FERTILIZER RESEARCH AND EDUCATION PROGRAM CONFERENCE

PROCEEDINGS

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TULARE, CA

CDFA™
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Fertilizer Research and Education Program

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Since 1990, the California Department of Food and Agriculture's Fertilizer Research and Education Program (FREP) has achieved great success in funding and extending agricultural research in California. The program's mission is to advance the environmental and agronomic use and handling of fertilizer materials. A primary objective is to improve the efficiency of commercial fertilizer use and minimize nitrogen losses to the environment. FREP also funds "nuts and bolts" agronomic studies that address crop fertility issues. From 1990-2001, FREP has supported 92 research and education projects for a total amount of $4.6 million in funding. Funding for FREP activities is generated from a mill tax on the sale of commercial fertilizers in the State of California, which currently generates close to $1 million per year for project funding and program activities.

This publication includes summaries and results to date of all projects that are currently receiving funds. Section III lists completed projects. Check our web site (www.cdfa.ca.gov/is/frep) for information on these projects or call our office for a copy of the final report.

FREP strives for excellence by supporting high quality research endeavors that have gone through a rigorous statewide competitive process, including independent peer review. FREP is also having a lasting impact on the advancement of applied agricultural research as many FREP-sponsored projects are published in the scientific literature. See Section IV of these proceedings for a list of articles published in peer-reviewed journals.

FREP's current funding priorities include:

- Irrigation interactions - water management as related to fertilizer use efficiency and the reduction of groundwater contamination and fertigation methodologies.
- Fertilization practices - nutrient balance, crop nutrient uptake, and partitioning; including amounts, timing, and partitioning of nutrients taken from the soil, foliar nutrient management, slow release fertilizers, green manures, and the use of agricultural composts.
- Precision agriculture (site-specific management) technologies and applications.
- Non-nutritive metals in commercial inorganic fertilizers and their relationship to agricultural crops and soils
- Development, testing, and demonstration of the use and benefits of practical field monitoring tools.
- Improving the understanding of the relationships between nutrients and pests and diseases.
- Air quality and PM 10/PM 2.5 concerns as they relate to fertilizer applications.
- Development and distribution of educational products and public information.

Project Funding Analysis

We have recently completed an analysis of the 92 FREP-funded projects to date. Figures 1-3 below show where the cumulative program resources have been distributed in terms of geographic location, discipline and agricultural commodity. Figure 1 shows that 60% of the funding to date has been conducted in, or has primary relevance to, the Central Valley. This is in line with current agricultural production for the state. The Central Coast has also received a significant portion of research funds. These have mostly been focused on fertility management of cool-season vegetables in the Monterey County and points south. Some projects have had a statewide relevance, while smaller portions have been directed at the desert and south coast areas where agricultural activity is less prominent.

As detailed above, FREP has numerous funding priority areas, which have remained relatively consistent over the life of the program. Because the nature of the nitrate problem is

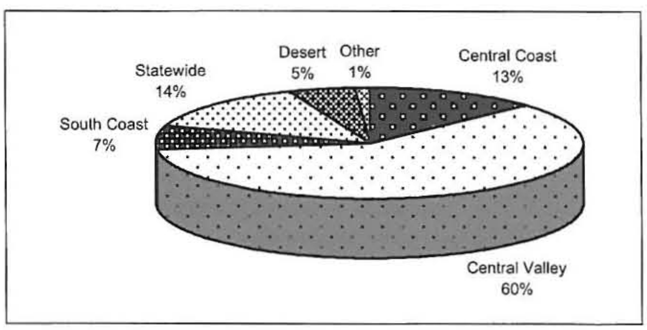

Figure 1. CDFA FREP Projects by Location: 1990-2001.

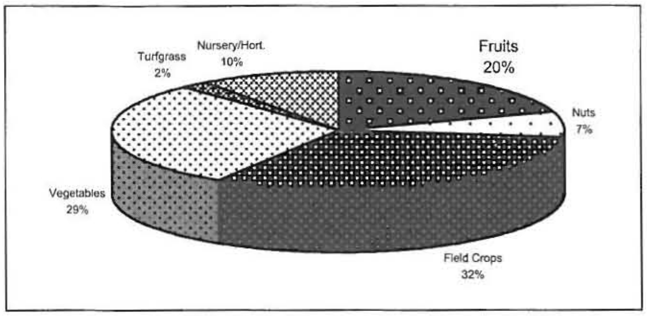

Figure 2. CDFA FREP Projects by Commodity: 1990-2001.

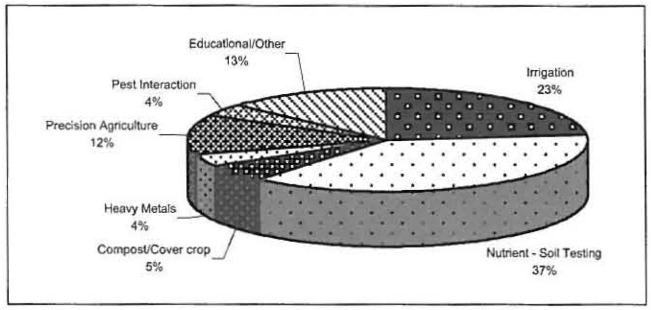

Figure 3. CDFA FREP Projects by Discipline: 1990-2001.

complex, different research approaches are necessary. Figure 2 shows the distribution of funded research projects by discipline. More than one third (37%) of FREP's projects have been related to developing, testing and demonstrating various nutrient tissue and/or soil testing procedures. The program has favored growers using standard laboratory testing for nutrient assessment. Much research efforts have also been directed at developing pre-sidedress testing for cool-season vegetables where growers can test their nutrient soil levels themselves to guide in-season nutrient applications.

Working in improving irrigation management to optimize water delivery has also been an important focus of the program (23%). In-season water applications have a marked effect of transporting nitrogen beyond the root zone.

New technologies for nutrient management such as using GIS, GPS, remotes sensing, using yield monitors has also received funding attention. 12% of FREP's research portfolio is in this area. Other areas under consideration include then relationship between pests and diseases with fertility management, composts and cover crops, heavy metals and air quality issues.

Figure 3 shows that research dollars are also being spent in roughly equal proportions among the general crop types; one third field crops, one third vegetable crops and one third fruit, nut and vine crops. Turf and nursery are also receiving a smaller amount of funds.

This year's program achievements include a new publication titled Chemigation in Tree and Vine Micro-irrigation Systems. This is the result of a 2-year study by Larry Schwankl and Terry Prichard of the University of California. This manual is published by the University of California Division of Agricultural and Natural Resources (Publication 21599), and is available by calling (800) 994-8849.

Currently in press is a comprehensive technical manual on Precision Agriculture for California written by G. Stuart Pettygrove and many other authors. Look for this publication this year.

We have also continued our efforts in the area of agricultural literacy. The California Plant Health Association has produced and distributed videos and companion materials that guide the viewer on developing, planning and installing gardens on school sites. To receive a copy of the video, contact CPHA at (916) 446-3316.

FREP is also continuing its support of the California Certified Crop Adviser Program. Now headquartered in Sacramento, this program is raising the level of professional knowledge of crop advisors in the state through a voluntary certification program. Visit their web site at www.cacca.org to learn more about their activities and upcoming test dates.

EDUCATION AND OUTREACH

One of FREP's primary goals is to ensure that research results generated from the program are distributed to, and used by, growers and the fertilizer industry. FREP serves a broad audience including growers, agricultural supply and service professionals, extension personnel, public agencies, consultants, Certified Crop Advisers, Pest Control Advisers and other interested parties. Proceedings from the annual FREP conference are disseminated throughout the year to interested members of the agricultural community. FREP has also funded a number of projects designed to increase the agricultural literacy of students in the K-12 setting.

In today's world of limited budgets, we know we must work with others to achieve our objectives. To that end, FREP staff collaborates and coordinates with other organizations with similar goals. Our partners include:

- California Chapter of the American Society of Agronomy
- California Certified Crop Adviser Program
- Sacramento Regional Wastewater Treatment Facility
- Monterey County Water Resources Agency

- University of California, Sustainable Agriculture Research and Education Program
- University of California, Small Farm Center
- State Water Resources Control Board, Interagency Coordinating Committee

ACKNOWLEDGMENTS

We would like to acknowledge the support of the fertilizer industry in providing funds for the program. Their foresight in creating FREP and their long-term commitment and dedication has been instrumental in achieving our successes.

We would also like to recognize the members of the Fertilizer Inspection Advisory Board Technical Advisory Subcommittee who review and recommend projects for funding. Al Ludwick, Brock Taylor, Jack Williams, Tom Beardsley, Jack Wackerman, David McEuen, John Weatherford, Tom Gerecke, Al Vargas, Jerome Pier and Eric McGee have exhibited dedication 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 greatly value the input and support received from the California Plant Health 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.

Special recognition also goes to the leadership at the California Department of Food and Agriculture including John Donahue, Director of the Division of Inspection Services who has recently retired after many years of service to California agriculture. Steve Mauch, Assistant Director of the Division of Inspection Services, and Steve Wong, Branch Chief of the Agricultural Commodities and Regulatory Services Branch and Stanley Buscombe, Program Supervisor have also provided valuable input. Additional support from Athar Tariq, Joanna Danquah and the Branch's clerical staff is also acknowledged. Finally, this year is marking a change in program staffing at FREP. Casey Walsh Cady left the program in October 2000 to work on CALFED agricultural issues, and Stephen Beam has stepped in to provide overall coordination of the program.

Relationship Between Fertilization and Pistachio Diseases

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INTRODUCTION

Fertilization of pistachio trees from a very young age is routinely conducted in California's commercial pistachio orchards. Botryosphaeria panicle and shoot blight caused by *Botryosphaeria dothidea* has become a disease of major importance for pistachios grown in California since the late 1980's. Alternaria late blight caused by at least three species of *Alternaria* has also caused significant losses in certain pistachio orchards recently. Because fertilization can affect diseases in general, it was speculated that perhaps nitrogen fertilization might have affected disease incidence and severity. The present study investigated the effect of various nutrient elements, and their levels on the susceptibility of pistachio to Botryosphaeria panicle, shoot blight, and Alternaria late blight in greenhouse studies.

PROJECT OBJECTIVES

1. Determine the effects of fertilization on pistachio diseases such as Botryosphaeria and Alternaria blights in a greenhouse.
2. Determine the effects of fertilization on pistachio disease resistance/susceptibility compounds.

PROJECT DESCRIPTION

Similar to the Botryosphaeria blight experiments (1999/00 and 2000/01), the susceptible pistachio cultivar Kerman was selected for a greenhouse experiment to study the effect of fertilization on Alternaria late blight. Three levels (50%, 100%, and 200%) of nitrogen (N), phosphorous (P), and potassium (K), and three levels, 0.1%, 0.2%, and 0.4% of $Ca(NO_3)_2$ were established in 4 each of replicated potted trees per treatment. The 100% solution contained 0.21 g N, 0.032 g P, and 0.234 g K, and microelements per liter solution. One liter was supplied per plant per week. After fertilizing the trees for 2 months, all trees were spray-inoculated with a 20,000/ml spore suspension of *Alternaria alternata*. Thirty days after inoculation, plants were checked for infection (leaf lesions) and evaluated. Unfortunately, no infections developed by *A. alternata* during the time when this experiment was done (in June). Because Alternaria late blight requires senescing leaves in order to infect, we will repeat this experiment, and inoculate the differentially fertilized potted trees later in the season (late August or during September) when leaves are fully mature, and start senescing. Therefore, we plan to inoculate the above trees again with 20,000 spores/ml of *A. alternata*, and then record disease severity (lesion area covering the leaf surface), using four (0 to 4) severity categories. The effects of fertilization on Alternaria late

Table 1. Effects of fertilization on Botryosphaeria blight in a greenhouse experiment (2000/2001).

Treatment	*Disease index (DI)*[1]
Check (100% N, P, K)	0.47 abc[2]
50% N	0.49 ab
200% N	0.44 abcd
50% P	0.53 a
200% P	0.40 bcde
50 K	0.48 abc
200% K	0.34 de
0.1% $Ca(NO_3)_2$	0.32 e
0.2% $Ca(NO_3)_2$	0.36 de
0.4% $Ca(NO_3)_2$	0.38 cde

[1]Disease index for each tree was calculated using the formula:

$$DI = \left(\sum_{i=0}^{4} N_i * i\right) / \sum_{i=0}^{4} N_i,$$

where i is severity (0 to 4) and N_i is the number of leaves with severity of i.

[2]Values with different letters are significantly different at P = 0.05 level according to LSD test.

blight will be assessed by using leaf disease index (DI) data as done for Botryosphaeria panicle and shoot blight.

The general conclusion from the trials thus far on the effects of fertilization on Botryosphaeria blight is that fertilizing trees with high levels of potassium or spraying trees with calcium nitrate can reduce the severity of Botryosphaeria blight (Table 1). Frozen leaf samples from each replicated tree in each treatment are being analyzed for disease resistance/susceptibility compounds. Results on the effect of fertilization on Alternaria late blight and on the disease resistance/susceptibility compounds are not yet complete and available.

RESULTS AND CONCLUSIONS

Two years (1999/2000 and 200/2001) results clearly showed that there were no significant differences among the percentages of infected leaves by *Botryosphaeria dothidea* among the various treatments of N and P fertilization. However, only the 200% K rate treatment significantly reduced severity of Botryosphaeria blight by about 30% on pistachio leaves as compared with the normal (100% N, P, K) fertilization treatments (Table 1). Results of the stem inoculation experiment were variable. A partial reason of this variability might be differences in the diameter of stems. Generally, lesions were longer in shoots with smaller diameter than in those with large diameter. In addition, disease index of trees sprayed with 0.1%, 0.2%, and 0.4% $Ca(NO_3)_2$ was reduced significantly ($P < 0.05$) by about 33%, 24%, and 19%, as compared to that of the control treatment, respectively (Table 1). We have just initiated a similar experiment this season, using *Alternaria alternata* as inoculum, but results are not yet available since Alternaria late blight disease starts to develop symptoms late August and during September, when pistachio leaves are fully mature and begin to senesce.

The Effect of Nutrient Deficiencies on Stone Fruit Production and Quality

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INTRODUCTION

This project was initiated in 1999 to develop a system where nutrient deficiencies could be studied in mature peach, plum, and nectarine trees. Sixty large tanks were installed in the field and filled with sand during the winter of 1999-2000 (see 2000 CDFA-FREP proceedings for details). During the 2000 season, one tree each of Zee Lady peach, Fortune plum, and Grand Pearl nectarine (white flesh) was grown in each tank. The goal during that year was to grow all the trees vigorously so they would be large enough to produce sufficient fruit for subsequent years when nutrient deficiencies would be imposed. The differential fertilization treatments were started in the summer of 2000 and continued through the 2001 season.

These trees will be a valuable tool for the study of nutrients in stone fruit growth and production. Our first objective is to evaluate the effect of nutrient deficiencies on fruit quality including size, color, sugar content, firmness, storageabililty, and disease resistance. Other productivity related factors such as tree growth, flowering, fruit set, and resistance of the vegetative growth to insects and diseases will also be studied. Furthermore, it is already becoming clear that this experiment will be very useful in reassessing the current diagnostic tools for measuring nutrient levels in the tree as well as evaluating new approaches such as DRIS. The interaction of nutrients in the plant is yet another potentially worthwhile use of these trees. High quality pictures of the different nutrient deficiencies for use in our education and outreach programs will also be developed.

OBJECTIVES

1. To induce nutrient deficiencies in full size peach, plum, and nectarine trees growing in sand culture in the field, and to study the effect of these deficiencies on tree growth, flowering, fruit quality, pest susceptibility, and yield.
2. To produce high quality slides and color photos of deficiency symptoms, and use these for various educational programs including a laminated field handbook, our stone fruit manual, and many extension meetings.

RESULTS AND CONCLUSIONS

Combinations of fertilizer salts were applied to the different tanks in an effort to achieve the following treatments. Each treatment was replicated in 4 tanks.

Treatment 1 – All nutrients
Treatment 2 – No nutrients

Treatment 3 – No nitrogen
Treatments 4 & 5 – No phosphorus
Treatments 6 & 7 – No potassium
Treatments 8 & 9 – No calcium
Treatment 10 – No sulfur
Treatments 11 & 12 – No magnesium
Treatments 13, 14 & 15 – No micronutrients (B, Zn, Mn, Fe, Cu, Mo)

Applications were made on June 23, 2000 and again on April 10 and April 23 of 2001. Also, extra applications of nitrogen alone were given to all treatments except 2 and 3 on April 13, June 15, June 21 and July 6, 2001. Leaf samples were collected from all 180 trees on May 15 and July 11, 2001. These were sent to the DANR analytical lab for determination of all macro and micronutrients.

Nitrogen deficiency symptoms were first observed in Treatments 2 and 3 in early spring, and remained obvious throughout the rest of the season. Zinc deficiency symptoms started to show up on some of the trees of Treatments 2, 3, 13, 14, and 15 by late summer. Other symptoms also became apparent by August, but it is still too early to determine their cause. At the time of this report, the July leaf samples had not been analyzed by the lab so it was not possible to correlate the symptoms with leaf concentrations. Some of these symptoms included leaf vein purpling followed by necrosis especially in the peach trees, marginal leaf burn in the plums, and leaf rolling in the peaches and nectarines.

Only the May leaf sample results will be presented here, as they were the only ones available at the time of this report. Although there are some interesting trends and conclusions, these should be considered quite preliminary since the July samples represent the more standard time for leaf sampling in fruit trees, and also would be expected to correlate better with fruit characteristics (harvested in July) and with August leaf symptoms.

The May leaf nutrient concentrations generally showed about a two-fold difference among individual trees with most nutrients. Furthermore, the lower concentrations were often below the published threshold for sufficiency, suggesting that deficiency symptoms should soon appear. For example, about 10% of the peach and nectarine leaf samples had boron levels below the threshold of 18 ppm. The plum trees showed a much more extreme situation with about 75% of all leaf samples below the 25 ppm threshold. Likewise, nitrogen concentrations showed the same general pattern with the majority of the plum trees below the sufficiency range. In this case, deficiency symptoms observed in the trees in the spring corresponded well to nitrogen levels, whereas no recognized boron deficiency symptoms have yet been identified. Iron leaf levels also measured quite low with 50% of the peach and nectarine samples falling below the 60 ppm threshold established for May sampling date. Again, no iron deficiency symptoms have yet been observed, but it is anticipated they will start appearing soon.

