over 4,000 individuals referring to our webpage.

Due to the need to reach state licensed pest control advisers (PCA's) in California, the first California Certified Crop Adviser newsletter was released simultaneously with the California Ag Production Consultants Association (CAPCA's) 1997 annual meeting in Reno. To demonstrate the complementary relationship with PCA's, a full-page ad from the California CCA program was featured in CAPCA's premiere magazine.

The program success is measured by the program integrity. The program is utilized by independent consultants, fertilizer manufacturers, and retailers to verify competency. It is utilized by growers to ensure compliance with regulatory agencies, because the recommendations were made by an agency-recognized certified professional.

On the national level, the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) recently signed the first national memorandum of understanding with a third-party vendor, the American Society of Agronomy Certified Crop Advisers. Third-party vendors—authorized in the 1996 Farm Bill—are organizations in both the private and public service that are approved sources of conservation assistance. This third-party agreement allows CCA's, under the director of NRCS, to provide expertise in nutrient and pest management in developing soil nutrient plans. EPA will be requiring these types of plans from confined feeding operations such as dairy or feedlot operations.

Through the above activities, the California Certified Crop Adviser Program is demonstrating a commitment to excellence.

For information on becoming a California CCA, contact Marilyn Martin at (602) 267-1890.

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

Project Leaders:
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OBJECTIVES

Nitrate-N is the most widespread contaminant in groundwater, causing as much as ten times as many well closures in California as all other industrial contamination combined. While a large amount of research has focused on nitrogen cycling in the root zone of California tree fruit orchards (0-6 ft depth), little is known about the fate of nitrogen between the root zone and the groundwater table. Unlike other agricultural regions of the United States, groundwater levels in many areas of Central and Southern California are from 30-ft to over 100-ft 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:

1. 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 of orchards and vineyards
2. Develop and validate an appropriate modeling tool to assess the fate of nitrogen in deep, heterogeneous vadose zones

DESCRIPTION

During 1998, we drilled and characterized approximately 3000-ft of geologic material from 60 cores drilled to groundwater at a 52-ft depth. Eighteen cores were sampled at each of three subplots in the orchard. The subplots had been subject to a twelve-year fertilization trial with different rates of fertilization, ranging from an average annual rate of less than 5 lb/acre in one subplot to more than 300 lb/acre in the third subplot. The second subplot was fertilized at a rate of 100 lb/acre.

During this first year, the goal was to obtain a detailed characterization of the geologic architecture that makes up the vadose zone underneath the orchard. We have been able to map several ancient soil horizons throughout the orchard. The ancient soil horizons are typically much less permeable than the remaining sediment and impede the downward movement of percolating water. Our hypothesis is that these so-called paleosoils may potentially be conducive to denitrification of nitrate-N. We also mapped out former river channels of the Kings River that meandered through the orchard during, or prior to, the last ice age. These channels are composed primarily of clean sands that readily percolate soil water and any nitrate dissolved in the water.

Currently, laboratory work is underway to determine the distribution of nitrate and ammonia in the vadose zone (See Figure below) and to determine the hydraulic properties of the various geologic units we encountered underneath the orchard. Subsequent laboratory work will also tackle the geochemical characterization of the core samples to determine the degree of denitrification that may occur in these thick vadose zones. Ultimately, our work should provide the geologic framework, the hydraulic framework associated with the geologic framework, and the geochemical process framework, all of which affect the fate of nitrate in the vadose zone. The "snapshot" of the nitrate distribution that we obtain from the cores is the result of the geologic-hydraulic-geochemical architecture.

RESULTS AND CONCLUSIONS

The figure below shows the typical vertical nitrate distribution in the subplot of the nectarine orchard that received 100 lb/acre of nitrogen fertilizer. There is no strong correlation with the geologic layering, although it appears that nitrate may accumulate at the bottom of sand layers that are the result of former river channels. Nitrate-N concentrations in the vadose zone underneath this subplot are only slightly elevated. After reaching the water table, dilution in groundwater further reduces the concentrations found in the vadose zone. The maximum contamination level in groundwater is 10 mg/l of nitrate-N. The three numbers on the top of the graph are the identification numbers of the boreholes. The profiles are approximately 10 feet apart from one another.

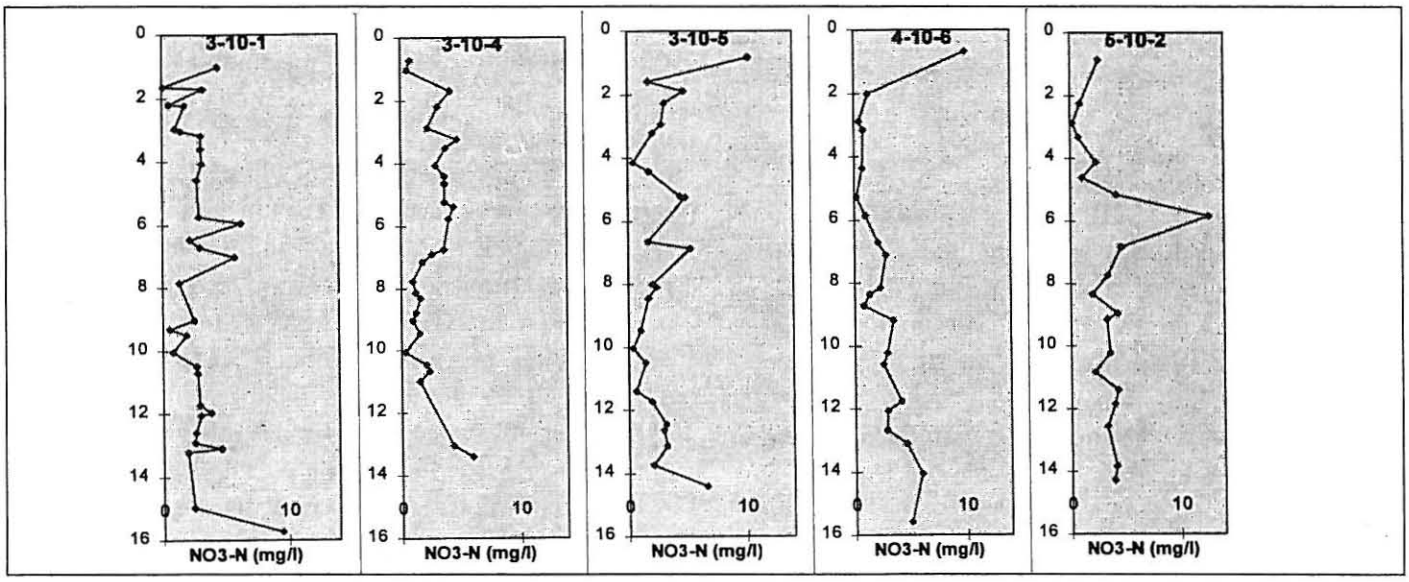

Figure 1.—Typical nitrate distribution in nectarine orchard subplot.

DEVELOPMENT OF IRRIGATION AND NITROGEN-FERTILIZATION PROGRAMS FOR TURFGRASS

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San Bernardino and Los Angeles Counties

OBJECTIVES

1. Test irrigating tall fescue at a defined annual amount (80 percent historical reference evapotranspiration [Eto] plus rain) with increased irrigation during the warm season to improve grass performance, and then proportionally adjusting the cool-season irrigation amount downward to make up for the addition of warm-season irrigation. These treatments are being compared to irrigating tall fescue at a constant rate of (1) 80 percent historical Eto plus rain and (2) 80 percent Eto (real time) plus rain
2. In conjunction with irrigation treatments, test the influence of the annual N-fertility rate on the performance of tall fescue
3. Quantify the effects of irrigation and N-fertility treatments on tall fescue visual appearance and drought stress tolerance, growth (clipping yield) and N uptake, along with treatment effects on soil water content and soil N status
4. Develop best management practices (BMPs) for tall fescue relating to turfgrass water conservation and N-fertilizer use efficiency, which provide optimal performance in terms of visual quality and drought stress tolerance, growth (clipping yields), and N uptake
5. Conduct outreach activities, including trade journal publications and oral presentations, emphasizing the importance of turfgrass BMPs and how to properly carry out these practices for turfgrass irrigation and N fertilization