The situation with zinc is interesting. Approximately 90% of leaf samples from all 3 varieties were below the threshold level of 15 ppm for peaches and nectarines or 18 ppm for plums. Yet, leaf deficiency symptoms did not appear until late summer (and still have not appeared on some trees) and there did not seem to be any negative effects on tree or fruit growth in trees that were as low as 8 to 9 ppm. Perhaps, the previously established threshold for zinc is too high, and will need to be revised downward. This experiment provides an excellent opportunity to be able to do this, not only for zinc, but for other nutrients as well. Also, it may be helpful to define nutrient thresholds in relation to different parameters. For instance, the threshold for leaf symptoms may be quite different than the threshold for fruit growth. With this kind of information, an orchard manager might be willing to tolerate some leaf deficiency symptoms if he/she knows it will not affect fruit growth and productivity.

Deficiency levels have not been established for some nutrients such as phosphorus, sulfur, and calcium because there are so few reports of deficiencies in the field. However, the levels measured in the leaves of some trees in this experiment are low enough to suggest we are approaching deficiency. Phosphorus at 0.15 %, sulfur at 830 ppm, and calcium at 1.15 % were measured in the May leaf samples. Likewise, potassium as low as 1.16% was also measured. Only magnesium and manganese leaf concentrations are substantially above deficiency levels in all samples. Hopefully, by the summer of 2002, deficiencies of most nutrients will be developing in the trees.

One interesting result that is becoming obvious from the beginning of this project is that there are lots of interactions among the various nutrients. If one calculates correlation coefficients among all the nutrients, hundreds of significant correlations can be shown. For instance, almost every nutrient correlates in some way with nitrogen (Table 1). Notice that some of the relationships are positive (meaning both increase together) and some are negative. Also, there is considerable variation in how strong the correlations are (the closer the value is to 1.0, the better the correlation). Furthermore, it appears that these relationships are not quite the same for peach, plum, and nectarine. In this experiment, we will pay close attention to these correlations for at least two reasons. First, the better we understand the physiology behind a given correlation, the better we can understand the cause of certain nutrient deficiencies and how to manipulate them. For example, notice the very strong, positive correlation between nitrogen and sulfur for all three varieties (Table 1). This occurred despite the fact that some low nitrogen trees were given lots of sulfur and some high nitrogen trees were given no sulfur. In other words, the sulfur level in the tree appears to be controlled by internal mechanisms rather than by external supply. If this is the case, it would be ineffective to correct a sulfur deficiency by applying sulfur to the soil. Second, these correlations can also present a challenge by confounding the results. In our efforts to find the nutrient most responsible for fruit quality parameters such as size, color, and sugar content, the nutrient interactions will have to be examined carefully. If a nutrient correlates with fruit quality, the question will be whether it is the main cause of the parameter or whether it merely correlates with another nutrient that is really the main cause.

Enough fruit was left on the trees in 2001 to have a preliminary look at fruit quality parameters. The plums had quite a few flowers, but fruit set was very poor so many trees only had one or two fruit and some had none. The peach and nectarine trees were thinned down to an average of 17 and 7 pieces of fruit, respectively. Harvest on all three varieties occurred in mid to late July. The main quality parameters measured in 2001 were average fruit weight, soluble solids content, and % red color.

Table 1. Statistically significant correlation coefficients between various leaf nutrients and leaf nitrogen from leaf samples collected on May 15, 2001.

	Variety		
Nutrient	*Zee Lady Peach*	*Fortune Plum*	*Grand Pearl Nectarine*
Phosphorus	.45	-.51	.72
Potassium	-.30	-.45	NS
Sulfur	.98	.88	.97
Calcium	NS	-.50	-.44
Magnesium	NS	-.59	-.56
Boron	-.69	-.38	-.57
Zinc	.49	NS	.66
Manganese	NS	-.34	NS
Iron	.79	-.37	.55
Copper	.36	.52	.41
Molybdenum	.38	NS	.41

NS = Non significant.

Fruit weight was quite good for Zee Lady peach and Grand Pearl nectarine, ranging from 104 to 209 grams and 76 to 145 grams, respectively. Fortune plum weight was also quite variable (28 to 77g), but overall was rather small, probably due to nitrogen deficiency in most of the trees. For all three varieties, nitrogen showed the best correlation with fruit weight. Many of the other nutrients also correlated significantly. However, as mentioned above, it is likely for many of these nutrients that they are reflecting their relation to nitrogen (Table 1), and do not have a direct effect on fruit growth. On the other hand, multiple regression analysis of Zee Lady peach weight suggested that nitrogen, potassium, and manganese all contributed independently to final fruit weight. These are still quite preliminary results, but hopefully this type of analysis will eventually help us figure out the relative contribution of different nutrients to fruit growth and final size.

Fruit soluble solids contents (SSC) were quite high in all three varieties ranging from 12.0 to 18.5, 15.4 to 21.0, and 16.4 to 25.0 % brix in the peach, plum, and nectarine, respectively. As with fruit weight, nitrogen tended to have the best correlation with SSC, but many other nutrients correlated as well. In this case, multiple regression did not suggest there were multiple nutrients acting independently on SSC.

Fruit color was very good on all trees since harvest occurred once the fruit were well matured. Most of the samples were rated at 90 to 95% red, so there were few differences among trees. As a result, % red color did not show a strong correlation with any of the nutrients.

Several other fruit quality parameters were observed, but sample sizes were too small to do a complete analysis. These included cork spots and bleeding in the flesh, and russetting on the surface of the nectarine (white fleshed). Some of the peach fruits had skin cracks which affected as many as 50% of the fruit on some trees. These parameters could be related to nutrition, and will be analyzed more completely in the future.

In conclusion, this experiment is just getting under way, so results are quite preliminary at this time. However, it is hopeful that this project will result in the development of a useful tool for evaluating the role of nutrients in fruit quality and tree productivity.

Nitrogen Management in Citrus Under Low Volume Irrigation

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PROJECT OBJECTIVES

Determine the effect of nitrogen applications on navel orange fruit quality and leaching losses of nitrogen

Compare the effects of foliar versus soil applied nitrogen on fruit quality and leaching losses of nitrogen;

Evaluate the impact of nitrogen application timing on fruit quality and leaching losses of nitrogen; and

Determine the effectiveness of various nitrogen application levels and methods on maintaining optimal nitrogen levels in navel orange trees.

In September 2000 additional funding was received to continue this project for one more year, thus the project will end in October 2002. The rationale for this request was to collect 3 years of fruit quality data following the establishment of clear field differences in leaf analysis and soil extract data. Spring of 2002 will be the 3rd year of fruit quality data collection.

PROJECT DESCRIPTION

This project has two components. The first component is the field site that we established in the Woodlake area of Tulare County. The 15.3-acre experimental site is a mature navel orange grove (Frost Nucellar) on Troyer Citrange rootstock. The tree spacing is 22 × 20 feet. Twenty-five experimental treatments are included in the project (Table 1). Each experimental plot consists of 12 trees, with the central 2 trees serving as the data trees. The cooperator's irrigation system was modified to accommodate the differential nitrogen treatments during Spring/Summer 1996. During 2000 - 2001, the project has continued as previously described in CDFA-FREP 2000 Proceedings. Tree measurements were taken in Fall 2000. On-tree fruit color measurements were also taken on a regular basis during Fall 2000 as the "orange" color developed on the fruit. Yield data was collected in April 2001 as previously planned.

RESULTS AND CONCLUSIONS

Table 2 and Figures 1 and 2 report the yield (lbs. per tree) and average fruit size of the different treatments. The control treatment had the lowest harvest weight, however, there was substantial variability in yield between treatments. There was

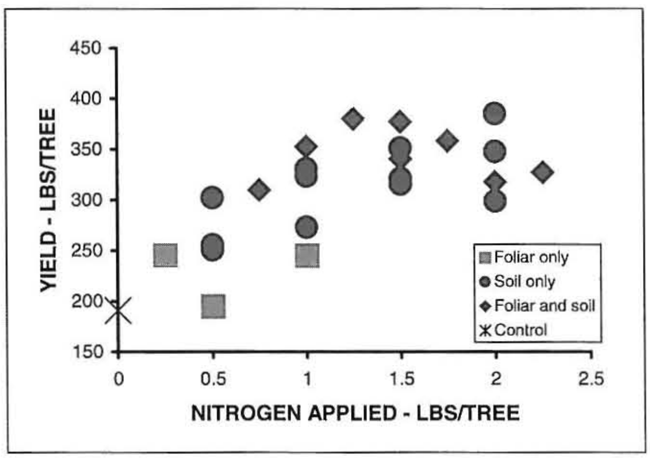

Figure 1. Yield (lbs/tree) from Woodlake experimental site. Fruit harvested April 2001.

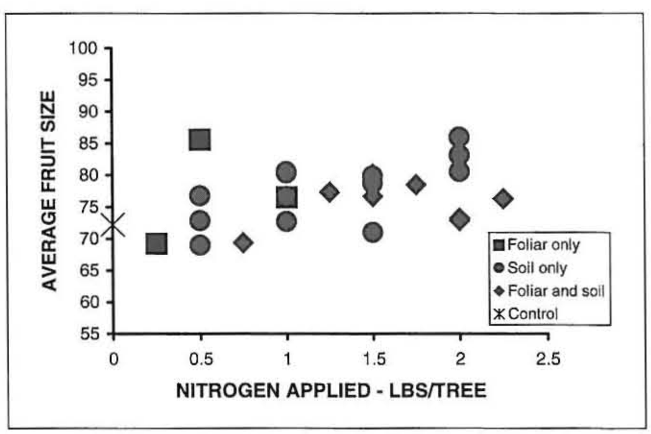

Figure 2. Average fruit size from Woodlake experimental site. Fruit harvested April 2001.

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

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

Foliar Only

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

Soil Only

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

Combination Treatments

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

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

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

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

a slight trend towards higher yield with increasing applied nitrogen but there were no clear differences due to the method of application. The average fruit size of each treatment varied in a similar way with no clear trends in the fruit size distribution data.

Table 2. Average yield and fruit size for Woodlake Experimental Plots for 2000 and 2001. Fruit harvested in April 2000 or March 2001.

		Year 2000	2001
	Average	**358**	**310**
Yield	Maximum	425	385
(lb per tree)	Minimum	278	191
Average Fruit Size	**Average**	**84.3**	**76.7**
(count)	Maximum	97.0	86.0
	Minimum	59.1	69.0

In March 2001, the north quadrant of each data tree was rated for the incidence of puff and crease using the protocol established by C. W. Coggins, Jr. Fifty fruit per north side of the tree were evaluated. Figure 3 illustrates that we did not observe any clear relationship between the amount of N applied and the incidence of puff and crease. Additionally, the method of nitrogen application did not appear to make a difference in the incidence. Puff and crease severity was also not influenced by either the amount of applied nitrogen nor the method of application (Figure 4).

The leaf N content of all treatments for Fall 2000 is presented in Figure 5. There is a trend for higher leaf N as the amount of applied nitrogen is increased but there were no significant differences due to the method of application. This is similar to the data collected in previous years.

The second component of the project was established with the aid of the Sunkist Research Foundation. This component has 2 grower cooperators located in Orange Cove and Exeter-Woodlake. These three sites are navel orange. We have taken 6 of the treatments listed in Table 1 (treatments 8, 11, 13, 14, 23, 24) and are applying these on a per row basis. All grove modification of the existing irrigation systems was donated by Fruit Growers Supply and the Sunkist Research Foundation. The sites have been maintained as described in previous reports. We obtained yield, packout data and storage data (from UC-KAC) in Spring 2001. The yield data and fruit quality data is not yet analyzed.

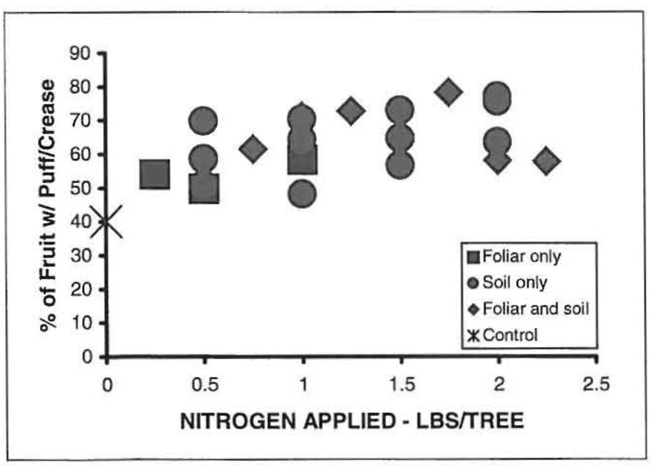

Figure 3. Fruit showing puff or crease expressed as percentage of fruit evaluated (approximately 50 fruit per tree on north half of tree). Fruit sampled at the Woodlake experimental site in March 2001.

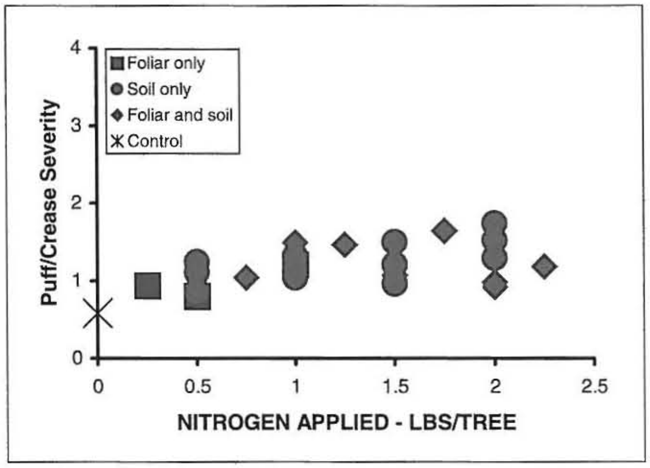

Figure 4. The average puff or crease severity (approximately 50 fruit per tree on north half of tree) as influenced by the amount of applied nitrogen. Fruit sampled at the Woodlake experimental site in March 2001.

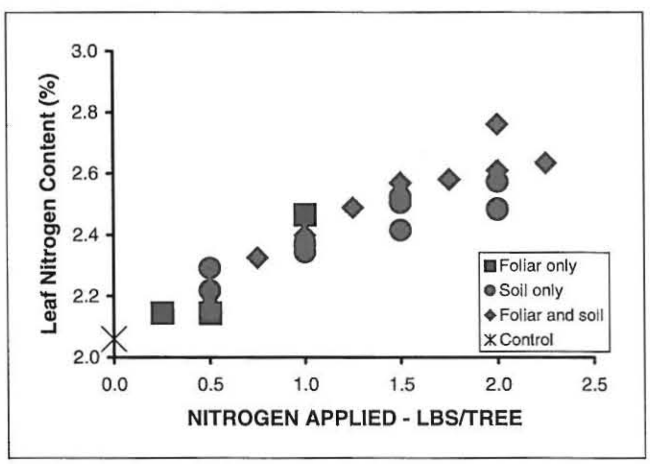

Figure 5. Average leaf nitrogen content for Woodlake experimental site. Leaves collected Fall 2000.

Effect of Cover Crop or Compost on Potassium Deficiency and Uptake, and on Yield and Quality in French Prunes

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OBJECTIVES

1. Design and lay out an experiment to test the hypothesis that certain management practices within a prune orchard can affect potassium deficiency.
2. Determine the effects of the four treatments (cover crop, compost, broadcast K fertilization, and banded K fertilization) on leaf K content.
3. Determine the effects of cover crops and mulch on soil solution potassium and on soil exchangeable potassium.
4. Determine the effects of a cover crop and compost on potassium leaf deficiency, yield, and quality.
5. Conduct educational /outreach sessions on K deficiency as part of CSU Chico and UC Cooperative Extension Field days, the new UC Environmentally Sound Prune System Program (ESPS), the Biological Prune Systems (BPS) Project, and through the outreach activities of commercial fertilizer suppliers and pest control advisors.
6. Determine the effects of the four treatments on soil water relations in prune orchards.

DESCRIPTION

Roughly 110,000 acres of prunes are grown in California, primarily in the northern California counties of Sutter, Butte, Yuba, Tehama, Colusa, and Glenn. Prunes are a strong sink for K, and prune flesh typically contains 1% K. Potassium deficiencies are significant on French prune trees growing in California's Sacramento Valley. Deficiencies are especially apparent in heavy crop years and in heavy textured, clay soils.

Potassium deficiency symptoms may be expressed as yellowing of the leaves, and marginal burn. Severe deficiencies may cause defoliation and limb dieback. Potassium deficiency can also cause decreases in both yield and fruit quality. Previous University of California research has shown that banding K at rates of up to 2,500 lb/acre will increase yields in prune orchards for 3-4 years, and decease foliar dieback during the heavy crop years. Recent work by Dr. Steve Southwick, however, indicates that some growers are applying excessive amounts of potassium resulting in nutrient imbalances in the trees.

Potassium fixation by soils depends on the quantity of the soil mineral vermiculite, and to a lesser extent illite, present in the soil. The soils of the upper east side of the Sacramento Valley were formed on volcanic parent material, which do not contain mica or vermiculite. We predict that these soils have minimal potential to fix K, and that the heavy clay soils typical of the region may cause poor crop root distribution. If poor root growth is limiting K uptake, cover cropping and compost applications may increase root exploration of the soil, and help to ameliorate K deficiency.

RESULTS AND CONCLUSIONS

Field plots were established in a low K orchard in a grower's field in Chico, California. Soils at the site were high in magnesium, and low in potassium and calcium, having percent base saturation levels of 50, 50, and 1% of Ca, Mg, and K, respectively. Low soil K/Mg ratios have been linked to K deficiency in prunes, and fruit disorders in tomatoes. In the fall of 2000, the following field operations were conducted: 1) 250 lb./acre of K_2O as potassium chloride was either banded or broadcast onto the K plots; 2) A hairy vetch cover was planted (35 lbs./acre); and 3) 3 tons of composted chicken manure was applied to the compost plots. Data collection included: 1) whole tree leaf K scores, 2) leaf K and soil K concentrations, 3) stem water potential measurements, and 4) trunk growth.

Leaf and soil K concentrations tended to be higher in the K treated plots, however, few differences were found among the K treatments (Table 1). No significant treatment differences were seen in terms of whole tree K deficiency ratings, stem water potential, and trunk growth. Compost and cover crop treatments are known to improve soil quality, however, to date, no discernible effects on tree growth and yield have been seen in this experiment. We believe that there has been insufficient time for these treatments to affect tree growth.