INTRODUCTION

Urban landscapes, including areas planted with turfgrass, offer numerous functional, recreational, and aesthetic benefits. Several functional benefits include excellent soil erosion and dust stabilization; improved recharge and quality protection of groundwater; enhanced entrapment and biodegradation of synthetic organic compounds; heat dissipation and temperature modification; reduced noise, glare, and visual pollution problems; and lowered fire hazard via open green-turfed firebreaks. The estimated $2,184,000,000 spent annually on turfgrass maintenance in California is also a significant benefit to the state's economy. This estimate is based on a published figure for 1982 and corrected for inflation (multiplier=1.54) and for population increase (multiplier=1.34).

Although the establishment and maintenance of quality, functional turfgrass is justifiable, developing and implementing BMPs is also important for the responsible use and protection of natural resources.

Currently, there is considerable interest in developing and implementing turfgrass BMPs for addressing (1) water conservation, (2) the potential contamination of runoff water and groundwater with applied nutrients, especially NO3-N, and pesticides, (3) the potential contamination of surface water with sediment and nutrients during turfgrass construction, (4) the potential development of pest populations with increasing resistance to chemical control, (5) the potentially negative impacts of chemical management on beneficial soil and nontarget organisms, (6) the potentially toxic effects of applied chemicals to nontarget plants and animals, (7) the potential loss or degradation of native habitat during construction and turfgrass maintenance, and (8) the reduction of

landscape waste, including grass clippings, that is dumped in landfills.

Considering the number of issues listed above, there are probably numerous research and education opportunities for developing and implementing turfgrass BMPs in California. Though each environmental issue is individually important for turfgrass management, the use (conservation) of irrigation water on urban landscapes, including turfgrass, is the most general driving force in California. Considering this point, coupled with the interest of CDFA/FREP in the improvement of crop-water management and fertilizer-use efficiency, we developed a research and education project concerning the BMPs for efficient use of irrigation water and N fertility on tall fescue, currently the most widely planted turfgrass species in California. Our rationale in developing the specific protocols of the project are founded on three assumptions listed below:

1. Future landscape water-use budgets will not exceed 100 percent of reference evapotranspiration (Eto) per square ft of landscape area (California Urban Water Conservation Council, 1998)
2. Fertilization of turfgrasses, according to established cultural strategies, presents a negligible potential for nutrient elements to pass through the root zone into the groundwater or be transported by runoff water into surface waters. This has been confirmed by a number of studies or reviews. However, turfgrass managers will need to give special attention to fertilization practices when (1) there is a potential for heavy rainfall, (2) the turfgrass is immature and the soil is disturbed, such as during establishment, and (3) root absorption of nutrients is low because of dormancy or stress
3. Although excessive application rates of water-soluble N fertilizers on turfgrass, followed by over-watering on sandy soils, has been shown to cause NO3-N leaching, this situation would be less likely to occur during the implementation of annual landscape water-use budgets at 80 percent to 100 percent Eto

In light of these assumptions regarding the management of tall fescue, we believe that the most pertinent crop-water management/N-fertility use efficiency project would involve the development of a balanced irrigation and N-fertility program which takes into consideration both the forthcoming limitations on landscape water-use budgets and optimal annual N rates for tall fescue performance in terms of visual quality and drought stress tolerance, growth (clipping yields), and N uptake.

RESULTS AND CONCLUSIONS

Previous research on tall fescue, maintained in the southern inland valley weather conditions of Riverside, showed that an irrigation amount of not less than 85 percent Eto would be required to maintain minimally acceptable visual quality during the warm season. Actually, even more irrigation water would be required by typical inland tall fescue landscapes because a higher visual quality may be desired, and the irrigation distribution uniformity of the research plots is probably 20 percent higher than that of most landscape irrigation systems. It should be noted that a substantial amount of landscape irrigation water is used by inland locations. Thus, there is a need to test irrigating tall fescue at a defined annual amount (80 percent historical Eto plus rain) with increased irrigation during the warm season to improve grass performance, and then proportionally adjust the cool-season irrigation amount downward to make up for the addition of warm-season irrigation.

Secondly, there is a need to test annual N-fertility levels in conjunction with water conservation. Previous research on turfgrass has shown a significant influence of the annual N-fertility level on water use and drought stress tolerance. Annual N-fertility levels that are either too low or too high significantly reduce turfgrass drought stress tolerance, and therefore are not efficient.

Seasonal timing and rate of N-fertilizer applications can also significantly influence the degree of turfgrass drought stress tolerance. Generally, slow-to-moderate growth four to six weeks prior to drought conditions is required to develop improved drought stress tolerance. The utilization of a higher proportion of slow-release N-fertilizer sources and the application of lower amounts of N per application can facilitate slower growth and result in a higher degree of turfgrass drought stress tolerance. Although this discussion is centered on N, a proper balance of all plant nutrients is required.

UNIFORMITY OF CHEMIGATION IN MICRO-IRRIGATED PERMANENT CROPS

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OBJECTIVES

1. 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
3. Conduct a series of workshops on chemigation of microirrigation systems

DESCRIPTION

Chemigation, the injection of chemicals through an irrigation system, is becoming common among permanent crop growers, especially tree and vine using microirrigation systems. Advantages to chemigation include:

1. Flexibility in timing fertilizer applications
2. Reduction of the labor required for applying chemicals
3. 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 and potassium sulfate) are not readily soluble and are being injected using "solutionizer" machines.

RESULTS AND CONCLUSIONS

Work is well underway on the initial stages of the project, which includes evaluation of commercial orchards and vineyards to determine the travel times of chemicals injected into the irrigation water of microirrigation systems. Chlorine is injected as a readily and immediately detectable component for water/chemical travel time determinations while potassium chloride is used as a tracer for injected chemical application uniformity.

Preliminary results from the evaluations completed indicate water/chemical travel times can be up to 50+ minutes in drip irrigation systems. In addition, the time required to clear the microirrigation system of the injected chemical after injection ceases is similar, but slightly longer than the initial travel time at the start of injection.

AGRICULTURE AND FERTILIZER EDUCATION FOR GRADES K-12

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OBJECTIVES

The purpose of this project is to provide educators and students with educational materials about the nutrient requirements of plants and to study how the agricultural industry produces the food, clothing, floral, and forest products people use. Educating teachers about ways to integrate agriculture and soil fertility information into their classrooms will not only better inform them as present-day consumers, citizens, and voters, but will also assist them in educating their students and colleagues about the important role agriculture plays in their daily lives.

DESCRIPTION

Throughout the years 1992-1995, the California Foundation for Agriculture in the Classroom (CFAITC) developed instructional materials for grades K-12, which integrate agriculture and soil fertility information. These units consist of five to thirteen student lessons each and contain background information and resources for the teacher.

The units are promoted in the Foundation's Teacher Resource Guide and in other publications, including Ag Alert (the weekly Farm Bureau newspaper) and the California Classroom Science educator newsletter, and are distributed at statewide and national educator conferences and workshops. The 1998 California Department of Food and Agriculture's FREP grant has provided funding to reprint 250 of each of the six units (and complementing Spanish student worksheets) to distribute to educators.

RESULTS AND CONCLUSIONS

CFAITC continues to develop new resources for educators. CFAITC has developed three Plant Nutrient Fact and Activity Sheets on Nitrogen, Phosphorus, and Potassium. Each Fact Sheet provides one page of information on the plant nutrient, including its production, how plants utilize the nutrient, the nutrient's history, and its economic value. The Classroom Activity Sheets provide teachers with mini-lessons and activities that further integrate plant nutrient education into their classroom curricula. The Plant Nutrient Fact and Activity Sheets will be distributed to over 5,000 AITC Ambassadors in a mailing, to occur in September 1998.

One content area of CFAITC's instructional materials program is to educate students and teachers about the nutrient requirements of plants. Through the variety of instructional materials available (six educational units, Spanish worksheets, and three Plant Nutrient Fact and Activity Sheets), CFAITC is meeting this goal. During the next two years, over 20,000 educators will receive complimentary copies of the Plant Nutrient Fact and Activity Sheets, and over 80,000 people, through the Cream of the Crop newsletter, will be informed of the plant nutrient lesson plans available. Each year, CFAITC's mailing list and contacts with educators is growing. The Foundation is pleased with its progress in educating teachers and students about the nutrient requirements of plants.