Table 1. Effects of K, compost, and cover crop treatments on whole leaf tree scores, leaf and soil K concentrations, stem water potential, and annual trunk growth.

		Whole Tree Leave scores 1 = no dieback 4 = severe dieback					
Treatments		*June 20*	*July 28*	*June 20 Leaf K Concentration*	*Soil K (ppm)*	*Stem Water Potential (Aug 3) (bars)*	*Annual Trunk Growth (cm)*
+K	Compost + Broadcast K	1.4	1.5	1.30	255	9.2	1.9
	Cover Crop + Broadcast K	1.3	1.6	1.26	198	9.0	1.7
	Resident Vegetation + Broadcast K	1.3	1.5	1.34	233	8.5	2.5
	Resident Vegetation + Banded K	1.2	1.6	1.27	160	10.1	1.8
–K	Cover Crop	1.5	1.8	0.93	171	9.3	1.7
	Resident Vegetation	1.2	1.7	1.17	145	11	1.8
	Compost	1.3	1.8	1.20	152	9.1	1.6
	LSD	NS	NS	0.14	34	NS	NS

Development of Nitrogen Best Management Practices for the 'Hass' Avocado

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OBJECTIVES

1. Quantify the nitrate pollution potential of the various nitrogen fertilization strategies.
2. Identify the threshold rate of nitrogen fertilization above which the pollution potential increases.
3. Evaluate the potential for replacing the April double dose or triple dose of soil nitrogen with foliar nitrogen.
4. Provide a ratio of enhanced-yield benefit to environmental cost for each nitrogen fertilization strategy.
5. Identify BMP's for nitrogen fertilization for the 'Hass' avocado in California.

DESCRIPTION

To protect the groundwater from potential nitrate pollution, 'Hass' avocado growers in California divide the total annual amount of nitrogen (56-168 kg.ha^{-1}) into six small soil applications made during the period from late January to early November. The lack of research data raised the question of whether 'Hass' avocado yield was being compromised by this fertilization practice. In a previous study, Lovatt (2001) addressed the question of whether yield of 'Hass' avocado could be increased by doubling the amount of N currently applied during specific stages of tree phenology. The control in this experiment was the practice of annually applying N as NH_4NO_3 at 168 kg.ha^{-1} (168 trees/ha) in six small doses of N at 28 kg.ha^{-1} in January, February, April, June, July, and November. From these six application times, five were selected on the basis of tree phenology and additional N as NH_4NO_3 at 28 kg.ha^{-1} was applied at each time for total annual N of 196 kg.ha^{-1}. Two phenological stages were identified for which N application at 56 kg.ha^{-1} in a single application (double dose of N) significantly increased the 4-year cumulative yield (kilograms fruit per tree) 30% and 39%, respectively, compared to control trees ($P \leq 0.01$). In each case, more than 70% of the net increase in yield was commercially valuable large size fruit (178-325 g/fruit). The two phenological stages were: when shoot apical buds have four or more secondary axis inflorescence meristems present (mid-November); anthesis-early fruit set and initiation of the vegetative shoot flush at the apex of indeterminate floral shoots (approx. mid-April). When the double dose of N was applied at either of these two stages, the kilograms and number of large size fruit averaged across the 4 years of the study was significantly greater than the control trees ($P \leq 0.01$). Averaged across the 4 years of the study, only the November treatment increased yield compared to the control trees ($P \leq 0.05$). Application of the double dose of N at flower initiation (January), during early-stage gynoecium development (February), or during June drop had no significant effect on average or cumulative yield or fruit size compared to control trees. Application of the double dose of N in April significantly reduced the severity of alternate bearing ($P \leq 0.05$). Yield was not significantly correlated with leaf N concentration. Time and rate of N application are factors that can be optimized to increase yield, fruit size, and annual cropping of 'Hass' avocado. When the amounts of N applied were equal (196 kg.ha^{-1}), time of application was the more important factor. You may receive a copy of this paper by e-mailing your request to me at <carol.lovatt@ucr.edu>.

To determine whether the results obtained in the previous study, which was conducted in Temecula, could also be obtained with a different soil type and location, this research, including objectives not covered in the first experiment, is being repeated in a new orchard in Somis, representing the soils and climate of the northern avocado growing area. The new study also includes additional application times based on the discovery by my lab. that avocado trees transition from vegetative to reproductive growth at the end of July-

Table 1. Effect of nine nitrogen fertilization strategies applied April 1997 to January 1999[y] on the yield of 'Hass' avocado harvested in 1998 and 1999. The applications were made for an "on" year.[z]

Treatment[x]	1997-99 total lbs. N/acre	1997-98 lbs. fruit/ tree	1998-99 lbs. fruit/ tree
2x N in August (all years)	40.0	73.6 a[z]	37.8
Grower fertilization practice	42.5	70.7 a	40.1
2x N in November (prior to "on" years) and April ("off" years)	40.0	68.1 a	40.5
2x N in November (all years)	40.0	62.3 ab	44.6
Control	80.0	58.8 ab	49.4
2x N in April and November (no N in February and June) (all years)	80.0	58.8 ab	32.8
2x N in April ("off" years) and 3x N ("on" years)	60.0	58.6 ab	48.5
2x N in April (all years)	40.0	56.8 ab	42.1
2x N in April ("off years) and 3x N ("on" years) applied foliarly	100.0	42.3 b	44.6
P-value		0.06	NS

[z]Values in a vertical column followed by different letters are significantly different at the specified *P* level by Duncan's Multiple Range Test.

[y]Grower's fertilization practice is 40 lbs. N as ammonium nitrate/acre split as two applications in July and in August for all years of the experiment.

[x]The time of treatment applications is based on the following phenological events: 1) April – anthesis, fruit set and initiation of the spring vegetative flush; 2) August – inflorescence initiation; 3) November – end of the fall vegetative flush and beginning of flower initiation.

beginning of August (Salazar-Garcia et al., 1998). The research also integrates the results of a previous 2-year long study we undertook with funding from the CDFA FREP program. The results of this CDFA project provided evidence that foliar N fertilization was successful in increasing yield when urea was applied at the time the leaves of the new flush were 66% to 100% fully expanded but not hardened. So our current project includes both irrigation and foliar ap-

Table 2. Effect of nine nitrogen fertilization strategies initiated in January 1999[y] on the average number of inflorescences per sylleptic shoot in spring 2000 and on yield of 'Hass' avocado harvested in 2001. The applications were made for an "on" year.[z]

Treatment[x]	2000-2001 lbs. fruit/ tree	Average number of inflorescences per shoot
2x N in August (all years)	179 ab	2.20 c
Grower fertilization practice	181 ab	4.36 abc
2x N in November (prior to "on" years) and April ("off" years)	201 a	4.68 abc
2x N in November (all years)	202 a	3.16 bc
Control	169 ab	3.85 abc
2x N in April and November (no N in February and June) (all years)	178 ab	4.50 abc
2x N in April ("off" years) and 3x N ("on" years)	199 a	5.25 ab
2x N in April (all years)	209 a	3.65 abc
2x N in April ("off years) and 3x N ("on" years) applied foliarly	150 b	6.15 a
P-value	0.10	0.06

[z]Values in a vertical column followed by different letters are significantly different at the specified *P* level by Duncan's Multiple Range Test.

[y]Grower's fertilization practice is 40 lbs. N as ammonium nitrate/acre split as two applications in July and in August for all years of the experiment. Since January 1999 control trees received 125 lbs. N as ammonium nitrate/acre, divided into five, 25 lbs./acre applications made in mid-January, mid-April, mid-July, mid-August, and mid-November. Trees in all other treatments received 125 lbs. N/acre applied as 2N=40lbs./acre or 3N=60lbs./acre in the months indicated. The total N applied in any treatment is 125 lbs./acre; the amount of N applied in other months is reduced to compensate for the extra N applied in the month(s) specified for the treatment.

[x]The time of treatment applications is based on the following phenological events: 1) April – anthesis, fruit set and initiation of the spring vegetative flush; 2) August – inflorescence initiation; 3) November – end of the fall vegetative flush and beginning of flower initiation.

plied nitrogen applications. Foliar applications are made to simulate helicopter application. We are also testing different nitrogen fertilization strategies that are designed specifically for "on" and "off" years to even out alternate bearing and increase cumulative yield. To understand the mechanism by which nitrogen fertilization influences alternate bearing, we are quantifying the effect of the nitrogen treatments on the quantity of sylleptic and proleptic shoots produced, the growth of each shoot type and the productivity of each shoot type. Basic information about the relative productivity of sylleptic vs. proleptic shoots is not only important for optimizing fertilization but is also fundamental to pruning practices. Our prior research was the first to consider tree phenology and crop load in the fertilization of the 'Hass' avocado and our current project is the first to use nitrogen fertilization as a tool to control alternate bearing.

RESULTS AND CONCLUSIONS

The results of the first harvest (1997-98) clearly demonstrated that the time of N fertilizer application is more important than the amount of N that was applied (Table 1). However, the rates of N applied that year were incorrect (Table 1). The error was corrected starting in January 1999. Henceforth, all treatments received 125 lbs. N/acre. Yields for the subsequent 1998-99 and 1999-2000 harvests were compromised by the freeze of December 1998. N treatments had a significant effect on both the number of inflorescences produced and the fruit set on sylleptic shoots tagged January 2000 and 2001 (Table 2). Time of N application had a significant effect on yield for the harvest of 2000-01 (Table 2). The best treatments were all due to extra N applied to the soil in November or April. These results are consistent with the results of our earlier research conducted in Temecula. Foliar application of urea in April was not effective. Harvest data for additional years is needed to confirm the results obtained in 2001.

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Seasonal Patterns of Nutrient Uptake and Partitioning as a Function of Crop Load of the 'Hass' Avocado

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INTRODUCTION

For the 'Hass' avocado industry of California, optimal rates and times for soil fertilization of nitrogen, phosphorus, and potassium have not been adequately determined. Fertilization rates, and optimal leaf nutrient ranges have been borrowed from citrus. Competition from Mexico and Chile requires the California avocado industry to increase production per acre to remain profitable. Optimizing fertilization is essential to achieve this goal.

The seasonal pattern of nutrient uptake is a key component of fertilizer management. Matching fertilizer application times and rates with periods of high nutrient demand not only maximizes yield, but also increases nutrient-use efficiency and, thus, reduces the potential for groundwater pollution. Experiments on nutrient uptake and allocation are routinely done to develop best management practices for commercial annual crops. However, determining nutrient uptake in mature trees is considerably more difficult, requiring repeated tree excavations at important phenological periods over the season. Thus, few best management practices have been developed for perennial tree crops.

The goal of this project is to determine the seasonal pattern of nutrient uptake and partitioning in alternate-bearing 'Hass' avocado trees. The research will quantify the amount of each nutrient partitioned into vegetative or reproductive growth, and storage pools. The research will identify the periods of high nutrient use from bloom to harvest as a function of crop load, and thus identify the amount of each nutrient required, and when it is required to produce an on-crop and good return crop the following year. The results will enable us to provide guidelines for fertilization based on maximum nutrient-use efficiency, and eliminate applications made during ineffective periods for uptake to thus protect the groundwater, and increase profitability for California's 6,000 avocado growers.

PROJECT OBJECTIVES

The objectives of the study include:

1. Quantify the seasonal pattern of N, P, K, B, Ca, and Zn uptake and partitioning in 'Hass' avocado trees bearing.
2. Quantify the effects of different crop loads on these seasonal patterns of nutrient uptake, partitioning into vegetative and reproductive growth, and storage.
3. Determine the seasonal patterns of nutrient uptake in alternate bear avocado trees and develop best management fertilizer practices for the 'Hass' avocado tree

PROJECT DESCRIPTION

The research is being conducted in a commercially bearing avocado orchard in Somis, CA. In June, 2001, 60 trees were selected for inclusion in the project based on their trunk diameter, height, canopy size, and fruiting potential. Thirty of these trees were subsequently defruited to establish both lightly fruiting and heavy fruiting trees. The experiment is a

Table 1. Effect of tree size on total fresh weight, and distribution of mature avocado trees.

Tree Component	Large Tree Fresh Weight (kg)	Large Tree Proportion of total	Small Tree Fresh Weight (kg)	Small Tree Proportion of total
Leaves	64	8	38	10
Immature Fruit	39	5	24	6
Mature Fruit	48	6	0	0
Fine Roots	37	5	23	6
Roots > 5 mm	105	13	41	10
Rootstock	85	11	39	10
Trunk	80	10	25	6
Scaffold Branches	310	38	177	45
Current Yr. Wood	40	5	23	6
Total	808	100	389	100

randomized complete block design, with the following factors: 1) cropping status (heavily cropping—On and lightly cropping—Off trees), and 2) time of excavation. Four trees (two on- and two-off year trees) will be excavated at each harvest date. There is a total of 13 excavation dates. For each date, two on- and two off-year trees will be excavated, the entire tree will be dissected into the following components, and the total weight of each component determined: leaves, new shoots, inflorescences or fruit (separated into seed and flesh), small branches (≤ 2.5 cm), mid-size branches (2.5-5.0 cm), scaffolding branches, scion trunk (dissected into bark and wood), rootstock trunk (dissected into bark and wood), scaffolding roots, small roots, and new roots. Sub-samples will be dried, ground, and analyzed for carbon, nitrogen, nitrate-nitrogen, phosphorus, potassium, calcium, iron, magnesium, manganese, zinc, boron, sulfur, copper, sodium, chloride, and aluminum. These analyses will allow us to meet objective (1) to determine the period(s) of high nutrient demand in the phenology of the 'Hass' avocado tree. Having trees with varying crop loads will enable us to meet objective (2) to quantify the effect of crop load on nutrient uptake and partitioning into new vegetative and reproductive growth, and storage.

Data analysis. The results obtained above will be used to calculate g nutrient per tree by the following equation using nitrogen as the example:

g N/g dry wt tissue X g dry wt tissue/g fr wt tissue X total fr wt tissue/tree = total g N/tree

Nutrient uptake will be determined as the difference in total tree nutrient contents from sequential tree excavations. The total amount of each nutrient required by developing flowers and fruit will be plotted monthly over the course of fruit development along with the increase in individual fruit biomass. The total increase in vegetative biomass (both roots and shoots) and total nutrient content of each component will be calculated and plotted monthly.

RESULTS AND CONCLUSIONS

As part of the first season of a two and half-year study, a large and small tree was excavated to see if tree size influenced the distribution of the various tree components (Table 1). Although the large tree weighed twice as much as the small tree, the tree components comprised similar percentages of the total tree weight in both trees. This is important because tree size can be used as a covariant in determining total tree nutrient uptake. The roots, leaves, and trunk and canopy branches, for example, comprised approximately 30%, 10%, and 50% of total tree fresh weight in both large and small trees. At the time of submitting this report, the nutrient and data analyses from the summer tree excavations were incomplete.

Precision Horticulture: Technology Development and Research and Management Applications

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INTRODUCTION

Recent studies have determined that yield is the primary determinant of nutrient demand and uptake efficiency and therefore, fertilizer needs. In tree crops, however, yields vary dramatically from tree to tree within an orchard and between orchards, making accurate fertilizer recommendations impossible. Given this fundamental limitation, it has been impossible to develop truly efficient orchard fertilizer management systems, or to conduct nutritional research experiments properly.

The ability to map yield in an orchard and to use that information to optimize inputs would revolutionize tree crop industries and directly contribute to improved resource use efficiency. The benefits to in-field experimentation would be equally significant. The most direct benefit of this information would be the ability to optimize fertilization strategies on a site-specific basis. This is the key to improving nutrient use efficiency.

This project aims to develop the means to rapidly harvest and map pistachio tree yields in commercial orchards on a tree-by-tree basis by integrating the Global Positioning System (GPS) and yield monitors into the harvesting machinery. This will be followed by development of statistical and visual computational methodology to analyze and map results. Soil and plant testing will be used to determine the cause of yield variability and experimental manipulations will be conducted to optimize yield and management efficiency. The lessons learned in this project will then be extended to all tree crops in California.

The ability to optimize production systems benefits everyone from producer to consumer. It will allow researchers to conduct better research programs and improve our ability to protect the environment.

PROJECT OBJECTIVES

Short-term aim: In the first years of this current project we will develop the harvesting machinery, initiate statistical and mapping methodologies to allow growers to view and interpret the annual productivity of each tree in their orchards. This will then be used to optimize fertilization strategies, and to improve on-farm research capability.

The specific objectives are:

1. To develop technology to allow large-scale, tree-to-tree yield analysis.
2. To utilize this technology to determine the factors that contribute to yield variability including statistical, mapping, and biological interpretations.
3. To conduct a demonstration research project utilizing these technologies.
4. To conduct workshops to demonstrate the technology.

PROJECT DESCRIPTION

We selected 80 acres containing roughly 12,000 trees of a pistachio ranch located at the Paramount Farming Company in southern California. Different tasks of the project are underway, including designing, developing, and building a modified pistachio harvest machine to allow for the collection of real-time, tree-by-tree harvest data. In collaboration with Paramount Farming and Precision Farming Enterprise, we are adapting a commercial pistachio harvester to include a yield monitor, profiler, and a modified GPS system. Building a yield monitoring system will allow us to monitor the yield on tree-by-tree basis. In addition, we are conducting crop diagnostics using high-resolution aerial maps that include growth, stress, and multi-spectral infrared map which combines thermal infrared, near infrared and visible light into a single image for maximum crop diagnostics. These images assist in the determination of tree growth and environmental variation. GPS-sensor- based systems of Electrical Conductivity (EC), and Texture and Compaction Index (TCI) were used to identify the variability in soil properties across the field.

RESULTS

In year 2001, we mapped 80 acres for soil Texture and Compaction Index (TCI), moisture content (MC) (Figure 1 and 2), and Electrical Conductivity (EC) (Figure 3 and 4) using GPS-based technology. Soil and leaf samples were taken to analyze the soil fertility and leaf nutrition status. The harvesting equipment for pistachio is being modified, and a weighing system has been designed and built.