CFAITC has a wide variety of educational materials available. Fact and Activity Sheets and lesson plan descriptions can be obtained by contacting CFAITC at Post Office Box 15949, Sacramento, CA 95852-0949, (800) 700-AITC.

IV. Completed Projects

The following is a list of FREP projects completed prior to October 1998. Summaries of many of these projects appear in earlier 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

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

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

Nitrogen Efficiency in Drip Irrigated Almonds
Robert J. Zasoski

Effects of Four Levels of Applied Nitrogen on Three Fungal Diseases of Almond Trees
Beth Teviotdale

Nitrogen Fertilizer Management to Reduce Groundwater Degradation
Steve Weinbaum

Avocado Growers can Reduce Soil Nitrate Groundwater Pollution and Increase Yield and Profit
Carol Lovatt

Relationship Between Nitrogen Fertilization and Bacterial Canker Disease in French Prune
Steven Southwick, Bruce Kirkpatrick, and Becky Westerdahl

VEGETABLE CROPS

Optimizing Drip Irrigation Management for Improved Water and Nitrogen Use Efficiency
Timothy K. Hartz

Improvement of Nitrogen Management in Vegetable Cropping Systems in the Salinas Valley and Adjacent Areas
Stuart Pettygrove

Nitrogen Management Through Intensive On-Farm Monitoring
Timothy K. Hartz

Development and Promotion of Nitrogen Quick Tests for Determining Nitrogen Fertilizer Needs of Vegetables
Kurt Schulbach and Richard Smith

On-Farm Demonstration and Education to Improve Fertilizer Management
Danyal Kasapligil, Eric Overeem and Dale Handley

FIELD CROPS

Impact of Microbial Processes on Crop Use of Fertilizers From Organic and Mineral Sources
Kate M. Scow

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

Establishing Updated Guidelines for Cotton Nutrition
Bill Weir and Robert Travis

EDUCATIONAL/MISCELLANEOUS

Use of Ion Exchange Resin Bags to Monitor Soil Nitrate in Tomato Cropping Systems
Robert O. Miller and Diana Friedman

Education Through Radio
Patrick Cavanaugh

Integrating Agriculture and Fertilizer Education Into California's Science Framework Curriculum
Mark Linder and Pamela Emery

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

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

Determination of Soil Nitrogen Content In-Situ
Shrini K. Updahyaya

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

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

Survey of Changes in Irrigation Methods and Fertilizer Management Practices in California
John Letey, Jr.

Practical Irrigation Management and Equipment Maintenance Workshops
Danyal Kasapligil, Charles Burt and Eric Zilbert

Irrigation and Nutrient Management Conference and Trade Fair
Danyal Kasapligil

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 Fruit and Nut Production: A Video
Thomas Doerge and Lawrence J. Klaas

V. New Projects

DEVELOPMENT OF NITROGEN BEST MANAGEMENT PRACTICES FOR THE "HASS" AVOCADO

Project Leader:
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To reduce potential nitrate pollution of groundwater, avocado growers apply nitrogen (NH_4NO_3) fertilizer to the soil in several small doses annually. This strategy ignores tree phenology and the possibility that the tree requires more N at certain times of the year. At the request of the California Avocado Commission (CAC), we undertook a four-year study to determine the impact of supplying extra soil N to "Hass" avocado trees at key times in the phenology of the tree, relative to supplying an equal amount of N in six small doses per year. The results clearly identified specific times when N fertilization reduced yield (February or June) and times when extra soil-applied N increased yield (April or November). Double applications of N in November or April increased yield by 201 lb and 133 lb more fruit/tree/four years.

Since orchards have approximately 100 trees/acre, the yield increases are economically significant. Hence, last year CAC funded a new six-year study to replicate the previous study and to quantify the effects of additional strategies with the overall goal to even out alternate bearing and increase annual and cumulative yield, without reducing fruit size and quality. The danger is that we don't know whether using double or triple doses of soil-applied N to increase yield will increase the potential for nitrate groundwater pollution. It is hypothesized that supplying an avocado tree with more N at times when demand is greater should not increase leached nitrate. Since yield increased, the interpretation is that the extra N was utilized by the tree. This hypothesis will be tested under this project.

We will use buried resin (strong anion and strong cation) bags to quantify the amount of nitrate and ammonia leaching past the root zone for the different N fertilization strategies and for the control. The results of this research will identify the best management practices for N for the "Hass" avocado in California. The avocado growers of California are proactively seeking this information.

EFFICIENT IRRIGATION FOR REDUCED NON-POINT SOURCE POLLUTION FROM LOW-DESERT VEGETABLES

Project Leaders:
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University of Arizona

Khaled M. Bali
Desert Research and Extension
University of California

Inefficient irrigation practices are a factor in water quality related issues. Data from southern California and Arizona indicate that irrigation practices are a significant factor contributing to N losses from soils used for vegetable production. There is a tendency for vegetable growers to apply generous amounts of water to produce because of anxiety about crop quality and the lack of sufficient information to do otherwise. Additionally, concerns about salt accumulation having an adverse affect on land sustainability often prompts growers to employ a generous leaching requirement. A perceived lack of practical technologies on irrigation scheduling is a major obstacle to progress in implementing efficient irrigation practices.

This project seeks to evaluate and demonstrate efficient irrigation practices for vegetables produced in the low-desert region of California and Arizona. We will focus on lettuce and melons because these two crops occupy the largest area of all vegetable crops produced. The first phase of this project will experimentally evaluate irrigation scheduling technologies and evaluate the influence of irrigation and N fertilization on crop response, N-leaching, and salt balance. The second phase of this project will be carried out in commercial fields and is primarily an outreach program to provide training in the utilization of scheduling technologies, demonstrate results to growers, and hasten implementation of developed practices. Crop water budgets, crop N nutrition, N leaching, and salt balance will be closely monitored on commercial vegetable fields managed by the developed irrigation practices and those managed using standard irrigation practices.

DEVELOPMENT AND DEMONSTRATION OF N BEST MANAGEMENT PRACTICES FOR SWEET CORN IN THE LOW DESERT

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Keith Mayberry
Farm Adviser
Imperial County

Marita Cantwell
Department of Vegetable Crops
University of California

Charles. A. Sanchez
Yuma Agricultural Center
University of Arizona

Sweet corn is an important crop produced during the fall and spring in the low desert. Large amounts of fertilizer are typically used to produce high quality sweet corn. Rates of N applied to sweet corn in the desert often exceed 300 kg N/ha. Concern about nitrate contamination of ground and surface water from N fertilizer has prompted us to seek improved N management strategies for crop production in the desert. The objective of this project is to identify and demonstrate N best management practices for sweet corn while maintaining crop yield and quality.

Experiment/demonstration sites will be established in the Coachella Valley, the Imperial Valley, and the Lower Colorado River Valley. Some of these experiment/demonstrations will evaluate variables of N rate, N timing, and N placement and will also evaluate new technologies such as controlled-release N fertilizers. Other experiment/demonstrations will be aimed toward developing and demonstrating plant and soil testing technologies. On selected sites, we will also perform post-harvest evaluations of sweet corn to assess the effect of N management on post-harvest quality. Field days and grower workshops will be held to demonstrate N best management practices to growers.

AIR QUALITY AND FERTILIZATION PRACTICES: AN INVENTORY OF FERTILIZER APPLICATION PRACTICES FOR AGRICULTURE IN THE SAN JOAQUIN VALLEY

Project Leader:
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Research for Hire
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Emissions of ammonia and NO_x from nitrogen fertilizers applied to agricultural land have been identified as a possible source of air pollution in the San Joaquin Valley (SJV). Work on this problem is currently proceeding without benefit of a nitrogen fertilizer application calendar. It is of concern to knowledgeable farmers that this deficiency could lead to erroneous conclusions about the relationship between the use of nitrogen fertilizers on agricultural lands and air pollution problems in the SJV.