Aerial images were taken using remote sensing technology (images are currently being analyzed). By comparing patterns and trends between the three images, a greater understanding of the crop conditions and potential causes of variability can be gained. The presence of a change in one or more of the images can yield important information on the possible causes, trends and implications of a crop production problem. The soil texture and compaction index showed differences across the field. This is indicated by the light and dark colors on the TCI map. TCI ranges from about 900 to 1300 (draft, lb). Also, the EC across the field showed differences at 1-foot deep (ranges from 16 to 153 mS/m) and at 3-foot deep (ranges from 18 to 164 mS/m). However, moisture content (MC) of the soil did not show a significant difference across the field (18-22%). Differences in TCI and EC across the field will be used for further investigation to understand the source of variations. Therefore, soil and leaf samples were taken from sites where differences in TCI and EC occurred. The samples will be analyzed for chemical and physical characteristics of the soil and nutrient status in leaf tissues. This approach would allow us to identify the source of variation across the field, and enable us to relate those variation sources to the location of each tree as mapped by the GPS. Our aim here is to link the measured parameters to the yield of each tree. The yield of each tree will be harvested using modified harvesting equipment, which is currently under testing using tomatoes. The non-significant differences in soil moisture content across the field may be due to the continuous irrigation of the field. Therefore, further TCI and MC measurements will be carried out under water stress conditions.

The preliminary results clearly indicate that this is a feasible project, and that it is possible to develop a practical, and valuable harvester to provide tree-by-tree yield data. Once this data is available, growers will be able to optimize tree performance, identify problem areas, locate superior trees, design and easily test new field practices, and spot pending orchard problems before they become serious.

We strongly believe this technology has important implications for all tree crops. Certain tree crops (prune, olive) can immediately adopt this technology, while others may need to see the advantages of precision management before considering adoption. As an example, almonds are currently shaken to the ground, raked, and picked in three operations, which makes individual tree harvesting and analysis difficult. These three operations also require a clean orchard floor (which in-

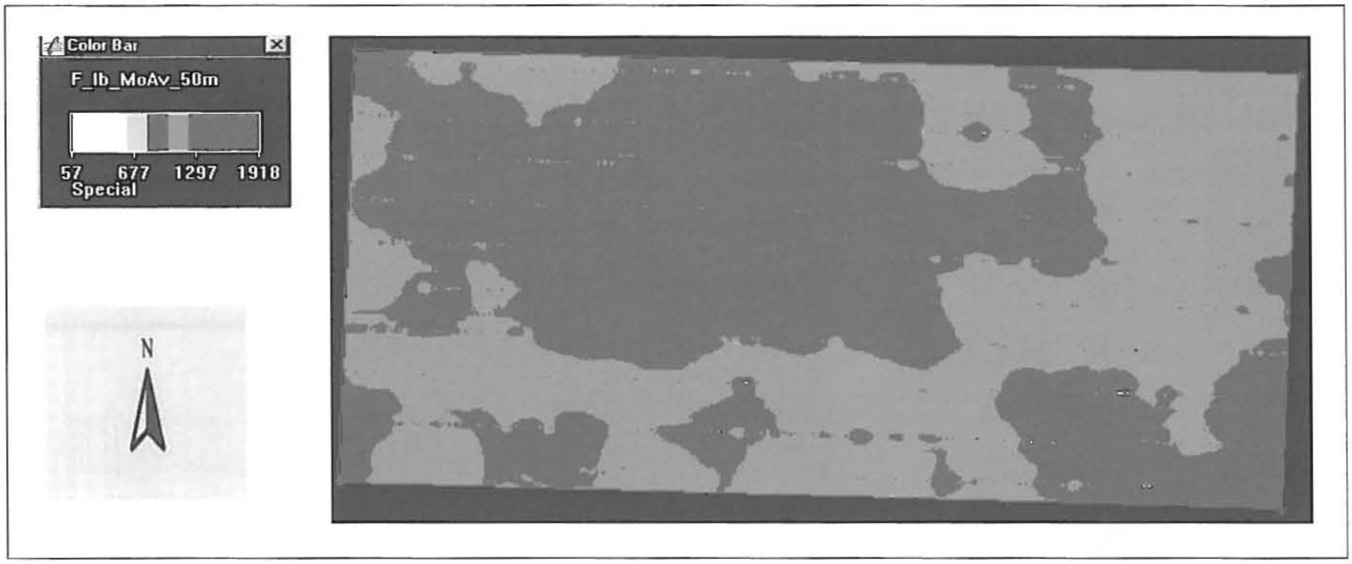

Figure 1. Distribution of soil compaction across the field. Soil compaction was measured using TCI-GPS-based technology sensors. Eighty acres of a pistachio orchard at Paramount Farming company was used for the study. TCI ranges from 900 to 1300 (draft, lb). Data are being analyzed. TCI will be measured under field stress conditions.

troduces herbicides and can prevent the use of cover crops), generates substantial dust (a major problem), limits management options, requires early irrigation cut-off (reducing efficiency of late season N-use), introduces ant problems and aflatoxin problems, and prevents individual tree analysis. Demonstration that tree-by-tree harvesting and mapping offers important management advantages might encourage the use of catch frames with all the contingent advantages in product quality, orchard management, and environmental health. (Of course there are many other factors to consider before a change of this magnitude could be considered—nut drying, nut drop, uneven maturity).

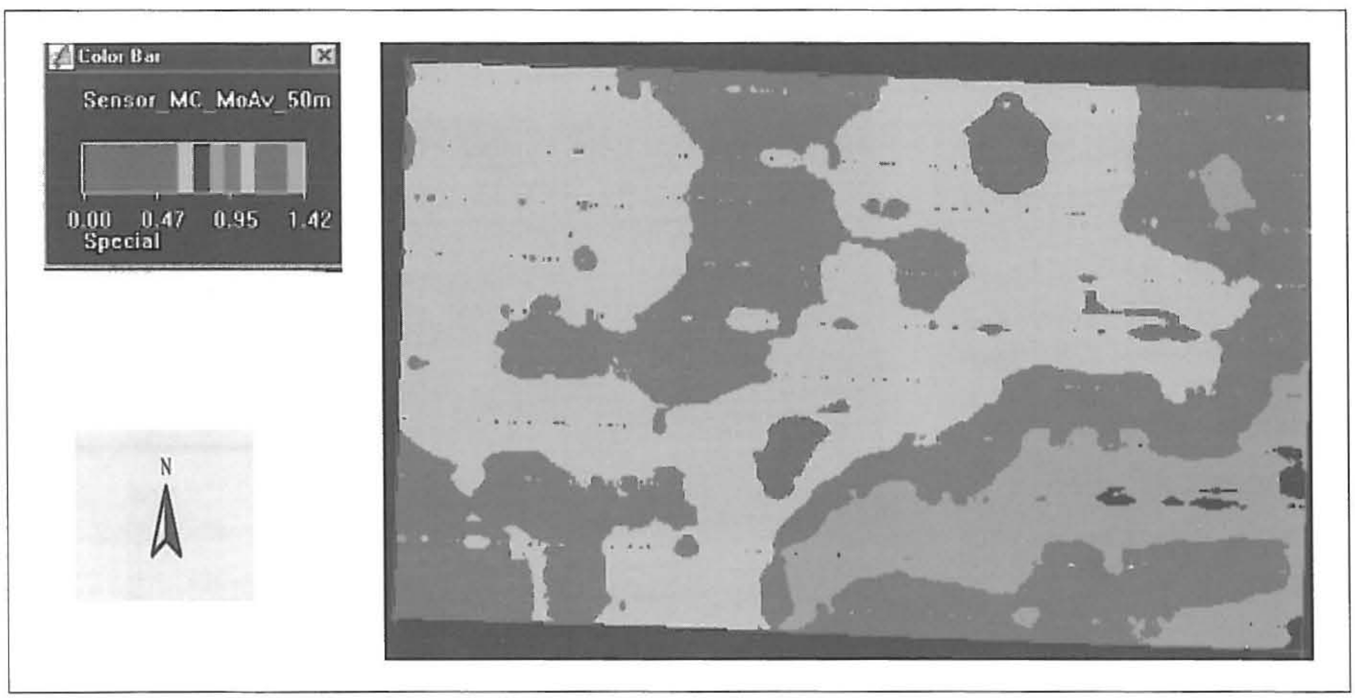

Figure 2. Distribution of soil moisture content (MC) across the field. Moisture content was measured using moisture-GPS-based technology sensors. Eighty acres of a pistachio orchard at Paramount Farming company was used for the study. 18-22% of soil moisture was detected across the field. MC will be measured under field stress conditions.

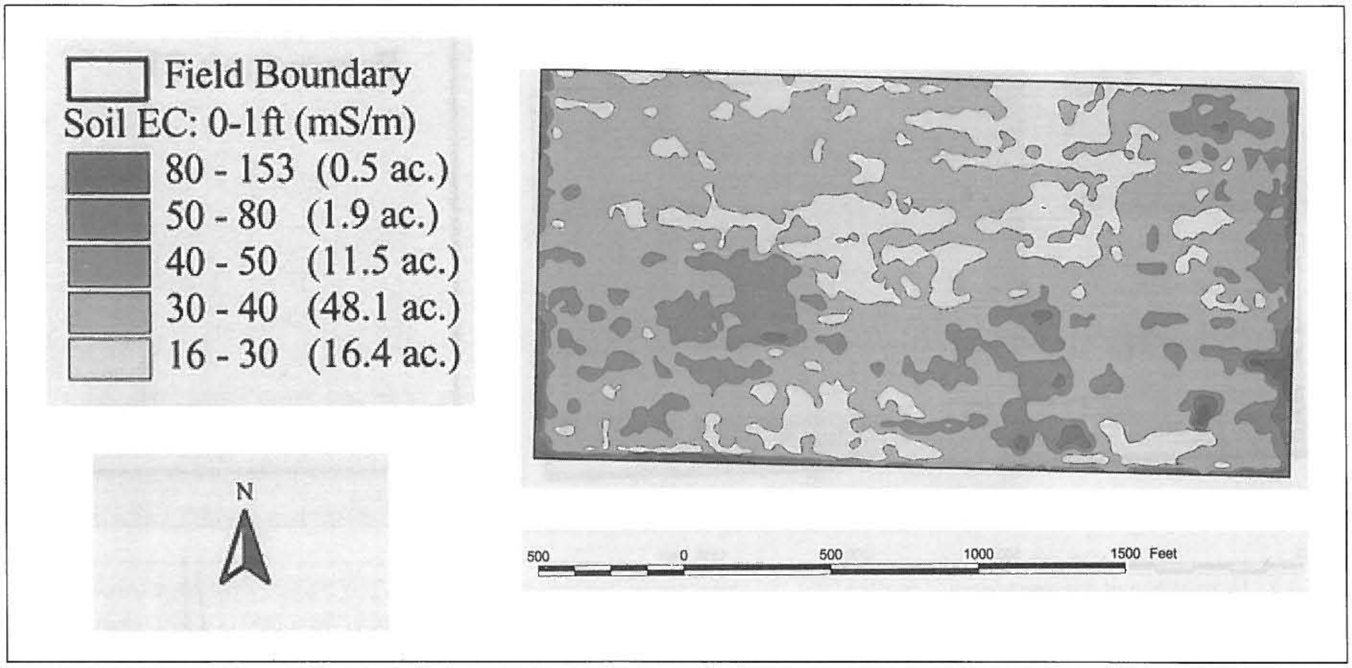

Figure 3. Electrical conductivity (EC) across the field. EC was measured using GPS-based technology sensors. Eighty acres of a pistachio orchard at Paramount Farming company was used for the study. At 1-foot deep, EC ranges from 16-153 mS/m. Soil samples will be takes from low and high EC for further investigation.

In summary, the use of precision orchard management will result in the development of a more sophisticated agricultural system, will allow for profound improvements in efficiency, and will encourage growers to view an orchards as an integrated ecological system. Further, the capacity to easily determine yield will provide researchers, growers and extension agents a greatly improved ability to conduct research, and test new management strategies. The ability for growers to easily test new technologies on their own fields is essential for the adoption of best management practices.

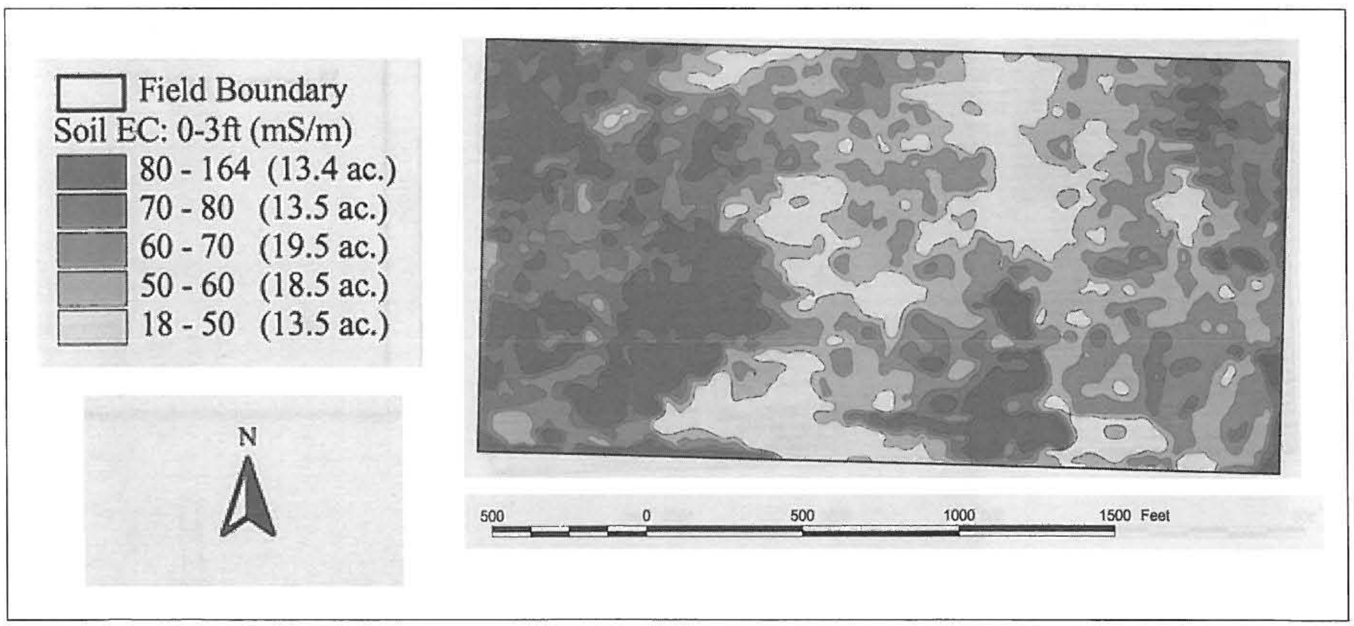

Figure 4. Electrical conductivity (EC) across the field. EC was measured using GPS-based technology sensors. Eighty acres of a pistachio orchard at Paramount Farming company was used for the study. At 3-foot deep, EC ranges from 18 to 164 mS/m. Data are being analyzed.

When we have enough information, we will plan and conduct workshops on precision harvesting and site-specific management, to be conducted at Paramount Farming and elsewhere. This will be in addition to participation in field days organized by farm advisors, talks to grower groups, presentation to the annual Pistachio Commission meetings, and presentation at the annual CDFA-FREP meeting.

Evaluating and Demonstrating the Effectiveness of In-Field Nitrate Testing in Drip and Sprinkler Irrigated Vegetables

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INTRODUCTION

Vegetable production, including lettuce, celery, baby greens, peppers, and onions, is an important sector of the agricultural economy in the Upper Pajaro River Watershed region, which includes the southern Santa Clara Valley. However, recent studies suggest that nitrate levels in the surface waters and the various aquifer zones of this basin often exceed the Maximum Contaminant Level (MCL) of 45 mg/ml due to excessive loading from residential septic systems, agricultural fertilization, animal enclosures, and other non-point and point sources. Concurrently, the Central Coast Regional Water Quality Control Board (Region 3) is currently developing a Total Maximum Daily Load Plan (TMDL) for nutrients (including nitrate) for Llagas Creek within the next few years. The high value of vegetable crops along with market demands for quality, make growers reluctant to increase economic risk by reducing nitrogen and/or irrigation inputs. To date, recognition and adoption of in-field soil and plant monitoring as a simple and effective N management decision-making tool in this region has been limited due to the lack of a significant research and education effort in this region.

OBJECTIVES

The primary objective of this project is to assist a few key Santa Clara County growers in evaluating and adopting the use of in-field nitrate testing and nitrogen management planning to improve fertilizer use efficiency and profitability, while potentially reducing nitrate loading to ground- and surface water. Routine field monitoring and comparative trials utilizing in-field soil and petiole testing is being used to:

1. Confirm the utility of in-field soil nitrate testing in this region for pre-plant and sidedress N scheduling on cool season crops like lettuce whether on sprinkler or drip irrigation.
2. Demonstrate how effectively in-field quick soil and petiole testing will work for crops on surface and buried drip systems for a long, warm season crop like peppers (green and colored bell types, and Jalapeno types) which have not had as much attention as the cool season crops (e.g. lettuce).
3. Evaluate and use the data, grower observations, and comments to demonstrate to a larger group of growers in outreach events that these tools actually work and are cost-effective under their regional conditions such as climate, crop type, and irrigation technologies.

This project is conducted in close partnership with the Santa Clara Valley Water District's (SCVWD) Nitrate Management Program. Additionally, the project has collaborated with the District's Mobile Irrigation Lab Program to provide cooperating growers with irrigation system evaluations.

PROJECT DESCRIPTION

As of September 2001, we have monitored a total of 21 fields and 28 crop sequences in the southern Santa Clara Valley. Crops have included head lettuce, baby greens, celery, broccoli, onions, and peppers (bell, pimento and chili types). Project activities began in January 2000 with presentations at two of the Water district's grower workshops. Beginning in early March, weekly and bi-weekly monitoring of lettuce, pepper, and celery fields is being used to document soil nitrate dynamics and identify key decision times for cooperating growers. The fields that were monitored for soil nitrate-N were on very different soil types, and were located between the Morgan Hill area and south almost to the Santa Clara/San Benito county line. This included: a) three head lettuce fields grown with sprinklers exclusively or a mix of sprinkler and drip, b) six pepper fields primarily grown with drip, although one used sprinkler irrigation for seed germination, c) two celery fields grown with a mix of drip and sprinklers, and, d) one broccoli crop with sprinkler irrigation that followed one of the lettuce crops.

In a number of these fields, we used weekly soil nitrate data to suggest if elimination or reduction of pre-plant or side-dress N might be practical. We also utilized small in-field plots or strips to assess the outcome of this change in N fertilization practice, monitoring soil and crop productivity. In all field trials, we plan to develop a simple nitrogen budget for each grower's fields that includes estimates of nitrate input from all sources, including irrigation water. The Water district provided invaluable assistance by providing a number of complete well water tests for participating growers.

This project has been enhanced by collaboration with the District's Mobile Irrigation Lab Program. Power Hydrodynamics has provided irrigation system evaluations for each grower and field where field trials or monitoring programs are in place. In addition, Mobile Lab technicians collect irrigation water samples for routine confirmation of nitrate content as well as tailwater/runoff estimates and samples for nitrate analysis where appropriate.

Additional public presentations of project objectives and early results were made in July and December of 2000. Prior to the 2001 season, we met with all participating growers to review the 2000 field data, identify specific field trial objectives for the coming season, and with two growers provided more detailed training on in-field monitoring. The fields that were monitored for soil nitrate-N were on very different soil types, and were located between the Morgan Hill area and south almost to the Santa Clara/San Benito County line. This included: a) three head lettuce fields grown with sprinklers exclusively or a mix of sprinkler, furrow, and drip, b) five pepper fields primarily grown with drip, although one used sprinkler irrigation for seed germination, c) one celery field grown with surface drip, d) one white onion crop (long day) with sprinkler irrigation, and e) three baby green crops grown with sprinkler irrigation. In the spring we successfully encouraged two of the grower cooperators to begin to use the soil nitrate quick test to evaluate pre-plant and residual nitrate levels. We would suggest the sample time and location, then compare the grower's test results to ours. We again utilized small in-field plots or strips to assess the outcome of this change in N fertilization practice, monitoring soil, and crop productivity.

RESULTS AND CONCLUSIONS

As expected, grower irrigation and N fertilization scheduling have varied significantly. Nitrogen applications to lettuce varied between growers and irrigation/fertilization systems. Large quantities of fertilizer N are applied to peppers in the Santa Clara Valley. At the end of 2000, we found high residual soil nitrate-N in all of these fields, with the exception of a field with plastic-mulched beds. The critical factors affecting soil nitrate dynamics and residual N appeared to be irrigation system type, irrigation/fertilization scheduling, (for drip systems, the timing of N injection during any set), soil texture, and the growth stage and relative condition of the crop. Some of the well waters tested contain high levels of nitrate-N, which could supply agronomically significant quantities of available N.

The results suggest that in many cases, crop use efficiency of applied fertilizer may be less than ideal. Differences between sprinkler- and drip-irrigated fields were less significant than differences due to vastly different irrigation scheduling for similar crops. Soil sampling methods for the nitrate quick test must be adapted to differences in fertilizer placement and the wetted zone where roots are active. Integrating the use of tensiometers complements the soil and petiole nitrate monitoring, and has identified both problems and successes of growers' irrigation systems and scheduling. We have found that providing grower cooperators with a seasonal 'picture' of the outcome of their N fertilization programs and irrigation scheduling is of great value. It has also raised important questions for some growers and validates where soil nitrate quick testing can improve the N fertilizer efficiency.

Collaboration with the SCVWD's Mobile Irrigation Lab to provide irrigation system evaluations has enhanced the scope of this project's fieldwork and ultimately, the value of our work with the cooperating growers and participants of public events. Generally, all of the irrigation systems tested had good to excellent distribution uniformity. However, we have found that irrigation scheduling by the cooperating growers is often erratic leading to both under- and over-irrigation. In particular, for bell peppers, we have found that growers do not appear to adjust irrigation scheduling for different developmental crop stages. In the 2001 season, we found that 4 of 5 fields were under-irrigated prior to fruit bulking stage, and then over-irrigated prior to first harvest and for the rest of the season. In-season leaching may often occur on coarse- and fine-textured soils with high gravel content, and it appears that some growers have typically 'over-corrected' with increased fertilization.

Field monitoring and small comparative trials suggests that substantial reductions in N fertilizer applications could be made in some crop systems. As in many cases, crop use efficiency of applied fertilizer may be less than ideal. However, we have also found that there are critical barriers to the use of soil nitrate and/or petiole testing by these growers. First is the challenge of incorporating this activity into the routines of grower, production foreman, or irrigator. Second is the lack of an established 'action threshold' or 'critical level' for the longer warm season crops, as has been established for some cool season crops. Finally, in this region with limited access to public-funded research, many of the cooperators feel that additional field experiments would provide them with more confidence and incentive to adopt in-field soil nitrate and moisture monitoring.

Winter Cover Crops Before Late-season Processing Tomatoes for Soil Quality and Production Benefits

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INTRODUCTION

Planting fall cover crops in fields that will later be planted to processing tomatoes is a departure from the conventional cultural practice among tomato growers of minimizing weed vegetation prior to seedbed preparation. Vegetation-free beds facilitate seedbed preparation especially with direct-seeded tomatoes. However, fall-bedding, coupled with clean beds, increases rainfall run-off once soils become saturated.

PROJECT OBJECTIVES

1. Document the contribution of a winter leguminous cover crop to plant nutrition, yield, and fruit quality in processing tomatoes in an on-farm field trial.
2. Document the impact of a winter cover crop on soil permeability and winter runoff vs. fallow, pre-bedded ground.

PROJECT DESCRIPTION

Field tests in 1998, 1999, and 2000 in the southern Sacramento Valley near Woodland were established with fall plantings of a common vetch-pea mix. Trials were 3-acre plantings in commercial fields with cooperator Blake Harlan of Harlan and Dumars. The cover crop was drilled into dry beds in the fallow period between two consecutive rotations of tomatoes. Field length strips were always planted alongside of our replicated trial to evaluate rainfall run-off. The cover crops were germinated with late fall rains. As expected, in all years, cover crop growth was slow during the winter and early spring. The peas were able to grow and develop during the cooler temperatures, compared to vetch, which grew more rapidly during late February and March. Vetch normally reaches maximum growth by early April in the Sacramento Valley. In all years, greenhouse-grown tomato plants were transplanted between late March to April.

During the late fall, we measured rainfall run-off in field-length runs, tying 3 consecutive furrows into a sump. Boat-type, automated bilge pumps pumped the collected water through flow meters. Four pumping systems, 2 each for the cover crop and the fallow treatments were used to measure the run-off. The bilge pump system was established too late to collect data in our first year. During the 1st two seasons, a weir-based measurement system (Stevens Stage Recorders®) was set up, but resulted in limited success.

Field plot design was a randomized complete block with 6 replications with each plot 3 beds wide by 100 feet long. Two factors were evaluated: 1) fallow vs. cover cropping with a vetch-pea mix and 2) spring-applied sidedress nitrogen rates of 0, 50, 100, or 150 pounds of N per acre. Sidedressed N,

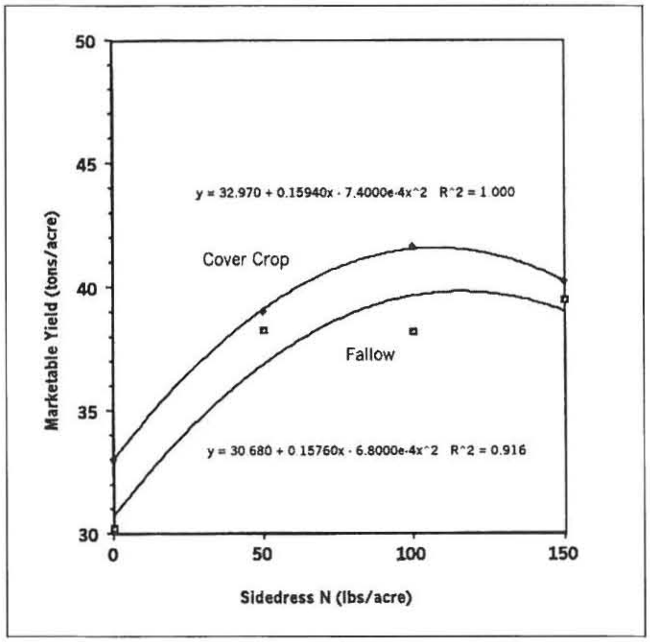

Figure 1. Marketable yield, Woodland, 1998.

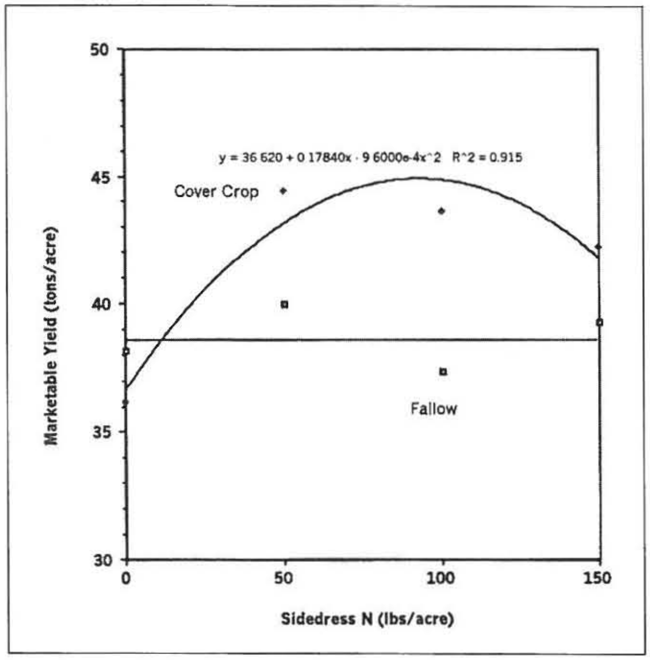

Figure 2. Marketable yield, Woodland, 1999.

as urea, was applied soon after transplants were well established. All other cultural practices were those common to the local area. Irrigation was primarily with the furrow method. Rainfall helped establish the tomato transplants in 1998. Sprinklers were used to establish the transplants in 1999 and 2000, and furrow irrigated thereafter.

In 2000, a duplicate trial was established near Meridian in Sutter County by UC Farm Advisor Mike Cahn. The treatments and procedures were similar to Woodland, except the crop rotation followed rice.

In all years, tomatoes were transplanted about 1 to 3 weeks after cover crop incorporation.

RESULTS

A single fall planting of a leguminous cover crop of vetch/pea mixture increased fruit yields of processing tomatoes by 5 to 13% (Figures 1-3). Nitrogen benefit from the leguminous

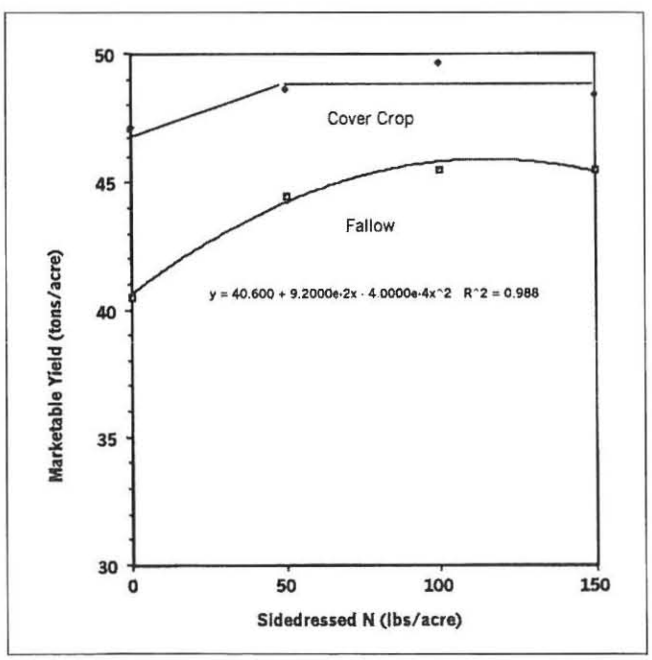

Figure 3. Marketable yield, Woodland, 2000.

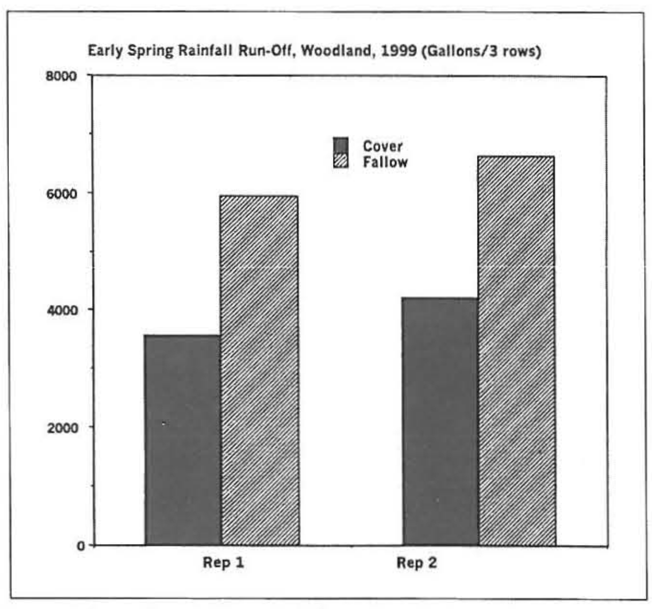

Figure 4. Early Spring Rainfall Run-off, Woodland, 1999.

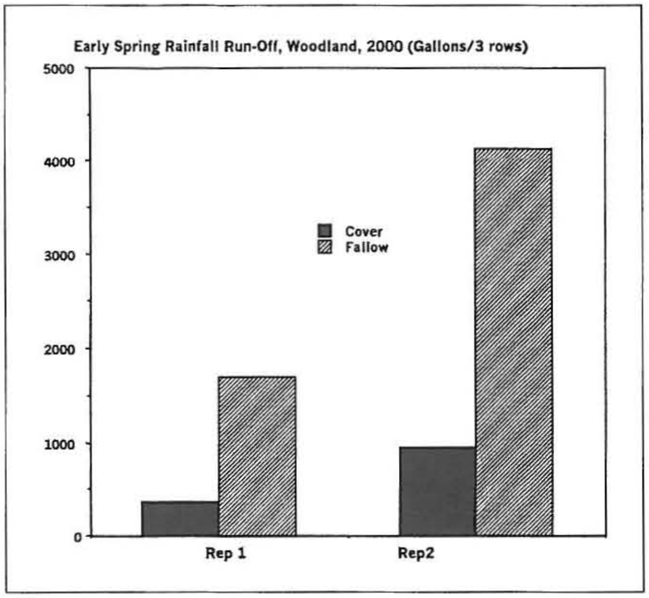

Figure 5. Early Spring Rainfall Run-off, Woodland, 2000.

cover crop appeared limited. Effects on soluble solids fruit quality were inconsistent between years. Rainfall run-off during the early spring was reduced up to 70% compared to the conventional, weed-free bed approach (Figures 4-5). Some growers have since adopted the planting of a leguminous mix of cover crops ahead of cropping to tomatoes. The yield increases were observed only when tomatoes were grown following the previous years tomatoes in the crop rotation.

In the Meridian location, when tomatoes followed rice in the rotation, no yield benefits from the cover crop program were found.

In none of the years and sampling periods was petiole nitrate-N or percent N from whole leaf tissue ever higher in the cover crop treatments compared to the fallow, although the reverse sometimes occurred.

In the Meridian trial, crop tissue levels were similar between fallow and cover crop treatments. Yields only responded well to springtime-applied sidedress nitrogen. There was no response to the cover crop treatment. The legumes fixed roughly 100 pounds of N per acre. Soil nitrate-N levels were similar between the fallow and cover cropping at the 1- and 2-foot depths. No benefit was observed when tomatoes followed rice in the crop rotation.

DISCUSSION

We anticipate winter-grown cover cropping may be attractive to tomato growers transplanting after late April. This planting period will maximize vegetative growth of the vetch cover crop, and leave sufficient time to incorporate the green manure crop. The delay in planting misses only the earliest harvest schedules.

In each of the years of the Woodland-located trials, where tomatoes succeeded tomatoes in the annual crop rotation, yield was increased when a cover crop was grown and incorporated ahead of the cash crop planting. Normal rates of applied N appear to be required rather than relying on the leguminous cover crop to supply a portion of the N. Tomato yields were not increased by cover cropping when tomatoes followed rice in the rotation. The flooded conditions associated with rice production are unique and may be a factor.

Cover cropping reduced winter rainfall run-off from fields, and may provide regional benefits to reduce local flooding in high rainfall years. An associated reduction in topsoil sediment loss can also be expected.

The cost of the cover cropping practice was economically beneficial as expense is estimated at roughly $75 per acre. A 2-ton tomato gain would pay for the added expense. Timely rainfall is needed to establish the cover crop early in the fall as well as to sustain growth through the early spring. The delay in tomato planting is also a consideration. The additional tillage required to incorporate the cover crop can be costly and less manageable than the clean, fallow bed practice. The program has a better fit for growers who transplant to establish a tomato stand rather than direct seed.

We are enthused that cover cropping for a single winter period provided the yield benefit the following spring as well as reduced rainfall run off. Future plans are to investigate how cover crops might fit into a reduced tillage system for California.

Efficient Irrigation for Reduced Non-Point Source Pollution from Low Desert Vegetables

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INTRODUCTION

Efficient water management remains a high priority in the southwestern United States. While the scarcity of water is a major impetus for improving water use efficiency in agriculture, inefficient irrigation practices are also a factor in water quality related issues. The influence of irrigation practices on salt loading of surface waters has long been recognized. Abundant evidence from southern California and Arizona indicates irrigation practices are a significant factor contributing to N losses from soils used for vegetable production. Recent data from Arizona showed that as irrigation levels increased above the amount required to replace evapotranspiration, N leaching below the root zone increased, and crop recoveries of N decreased.

Vegetable growers tend to apply generous amounts of water for production because of anxiety about crop quality, and the lack of sufficient information to do otherwise. Additionally, concerns about the impacts of salt accumulation on long-term land sustainability often prompts growers to use a generous leaching requirement. A perceived lack of practical technologies on irrigation scheduling is another major obstacle to progress in implementing efficient irrigation practices. We believe that once efficient scheduling and water management strategies are confirmed and demonstrated to vegetable growers in the desert, progress in efficient irrigation will be hastened. However, demonstrating advanced irrigation technologies that do not impact yield, crop quality or long-term land sustainability is of the utmost importance.

The first phase of this project is an experimental evaluation of irrigation scheduling technologies and management practices as well as the influence of irrigation and N fertilization on crop response, N-leaching, and salt balance.