This project will generate a general nitrogen fertilizer application calendar for major crops in the SJV and an accompanying report and map. The report will describe factors that will account for differences in the timing of nitrogen fertilizer use among farms and among crop years. The report will also describe the amount, form, and method of application of nitrogen fertilizer for the subject crops. The report and map combined will describe factors that account for differences in the timing of nitrogen fertilizer application among regions of the SJV. This project will also identify and describe circumstances that make it feasible to predict and inventory within a comparatively precise time frame instances of strongly expressed pulses of nitrogen fertilizer application to agricultural lands.

The nitrogen fertilizer application calendar will be used for research, monitoring, inventories, and advocacy. Its quality can be evaluated by comparing time frames that it delineates for the application of nitrogen fertilizer against actual farm practice.

EFFECT OF COVER CROP OR COMPOST ON POTASSIUM DEFICIENCY AND UPTAKE AND ON YIELD AND QUALITY IN FRENCH PRUNES

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Nutrient deficiencies can be caused by either a total deficit of the nutrient in the soil, an inability for the soil to supply the nutrient to the crop, or an inability of the crop to take the nutrient up in great enough quantities to meet its demands. To design effective fertilizer regimes, it is crucial to understand the causes of nutrient deficiency. Potassium (K) deficiency is very pronounced on French prune trees growing in the Sacramento Valley. The deficiency is especially apparent in heavy crop years and in heavy-textured soils.

Long-term studies have shown that banding K at rates of up to 2,500 lb/acre will increase yields in prune orchards for 3-4 years and will decrease foliar die-back during the heavy-crop years. Banding of fertilizer is appropriate if a nutrient has the potential to be fixed by the soil. Potassium fixation by soils is dependent on the quantity of vermiculite, and to a lesser extent illite, present in the soil. These minerals are derived from granitic parent materials. The soils of the upper Sacramento Valley are formed on volcanic parent material which contains no mica or vermiculiten; thus it would be predicted that these soils have little potential to fix K. Heavy clay soils may cause poor root distribution. If poor root growth is limiting K uptake, management practices that increase root exploration of the soil should help to ameliorate K deficiency.

This project will investigate alternatives to banded K applications at high rates. In our study, we will determine:

1. Whether these soils have the capacity to fix potassium by performing mineralogical analysis and K adsorption and release studies in the laboratory

2. Whether cover crops and compost application (management practices that encourage root growth in the upper portion of the profile) enhance K uptake and reduce K-deficiency

These parameters will be determined by the following measures: leaf K, exchangeable K, soil-solution K, foliage symptoms, and fruit yield and quality. A replicated field trial will be undertaken on an established planting of French prunes which has regularly shown K deficiency symptoms. Factors investigated will include orchard floor management and method of K application.

INTERACTION OF COTTON NITROGEN FERTILITY PRACTICES AND COTTON APHID POPULATION DYNAMICS IN CALIFORNIA COTTON

Project Leaders:
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Robert Hutmacher
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University of California, Davis

During the last ten years, the cotton aphid (Aphis gossypii) has developed from a non-pest to one of the most significant insect pests of California cotton. In 1997, cotton aphid outbreaks were severe and widespread. An estimated 3.5 percent yield loss occurred, and ~$40/acre control costs were incurred. Cotton aphid infestations during the late-season (mid-August to September) are problematic, because the aphids deposit honeydew on the exposed cotton lint. The damage reduces the value of the lint and threatens the reputation of the industry for high quality cotton. However, since ~1992 mid-season (July to mid-August) cotton aphid infestations have been the most prevalent and damaging. The mid-season aphids compete with the fruiting structures for photosynthesis, and thereby directly reduce cotton yields.

Reasons for this change in pest status of cotton aphids are unclear. This insect pest and other traditional insect pests have contributed to the lack of economic return for cotton production and, in part, to the decline in acreage in recent years. One of the most noticeable changes in cotton production over the last ten years is the use of a plant growth regulator (mepiquat chloride), instead of irrigation and nitrogen deficits, to limit early season cotton vegetative growth. This has allowed cotton production practices in the San Joaquin Valley (SJV) to evolve to higher nitrogen fertilization and irrigation inputs. Host plant conditions including high nitrogen and high leaf water potential, i.e., adequate moisture, are generally optimal for aphid population growth and development.