The second phase of this project includes training in the use of these technologies, and their demonstration in commercial production operations.

OBJECTIVES

The objectives of this project are:

1. Evaluate and develop irrigation scheduling criteria for lettuce and melons produced in the low desert, and evaluate the influence of irrigation and N fertilization on crop growth, crop N nutrition, N leaching, and salt balance,
2. Conduct an outreach program aimed at promoting and implementing efficient irrigation practices.

DESCRIPTION

Over 99% of all lettuce, and a significant percentage of the melons produced in the desert are furrow irrigated, and this project is focusing on the development of efficient furrow irrigation practices. However, because some vegetable acreage, particularly melons, has been converted from furrow to buried drip, studies were also conducted with drip irrigation.

Evaluation of management allowable depletion (MAD) values and crop coefficients (kc) for furrow irrigated lettuce and melons

Experiments were conduced during 1999, 2000, and 2001 to evaluate "management allowable depletion" (MAD) values and crop coefficients (kc values) for furrow-irrigated lettuce and melons. Treatments were selected such that irrigations were applied at MAD values ranging from 20 to 80% depletion of available soil water (SWD). Neutron probe access tubes were installed to a depth of 1.5 m in all plots. Soil moisture measurements were made two to three times weekly. Irrigation was applied to all replications of a treatment when the mean SWD of the treatments reached the targeted SWD. Growth and yield data were collected so that we could identify MAD values associated with maximum crop production. Data from the treatments receiving optimal irrigation were used to calculate kc values from ET as measured by soil water depletion and penmen ET^0 values.

Evaluation and demonstration of irrigation scheduling for lettuce

Two studies were established in 2000 and 2001 to evaluate and validate irrigation scheduling for lettuce. The first experiment evaluated three irrigation regimes and five N rates. The irrigation regimes were grower standard practice, irrigation based on frequent neutron probe measurements, and irrigations based on weather based irrigation scheduling program (AZSCHED). The N rates ranged from 0 to 250 kg/ha. Information for MAD and kc values utilized in AZSCHED were determined or validated in studies described in the previous section. The second experiment evaluated the three aforementioned irrigation regimes but did not include N rates.

Design and management guidelines for furrow-irrigated desert vegetable production units

We have come to realize that irrigation scheduling alone will not result in efficient irrigation practices. Therefore, we initiated studies aimed at optimizing system variables for furrow-irrigated vegetables. The development of a management package for the furrow-irrigated vegetable production units of the low desert area had been undertaken in four stages: (1) experimental studies (1998, 1999, and 2000), (2) model calibration and validation (2000), (3) simulation experiments and development of management tools [i.e., performance charts and lookup tables (2001)], and (4) development of management guidelines that facilitate effective use of the management tools (2001). The primary objective of the field experimental study was to develop a complete database that would be used in the modeling studies (i.e., model calibration and validation). Models were calibrated by field experiments using volume-balance based parameter estimation models. These models were validated with independent data sets. Simulation experiments with the validated models were used to develop management guidelines.

Drip irrigation for lettuce and melons

Studies were established to evaluate irrigation scheduling approaches for drip irrigated vegetables. This particular experiment focused on evaluating crop coefficients and the interaction between N management and irrigation management. Treatments were four irrigation regimes ranging from 0.2 to 0.8, Penman ET^0 values. These treatments were in factorial combination with 3 nitrogen fertilizer treatments. Daily irrigations were computed from average ET^0 values as calculated from the previous week's weather data. The influence of irrigation regimes on growth and yield were determined from weekly measurements of plant growth, and dry matter accumulation as well as marketable yields at maturity.

RESULTS

Evaluation of management allowable depletion (MAD) values and crop coefficients (kc) for furrow irrigated lettuce and melons

Data from these studies suggest using a MAD of 35 to 40% depletion of available water to a 0.3 m soil depth as a basis for scheduling irrigations for lettuce. Crop evaporation (ETc) estimates from several experiments, and Penman generated reference evaporation (ET^0) values indicate that crop coefficients for lettuce are approximately 0.1 early in the season (six to eight-leaf stage), and increased to 0.7 during the rapid growth period (after cupping). Preliminary data for melons suggest a MAD of 40% depletion of available water to a 0.6-m soil depth, but studies for melons are currently incomplete.

Evaluation and demonstration of irrigation scheduling for lettuce

Lettuce yields were not affected by irrigation regime, indicating that irrigation scheduling would not compromise yield compared to grower standard practices. Yield and crop N uptake were not affected by N rate indicating that residual N was high on this site. Lettuce midrib-nitrate varied by N rate, but were near or exceeded critical concentrations at all N rates. Residual N as measured by soil analysis, and N leaching as measured by resins increased with N rate. We hope to initiate similar experiments for melons in 2001 and 2002.

Design and Management Guidelines for furrow irrigated desert vegetable production units

This study included field and modeling components. Field experiments were used to calibrate and validate models. Inputs for a surface hydraulic model were measured directly, or calculated using surface irrigation parameter estimation models. Models were validated using independent data sets by comparing observed and predicted irrigation advance. Simulations using the validated models were used to develop performance charts and look-up tables for the selection of efficient irrigation practices. Substantial improvements in irrigation application efficiencies and distribution uniformities would be realized using the proposed management guidelines.

Drip irrigated lettuce and melons

For lettuce and melons, optimal yields were achieved at irrigation regimes appreciably below ET^0 estimates. Melons appeared to derive appreciable amounts of water from capillary movement from lower soil depths.

Evaluation of Slow Release Fertilizers for Cool Season Vegetable Production in the Salinas Valley

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Introduction

This project is evaluating the nitrogen release characteristics of various slow release fertilizers by conducting laboratory and field trials on winter-grown broccoli. The laboratory evaluations are being conducted only in the first year of the project (2000-01). The data generated by the controlled incubations will then be used to select materials to include in further field evaluations. The lab evaluations include characterization of the release patterns of nitrate and ammonium from the materials. The field trials are evaluating the effect of various rates of slow release materials on the broccoli yield, and the economics of slow release fertilizer use. Broccoli was selected as the test crop because it is a key cool-season vegetable that is extensively planted in the Salinas Valley (61,500 acres in 2000). In addition, it is grown during the winter, the rainiest time of the year, when the potential for losses of nitrogen from leaching is highest.

Objectives

1. Evaluate coated-urea slow release fertilizer materials under controlled conditions to evaluate relative release of nitrogen.
2. Evaluate nitrogen release, yield, and the economics of a select number of coated-urea, slow release fertilizer materials in field trials conducted on winter broccoli.

Description

Controlled Incubations

Nine slow release fertilizers, including those used in the field study, were evaluated for rate of N release in a 16-week incubation study conducted at the Department of Vegetable Crops at U.C., Davis. Each of the fertilizers was mixed into soil / sand mixture and placed in plastic columns, wetted to field capacity, and incubated at a constant temperature (either 50° F or 68° F). At monthly intervals, these columns were leached thoroughly, with the leachate analyzed for mineral N concentration.

Field Evaluations

A slow release fertilizer trial was conducted in a commercial broccoli field in the Salinas Valley during the winter of 2000-01. An over-wintered field with a medium-textured soil was selected for the trial to provide the greatest potential for exposure to the high rainfall months and greatest potential for nitrogen movement from the root zone (i.e. December to February). This was not an exceptionally high rainfall year as a total of only 8.79 inches of rain fell during the trial with no one rainfall event exceeding 1.20 inches in a 24-hour period.

Table 1. Total nitrogen in leaf tissue on three sampling dates.

Treatment	*Jan. 29*	*March 13*	*April 3*
Untreated	4.75	5.54	4.27
Standard 250	5.35	6.04	4.96
Polyon 200+50	5.30	6.28	4.76
Polyon 150+50+50	5.35	6.23	4.63
Polyon 100+50+50+50	5.51	6.24	4.86
Duration 200+50	5.25	6.18	4.74
Duration 150+50+50	5.28	6.35	5.16
Duration 100+50+50+50	5.51	6.49	5.07
LSD (0.05)	0.15	0.38	0.43
Contrast[2]			
Slow vs standard	n.s.	**	n.s.

1. Slow release fertilizer + conventional fertilizer sidedress
2. ** $P < 0.05$

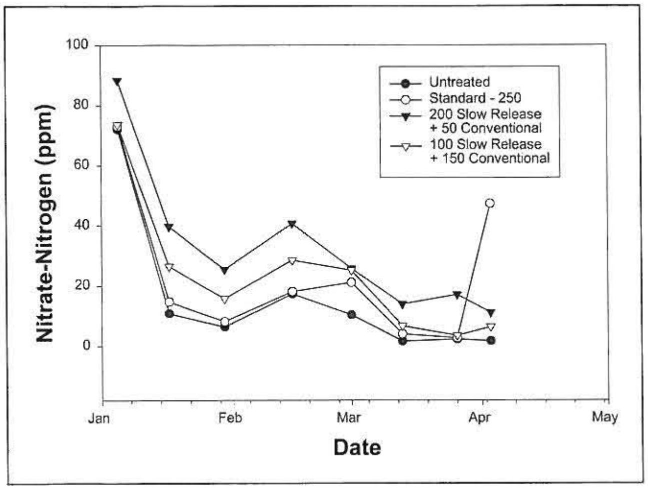

Figure 1. Nitrate-N in soil of various treatments over season

The slow release fertilizer was shanked into listed beds on November 27, and the broccoli was direct seeded one week later. A total of 54 pounds of additional nitrogen was applied to the plots from preplant nitrogen applied in the fall, and from the irrigation water. Two hundred pounds of nitrogen was applied as all slow release fertilizer, or as combinations of slow release fertilizer and sidedress applications of conventional fertilizer (see table 2). Fifty pounds of nitrogen was added to each plot in an application of ammonium thiosulfate as a weed control application in early February. The slow release treatments were compared with an untreated control, and a standard treatment that received a total of 250 lbs N/A.

Biweekly soil samples were collected during the course of the growing season, and analyzed for nitrate and ammonium. Leaf blade and petiole tissue samples of the broccoli were collected at three times during the growing season, and analyzed for total nitrogen and nitrate-nitrogen. In order to have a measure of the relative amounts of nitrate removed from the soil by plant removal or leaching, soil samples were collected at one-foot increments to three feet at the beginning and at the end of the growing season. The samples were analyzed for nitrate and ammonium. The trial was harvested by commercial harvesters on three harvest dates from April 13 to 24, and the number and weight of broccoli heads per plot was collected.

RESULTS AND CONCLUSIONS

Controlled Incubations

At the time of this report, leachate analysis was incomplete, but it was clear that these fertilizers had widely varying release patterns, with some materials releasing half of the original N content in the first 4 weeks, while other materials had released as little as 20% in that time.

Field Evaluations

Two hundred pounds of slow release fertilizer applied at the beginning of the season maintained higher levels of nitrate-nitrogen in the soil over the course of the season than either a combination of slow release and standard fertilizer, or the standard fertilizer treatment (Figure 1). The reason for the jump in the soil levels of the standard fertilizer treatment on the last sampling date is not clear. The generally higher levels of nitrate-nitrogen in the soil of the slow release treatments

Table 2. Fertilizer application schedule1 and yield of broccoli

Treatment	*11/27/00 lbs N/A*	*Sidedress #1 1/6/01*	*Sidedress #2 2/5/01*	*Sidedress #32 2/8/01*	*Sidedress #4 2/28/01*	*Total No. Heads*	*Total Wt. (lbs)*	*Mean Head Wt.*
Untreated	0	0	0	50	0	189.0	84.31	0.44
Standard	0	50	50	50	100	203.0	90.70	0.44
Polyon	200	0	0	50	0	194.0	92.71	0.48
Polyon	150	0	50	50	0	184.5	91.61	0.50
Polyon	100	50	50	50	0	197.0	97.30	0.50
Duration	200	0	0	50	0	188.3	89.64	0.48
Duration	150	0	50	50	0	190.5	90.48	0.48
Duration	100	50	50	50	0	195.8	93.40	0.48
LSD (0.05)						19.21	9.87	0.04
Contrasts3								
Polyon vs Duration						n.s.	n.s.	n.s.
Slow vs Standard						n.s.	n.s.	**
200 slow vs standard						n.s.	n.s.	n.s.
200 slow vs 100 slow						n.s.	n.s.	n.s.

1. Sidedress #1 = CAN 17; Sidedress #2 = Ammonium nitrate; sidedress #3 = ammonium thiosulfate; sidedress #4 = ammonium nitrate
2. Application of ammonium thiosulfate for weed control
3. ** P<0.05

reflected, in general, a higher total nitrogen in the plant tissue of the broccoli on the March 13 sampling date, which was the pre-budding stage of growth (Table 1).

The number and weight of broccoli harvested from the standard and slow release fertilizer treatments were comparable. However, there is consistently higher mean head weight of broccoli in the slow release fertilizer treatments (Table 2). The 2000-01 growing season was not a particularly rainy season. Further tests in other years with heavier rainfall events may provide greater opportunities to observe the ability of slow release fertilizer to provide nitrogen to winter grown broccoli, as well as its ability to resist leaching by winter rains.

Effect of Different Rates of Nitrogen and Potassium on Drip-Irrigated Beauregard Sweet Potatoes

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INTRODUCTION

Merced County sweet potato acreage accounts for approximately 73% of the total production acreage in the state. Most of this area is centered near Livingston, CA, and is dominated by soils classified as loamy sand, sand, and sandy loams. Deep, well-drained sandy soils are preferred for sweet potato production because they produce the best-shaped and most attractive roots.

In 2000, the total area in sweet potatoes in California was about 10,000 acres, accounting for 12% of the total production area in the U.S. Essentially not used just ten years ago, drip irrigation in sweet potatoes is gaining popularity, and is now used on roughly 40 to 50% of the acreage.

Growers use drip irrigation to fertigate their crop with nitrogen and potash, but to date, no fertility trials have been performed by UCCE in drip irrigated sweet potatoes. Trials performed in 1967, 1968, and 1974 on furrow irrigated potatoes found that best marketable yields occurred at 120 to 240 lbs N, 50 lbs P_2O5, and 100 – 200 lbs K_2O per acre. The last fertilizer trial performed was in 1976 in Merced and Fresno counties. Results were similar to the earlier studies.

Since 1976, considerable change has occurred in the production of sweet potatoes in California. Higher yielding varieties (notably Beauregard), improved seed stock through meristem culture for virus removal, and drip irrigation have contributed to increased yield and nutrient removal. From 1967 to 1997, the county yield average for fresh market sweet potatoes increased more than 50%. Additionally, the use of drip irrigation has provided growers with the ability to precisely control fertility inputs, especially nitrogen. This greater control may decrease the amount of N needed by the crop because of increased fertilizer efficiency. Conversely, because of the greater yields observed with drip irrigation, nitrogen inputs may need to be increased over conventional furrow irrigation.

Most growers in California apply more than the UCCE recommended rates because of increased production, and use drip systems to "spoon feed" the crop for 4 – 6 weeks during the growing season. Typically, more than 200lbs of N and more than 300 lbs of K_2O per acre are used by commercial sweet potato producers. Drip-applied N and K usually supplement a preplant program that provides roughly one-third of the total applied nutrition.

While Beauregard sweet potatoes (and many other varieties) respond well to high rates of nitrogen, this practice creates the possibility for nitrate leaching. The leaching potential in this area has already been demonstrated for certain pesticides. Prior to 1999, the California Department of Pesticide Regulation (DPR) classified one section in the Livingston area as a Pest Management Zone (PMZ). In 1999, DPR determined that the original PMZ should be expanded to include a much larger Ground Water Protection Area. This designation was based on the vulnerability of the area to pesticide leaching because of the sandy soils in the area.

Because of the large difference in the recommended fertilized rates, and what is actually used in the industry, a test is needed to determine if current recommendations should be revised because of changes in irrigation management. Additionally, this trial offers the chance to determine if leaf and petiole analysis guidelines may also need revision.

OBJECTIVES

Given the significant changes seen in the industry in the last 20 years and increased concerns about nitrogen use, the objectives of this trial are:

- Determine the optimal rates of nitrogen and potassium for best yield and quality in drip irrigated Beauregard sweet potatoes.
- Determine the effect of different rates of potash and nitrogen on moisture loss in storage.
- Re-evaluate current fertilizer application and tissue analysis guidelines.
- Determine if drip irrigation reduces the potential for nitrate leaching, even at high nitrogen fertilizer rates.

DESCRIPTION

A trial was initiated with a commercial sweet potato grower in April 2001. Nitrogen rates were 0, 50, 100, and 200 lbs N/A, and potash rates were 0, 75, 150, and 300 lbs K_2O/A. Part of the field was sectioned off from the main irrigation assembly so that nutrient inputs could be applied independent of the grower's fertilization schedule. No preplant incorporated fertilizers were applied. Plots are 2 rows wide by 45 feet long, and replicated four times.

Granular potassium sulfate was applied to the beds under the drip lines at transplant. Phosphorous was uniformly applied to all plots. Nitrogen treatments began in early July. CAN17 was injected on a 5-day schedule for 35 days. All nitrogen was applied through the drip tube during this period.

RESULTS

Currently, this trial is in the middle of the first growing season, and we have only a few preliminary results. Initial soil test values showed this site to have low residual nitrate values (< 13 ppm NO_3N), high P (> 20 ppm), and marginal K (35 – 70 ppm). The soil is a sandy loam, deep, well drained, and slightly acidic.

Nitrogen applications began July 5, and were completed August 13, 2001. While there are no discernable differences in vine growth and/or color with the potash treatments, the 0 lbs N/A treatments are yellowed and much smaller than the treatments that received nitrogen.

Plant tissue and water samples were taken during the growing season. These samples have been sent to University of California DANR labs, and we are awaiting the results.

In conclusion, it appears from the vine growth that we are seeing a response to nitrogen at this point. Later soil and plant samples, plus yield data, will provide us with further means for evaluating the project objectives.

Reducing Fertilizer Needs of Potato with New Varieties and Clonal Strains of Existing Varieties

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INTRODUCTION

Potatoes are one of the important vegetable crops grown in California. Potato is also one of the heaviest fertilized crops in California. An average of approximately 300 lbs. of N per acre is applied, with rates varying from 200 to over 400 lbs/Ac. The most widely grown variety (Russet Norkotah) has a weak vine, and is susceptible to early dying diseases. To compensate for these variety deficiencies, growers have increased the amount and duration of nitrogen fertilization in an effort to keep the vines alive longer and healthier.

The rates of application are high for several reasons: (1) Potatoes are a high value crop (approx. $4,000/Ac gross farm gate), thus rates are applied for maximum yield; (2) Potatoes are relatively shallow rooted, and have low root density, thus are inefficient; (3) Much of the production is on sandy soils, thus with high leaching potential; and, (4) A relatively new reason: the most widely grown variety (Russet Norkotah) has a weak vine, and is susceptible to early dying diseases. To compensate for these variety deficiencies, growers have increased the amount and duration of nitrogen fertilization in an effort to keep the vines alive longer and healthier. This situation is not unique to California. Russet Norkotah is widely grown, particularly in western U.S. Thus, even a 10% reduction in fertilizer nitrogen requirement for optimum yield and quality could result in tens of thousands of tons of nitrogen that 1) growers do not have to purchase, and 2) that are not subject to leaching below the root zone, and potentially contaminating runoff and ground water.

Several new clonal selections have been made of Russet Norkotah that have stronger vines and later maturity. Preliminary indications are that, at least some of these clonal selections, or strains, have lower nitrogen fertilizer needs than the standard Russet Norkotah. New varieties are also being grown and/or recently released in the long white, round red, as well as russet market classes. These varieties (e.g. Cal-White, CalRed, Silverton Russet, and Klamath Russet) may also have lower nitrogen, phosphorus and/or potassium requirements than the previous or current standard varieties.

Potassium and phosphorus fertilizers are also commonly applied in excess of rates recommended from previous University research. Essentially, all of that research was conducted on older varieties; none has been conducted on new varieties. This is an opportunity to demonstrate economic and sustainable rates of potassium and phosphorus as well as determine if some of the newer varieties utilize these nutrients more efficiently. Determination of the current status of P and K fertilizer practices and soil nutrient status of potato soils in California is essential before extensive experimental trials are conducted.

OBJECTIVES

1. Determine the responses of standard and new potato varieties to nitrogen fertilization rates.
2. Determine if the new Russet Norkotah strains are more efficient in nitrogen utilization, and thus require lower fertilization rates.
3. Determine if other new or potential potato varieties are more efficient in nitrogen use than existing standard varieties.
4. Demonstrate to potato industry the feasibility, profitability, and sustainability of utilizing varieties/strains with lower fertilization requirements.
5. Demonstrate to potato industry the feasibility, profitability, and sustainability of lower fertilization rates on standard and new varieties.
6. Determine the current use of phosphorus and potassium fertilization, and initiate experiments similar to nitrogen, as needed and as feasible.

PROJECT DESCRIPTION

In 2000, nitrogen rate experiments were conducted with 10 new varieties, including three new Russet Norkotah strain selections, at three locations – Kern Co., Davis, and Tulelake. Three years of experiments are necessary for conclusive results and recommendations to the industry. Thus, the 2001 experiments are the second year of the study, the first year of the CDFA-FREP project.

The three components of the FREP project are, as follows:

1. Nitrogen x Variety Trials. In 2000, trials were conducted in Kern County, UC Davis, and IREC-Tulelake. Nine variety entries and five fertilizer rates were used at each location, although the varieties and the rates were not the same at any two locations. A total of 12 varieties were studied. Nitrogen rates varied from 0 to 350 pounds per acre. Applications were split into two equal components at UC Davis and UC-IREC, with half at planting and half as a side-dress 45-60 days after planting. At Kern County, all rates were applied at planting time; however, the grower applied a uniform amount of nitrogen via sprinkler to all plots during the season.

   In 2001, trials were conducted in Kern County, San Joaquin County and UC-IREC. Twelve varieties were studied in Kern County and six each at the other two locations. Only russets were studied at Tulelake, and only reds and whites were included at the Stockton Delta site. A total of fifteen varieties are being evaluated. Five nitrogen rates were used at each location, with zero being present at all locations, including the Kern County site. Split applications were used at Kern and Tulelake sites; all N was applied at planting time in the Delta.

   Petiole samples were accomplished at 15-day intervals. Soil samples were collected at the beginning and end of growing seasons. Whole plant samples have been collected at two sites, and root samples will also be collected at two sites. Nutrient analyses, as well as fresh and dry weights, are being conducted.

2. Field Days, Grower Meetings, Other Dissemination of Information. Field days were conducted in 2000 at harvest, at Kern County and UC-IREC locations, and in 2001 at the Kern County harvest. The annual results are published in the California Potato Research Advisory Board annual report and orally presented to the Board at their annual meeting. The FREP annual report and annual conference will be used to disseminate information. Upon completion, results will be published in California Agriculture, California trade magazines and journals, and professional society journals.
3. Grower Surveys. To determine and evaluate current fertilizer practices, attitudes toward changing those practices, and to determine the need for phosphorus and potassium trials, a grower survey has been developed. In combination of soil and plant analyses, this survey will be used to determine the need for P and K trials. The survey will also provide a basis for evaluating the success and impact of this FREP project.

RESULTS AND CONCLUSIONS:

No conclusions can be made at this time. Preliminary data were collected in 2000. One of three sites in 2001 has been harvested. No 2001 data are available at this time, but will be at the time of the November conference.

Nitrogen rate and spacing experiments were conducted with nine varieties in Kern County – CalRed, Cherry Red, Red LaSoda, CalWhite, Russet Norkotah, CORN #3, TXNS 112, TXNS 223, and Silverton Russet. The varieties included in Tulelake trials were Gem Russet, Klamath Russet, Russet Burbank, Russet Norkotah, CORN #3, TXNS 112, TXNS 223, Silverton Russet, and CalRed. At UC, in the spacing and growth rate study, the varieties included were CalRed, Cherry Red, Red LaSoda, CalWhite, Russet Norkotah, CORN #3, TXNS 112, TXNS 223, and Russet Burbank.

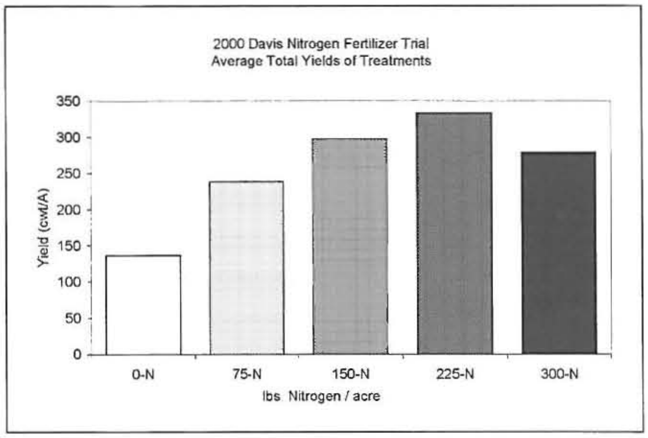

Figure 1.

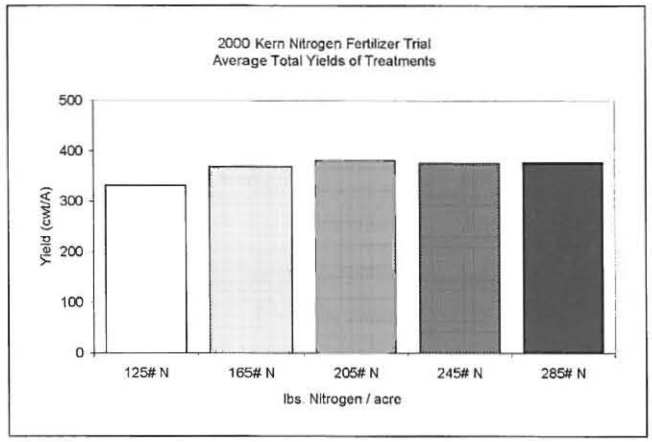

Figure 2.

Results from the Nitrogen-Cultivar study must be considered preliminary, and conclusions cannot be made from only one year of data. In the Kern County study, all plots received 120 units of N via fertigation, in addition to the variable rates of 0, 75, 150, 225, and 300 pounds per acre. CORN3 was the highest yielding entry, and CalRed the lowest yielding. Response above the lowest nitrogen rate was significant by all varieties; response at the 2nd lowest rate was variable; overall, the 3rd, 4th and 5th highest rates were equal. The response curves by the individual varieties appear to be different, indicating that some will respond to higher rates of nitrogen than others.

At UC Davis, the same variable rates of 0 to 300 pounds were applied, half at planting time and half as a later side-dress. No additional nitrogen was applied through the irrigation water. As in Kern County, yield differences were measured among varieties, among nitrogen treatments, and the nitrogen response varied among varieties. All varieties responded to the maximum rate of 150 or 225 pounds per acre; optimum rate for most varieties was 200-225 lbs/A; in most cases, higher rates resulted in a yield decrease. Cherry Red, Red La Soda, and TXNS 112 recorded maximum yields at the lowest rates. In all cases, yields decreased at the highest nitrogen rate. The highest yielding (total yield) varieties were CalWhite, Red La Soda, and CORN #3; the lowest were CalRed, Russet Norkotah, and Russet Burbank; intermediate were TXNS 112, TXNS 223, and Cherry Red.

At Tulelake, the average response was a small, gradually increasing yield as nitrogen rates increased, even at 400 pounds per acre. Response among varieties varied, and the response was different for total yields than for No. 1 yields. The highest yields of No. 1's were by Russet Norkotah, TXNS 112, Silverton Russet, and CalRed. Intermediate yields were by CORN #3 and TXNS 223. Lowest yields were by Russet Burbank, Klamath Russet, and Gem Russet. Maximum No. 1 yields were achieved at rates of 100 #/A, 200 #/A, 300 #/A, and 400 #/A. Figures 1-8 illustrate the yield and responses by the different varieties in 2000.

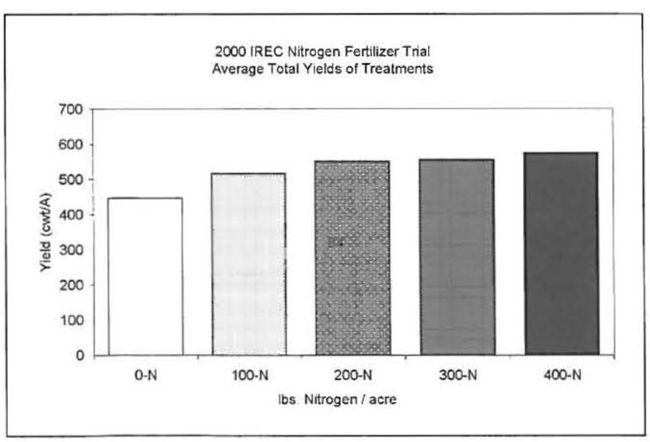

Figure 3.

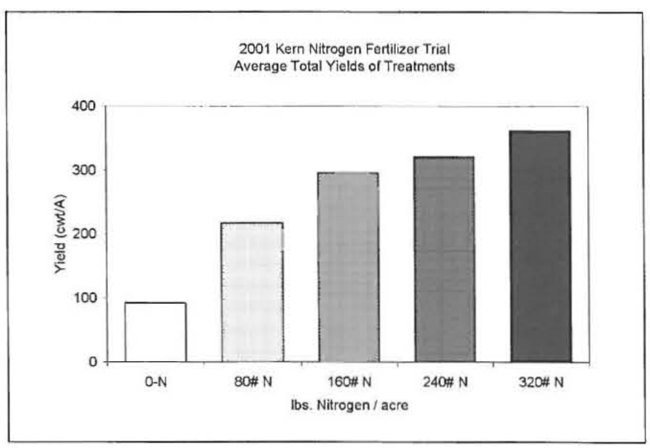

Figure 4.

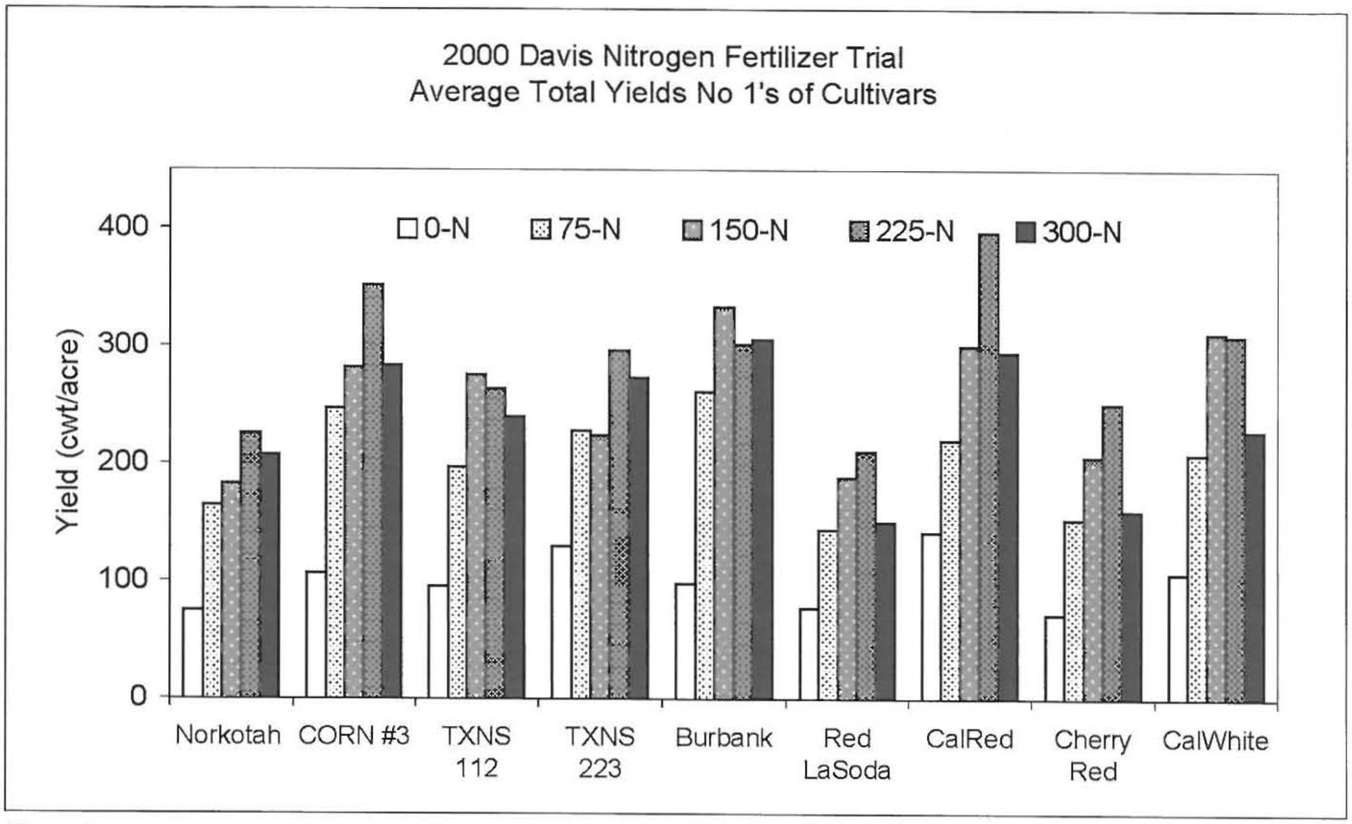

Figure 5.

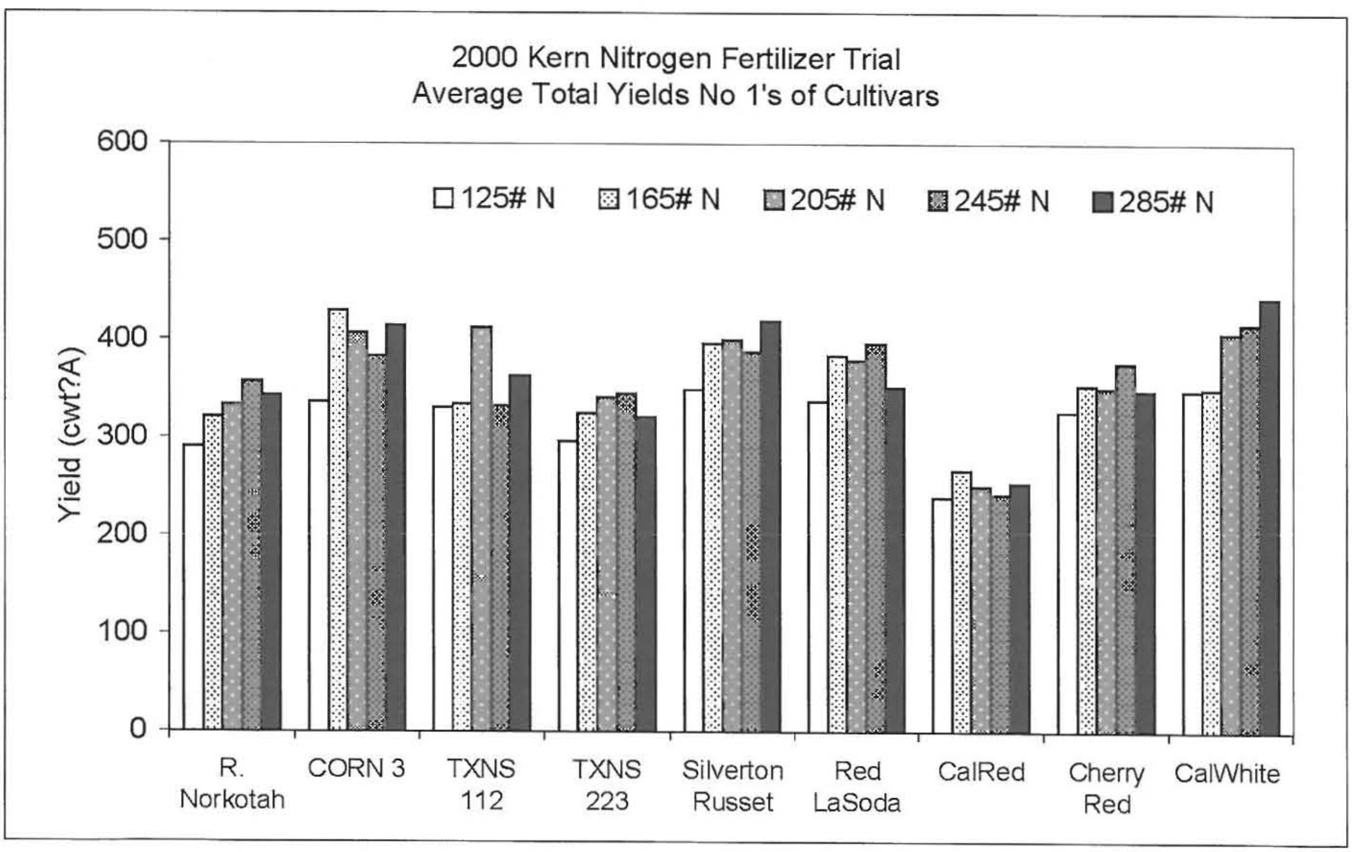

Figure 6.