Cisneros and Godfrey, in a small plot study in 1997, found there were three times more cotton aphids on cotton in high-nitrogen treatment (200 lb N/acre) compared with the low-nitrogen treatment (50 lb N/acre). This study has heightened our interest, as it suggests a way to mitigate cotton aphid populations. However, 50 lb N/acre is not feasible for cotton production, as the cotton was noticeably affected in our study. This study seeks to investigate the influence of cotton nitrogen fertilization levels and cotton aphid population in grower fields in the San Joaquin Valley. Nitrogen levels optimal for plant growth, but low enough to limit aphid reproduction, are sought. With the awareness of growers to cotton aphids, and the dependence on insecticides to control this pest (and impending changes in insecticide registration status), we believe growers will adapt new practices if they are designed.

POTASSIUM RESPONSES IN CALIFORNIA RICE FIELDS AS AFFECTED BY STRAW MANAGEMENT PRACTICES

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When rice straw is removed on a continued basis, this management practice will have a pronounced effect on the available K levels in the soil. Some preliminary data gathered from the long-term straw rotation studies showed that the extractable K levels in the soil in the top 15 cm declined significantly to less than 60 ppm when straw was baled. Under eight different straw management practices, grain yield showed a linear positive response to K fertilizer application. The amount of extractable K was significantly correlated with the percent K in the straw which was significantly correlated with rice yield. These data strongly suggest that baling and possible burning of rice straw may require higher K fertilizer inputs in order to sustain yield. It would also suggest that the current soil K test may not adequately reflect plant-available K.

Another interesting observation in these studies was how K interacts with N and affects the N use efficiency of rice. The amount of N that has to be available to produce a ton of grain, or unit N requirement (UNR), was 14 lb/acre when there was not a K limitation, but doubled to 28 lb/acre at the site where K was deficient. The interaction between K availability and UNR is remarkable and apparent; so strong that it requires further attention. Adequate K levels in the soil have also been shown to reduce the occurrence of diseases. For example, adequate levels of plant available K reduce the occurrence of aggregate sheath spot and rice stem rot diseases. By reducing the occurrence or the severity of diseases, the UNR will decline, and less N has to be available to produce a ton of grain.

Based on the above, the following objectives are formulated:

1. Re-evaluate the effect of K fertilization response of rice yield and its interaction with N
2. Determine how adequate levels of available K affects the occurrence of rice diseases
3. Re-access the accuracy of the soil K test on predicting plant available K

The soil test currently used to determine plant-available K levels will be re-examined. Soil with different clay and soil organic matter content will be collected from sites across the Sacramento Valley. Rice will be grown under controlled conditions, and the extractable soil K levels will be correlated with the K content in leaves during the growing period. Different extractants will be used to test for soil-available K.

The ultimate goal of the project is to re-adjust K fertilization recommendations, once we have determined how K fertilization affects the use of N when rice straw is removed or burned versus incorporated. We believe that adequate levels of K will strongly increase the plant use of N fertilizer and that incorporating rice straw will enhance the use efficiency of both K and N.

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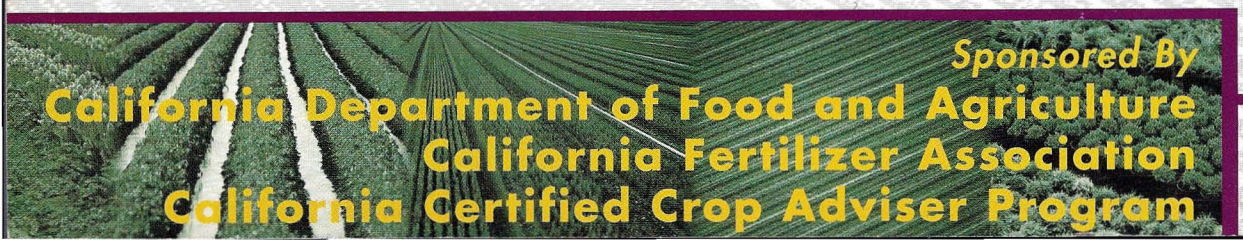

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