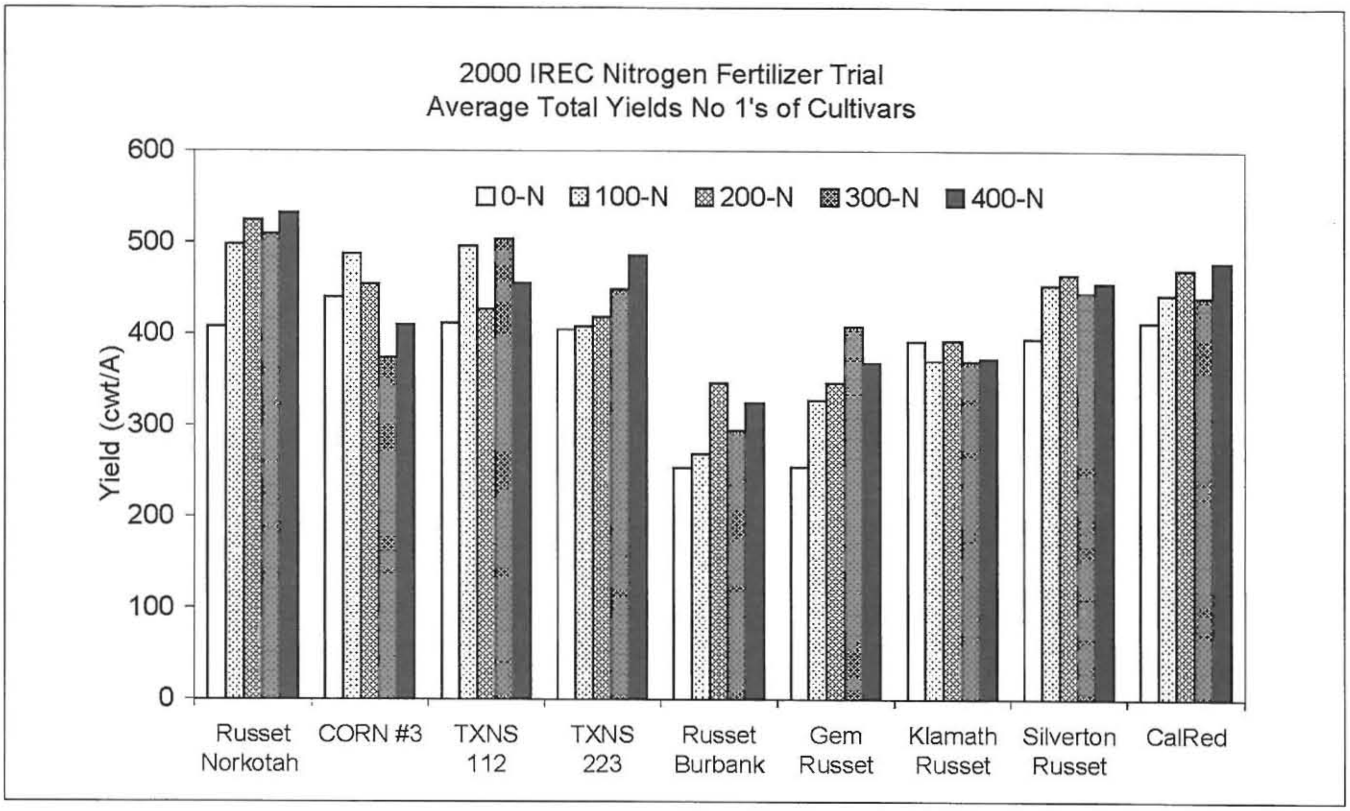

Figure 7.

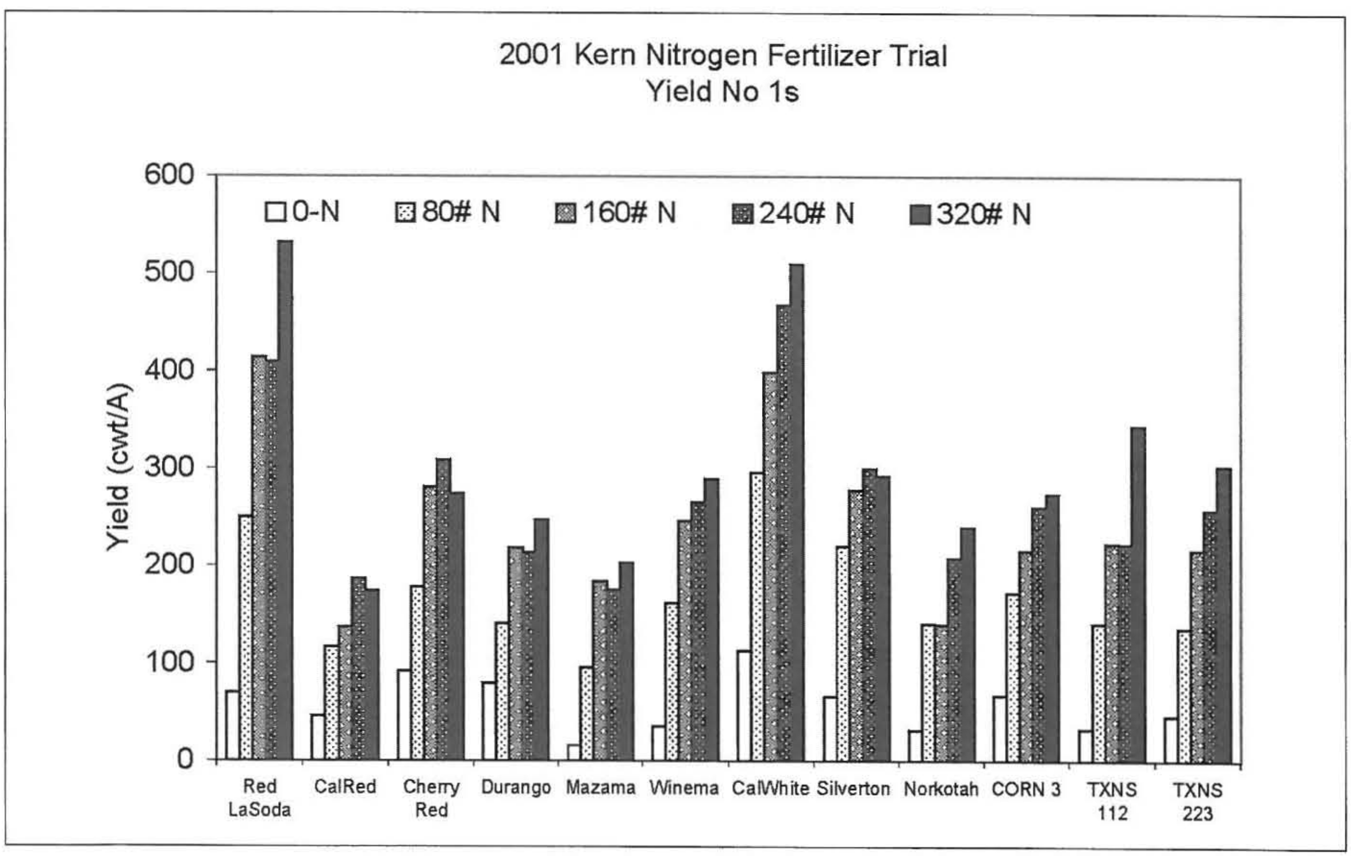

Figure 8.

Fertilization Technologies for Conservation Tillage Production Systems in California

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INTRODUCTION

Despite a 300% increase in conservation tillage (CT) production in the Midwestern United States during the past decade, less than 0.3% of the acreage in California's Central Valley (CV) is currently farmed using CT practices. Preplant tillage operations typically account for 18 – 24% of overall production costs for annual crops grown in this region. An average of 9 to 11 tillage-related passes are routinely done during the fall-spring period just to prepare the soil for summer cropping. These passes represent not only considerable energy, equipment, and labor costs, but recent research indicates that tillage reduces soil organic matter (SOM) and emits considerable respirable dust as well. Because SOM is widely regarded as an important attribute of good soil quality and long-term productivity, interest has been growing over the last several years, in developing alternative production systems that reduce costs, while improving soil resources through greater carbon sequestration.

Recent pioneering studies by Reicosky and Lindstrom (1993) involving a variety of tillage methods indicate major gaseous losses of carbon (c) immediately following tillage, but point to the potential for reducing soil C loss and enhancing soil C management through the use of conservation tillage (CT) crop production systems. Though these practices have been developed over the past several decades primarily for erosion control in other parts of the US, recent concerns regarding the need to sustain soil quality and profitability have prompted an examination of CT practices in California.

Tillage in most annual cropping systems in California's Central Valley is typically done in a "broadcast" manner through a field, without deliberate regard to preserving dedicated crop growth or traffic zones. Studies by Carter (1991) over the last several decades, however, have confirmed the potential to eliminate deep tillage, decrease the number of soil preparation operations by as much as 60%, reduce unit production costs, lower soil impedance, and maintain productivity in a number of CV cropping contexts using reduced, precision, or zone tillage practices that limit traffic to permanent paths throughout a field. Using this approach can reduce soil compaction and preserve an optimum soil volume for root exploration and growth. No systematic studies have been conducted in California, however, that evaluate optimal fertilization strategies for these reduced tillage systems. Horwath *et al.*, (1999) has shown that changes in fertilizer use efficiency occur when soils are managed for C sequestration in California. Additional work in other regions of the country has shown that the selection of nitrogen fertilizer rates, source, and application methods requires management decisions in CT systems that differ from those used in conventionally tilled systems (Touchton *et al.*, 1995). Factors such as the type or quality of surface residue, residual soil fertility levels, soil temperatures, planting dates, crop variety, and soil moisture (Touchton *et al.*, 1995) determine optimal fertilization programs in CT systems. Soils in conservation tillage tend to be cooler, wetter, more firm, and higher in organic matter near the surface than in conventional tillage (Denton, 1993). The likelihood of obtaining a yield response to starter fertilizer increased rapidly as tillage operations decrease (Touchton *et al.*, 1995).

In this project, we are adapting fertilization equipment that is currently used in CT systems in the midwest and southeast US, and determining fertilizer use efficiency using CT practices under development for San Joaquin and Sacramento Valley row crop systems. The hypothesis that we are testing is that CT practices will promote an increase in soil organic matter (SOM), which in turn will lead to a greater nutrient cycling potential in the soil. This increased potential may then result in a lower fertilizer use efficiency, but a correspondingly lower rate of required fertilization.

OBJECTIVES

The objectives of this proposed research are:

1. Evaluate the effectiveness of various fertilization practices in conservation tillage tomato, corn, and cotton production systems,
2. Determine the fertilizer use efficiency in these production systems transitioning to CT,
3. Compare crop tissue nitrogen status in standard and conservation tillage production systems, and
4. Extend information developed by the proposed project widely to Central Valley row crop producers via field days, equipment demonstrations, and written summaries.

PROJECT DESCRIPTION

Two four-year field research and demonstration sites, one at the UC West Side Research and Extension Center (WSREC) in Five Points, CA, and one that is part of the Sustainable Agriculture Farming Systems (SAFS) Project on the UC Davis campus, are being used for this project. The WSREC experiment consists of a comparison of a standard tillage (ST) cotton-tomato-cotton-tomato production system with and without off-season rye/vetch/triticale cover crops and a conservation tillage (CT) cotton-tomato-cotton system with and without cover crops. The comparison is conducted using 60" beds that will be maintained throughout the course of the project in conservation tillage plots and managed as would routinely be done under West Side conditions in the conventional tillage plots. Tillage plots are 6 beds wide, and run the entire length of a 270 ft field which facilitates tractor operations. Each plot of the two tillage systems (with and without cover crops) is replicated four times, and there are "turn rows" for postharvest tillage and land preparation in the standard tillage plots between CT and standard tillage plots. 60-inch beds were selected because they provide the greatest inter-crop flexibility for current and anticipated Central Valley (CV) rotations. Existing and prototype equipment is accessible for this row spacing, because of the interest in developing more standard, but flexible row configurations in the CV (M. Borba, *personal communication*). The com-parison at the SAFS site consists of both standard and conservation tillage systems in a corn/tomato/corn/tomato rotation with and without a faba bean/rye grain/common vetch/subclover cover crop mixture that will be grown on 60-inch beds that will permit ridge-till planting, and cultivation using a *Buffalo 8000* planter and a high residue cultivator.

Baseline soil sampling has been completed at each site to determine residual levels of total N and C, NO_3-, particulate organic matter (POM), Olsen P, and exchangeable K at 0 – 15 cm and 15 – 30 depths. Experimental protocols and treatments are being imposed this fall at the WSREC site and in the spring of 2002 at the Davis site. No findings are available at this time.

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Nitrogen Fertilization and Grain Protein Content in California Wheat

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INTRODUCTION

The nitrogen fertilization requirement for wheat depends on factors such as yield potential, the previous crop and residual fertility from it, soil fertility, and the amount of irrigation planned. Nitrogen fertilizer applications are made preplant, with seed, at tillering and/or at various other growth-stages during the season. In practice, total seasonal nitrogen applications may vary from 0 to over 300 lb nitrogen/acre, with some acreage over-fertilized and some acreage under-fertilized because of the difficulty of matching fertilizer need with yield potential in each growing season. Grain protein content at harvest may be higher, or lower than the desirable level regardless of the total amount of nitrogen fertilizer applied. Anthesis-time nitrogen applications, in combination with irrigation, can increase grain protein content and improve baking quality of wheat. Such applications have increased grain protein content by 1-3%. Currently, however, growers are unable to predict what the final protein status of the crop is likely to be, under such management. That is; is the potential 3% increase from 11 to 14% or from 8 to 11%? If the former is true, the grower may qualify for a price premium based on grain protein content. If the latter is true, no price premium will be available. Previous research has shown that for optimal production of high protein wheat, the preplant nitrogen amount has to be high enough for the yield potential to be realized, yet not so high that excessive vegetative biomass is produced. Studies also have shown that flag-leaf nitrogen content at anthesis is positively correlated with grain nitrogen content (but not with grain yield) and that if flag-leaf nitrogen content is greater than 4%, additional nitrogen usually is not required to achieve the target (13%) grain protein content. In order to accurately estimate anthesis-time nitrogen requirements, however, it is necessary to be able to predict both final grain nitrogen content, and grain yield at anthesis. In order to produce high quality wheat consistently, and economically, growers need to be able to determine: 1) if anthesis-time nitrogen fertilization is needed to reach the target (13%) grain protein level and, if so, 2) how much nitrogen fertilizer must be applied. Wheat growers, crop consultants, and farm advisors will be able to apply findings from the project in their attempt to produce high quality wheat in a cost-effective manner.

OBJECTIVES

The primary objective of this two-year project is to link plant nitrogen status and crop yield potential (based on crop biomass) at anthesis with a desired response of grain nitrogen content (i.e., final grain protein content of 13%) to anthesis-time nitrogen fertilization. Experiments are designed to measure the response of grain protein content to different rates (0, 30, and 60 lb nitrogen/acre) of anthesis-time nitrogen fertilization under different pre-anthesis nitrogen management practices (thus different yield potentials). Efficacy of broadcast vs. foliar-applied nitrogen also is being compared. Future work will focus on identifying predictive quick tests for use in fine-tuning anthesis-time nitrogen application rates.

PROJECT DESCRIPTION

The project is managed within the framework of the UC Statewide Small Grain Evaluation program led by Project Leader, Lee Jackson, Extension Agronomist and Statewide Cereal Specialist. Experimental sites are among those used in the UC Regional Cereal Testing Program. For the 1999/2000 and 2000/2001 seasons, three sites were established in the Sacramento Valley using the common wheat cultivar "Kern" and three sites were established in the San Joaquin Valley using the durum wheat cultivar "Kronos". The sites in the Sacramento Valley are the Chico State University farm in Chico (Butte County), the Erdman ranch near Grimes (Colusa County), and the UC Davis Agronomy Farm. The sites in the San Joaquin Valley are the Dupont Research Farm (Madera County), the J.G. Boswell farm in Corcoran (Kings County), and the J.G. Boswell Kern Lake Ranch (Kern County). University of California Cooperative Extension Farm Advisors Cass Mutters (Butte Co.), Doug Munier (Glenn Co.), Jerry Schmierer (Colusa Co.), Ron Vargas (Madera Co.), Steve Wright (Tulare/Kings Co.), and Brian Marsh (Kern Co.) arranged for use of grower fields in their counties, worked with and advised the growers on field management operations, and assisted in the application of anthesis-time nitrogen, collection of biomass samples and tissue samples for nitrogen determination, and plot harvest. Project Leader Lee Jackson's Staff Research Associates Ray Wennig (1999/2000, resigned in August 2000) and Steve Scardaci (replaced Ray Wennig in October 2001, resigned in July 2001) coordinated the sowing of the experiments, collection of soil samples, application of anthesis-time nitrogen treatments, collection of biomass and tissue samples, flag-leaf chlorophyll meter readings, harvest of the plots, and initial data analysis. Tissue and grain samples were submitted to the UC DANR Diagnostic Lab for determination of nitrogen content.

Experiments at each site were sown in the fall of 1999 and 2000, using the randomized complete block design with four replications. Treatments at each site consisted of 30 and 60 lb nitrogen/acre as ammonium nitrate and 30 lb nitrogen/acre as foliar-applied urea applied at anthesis. The anthesis-N application was followed with irrigation. A check treatment of zero applied nitrogen at anthesis was included. Plot size was approximately 300 ft^2. Composite soil samples (0-12" depth) were taken at each site at the time of sowing and also just prior to the application of anthesis-nitrogen to provide information on the differing N-status of each site (Table 1). Crop management through anthesis followed accepted grower practices at each site, thus providing differing crop biomass and nitrogen status environments. Crop biomass and nitrogen content of specific tissues (flag-leaf and uppermost stem internode) were measured at the time of anthesis-applied nitrogen, 14 days post-anthesis, and at harvest. Crop biomass samples at each sampling date consisted of plants from 1-meter row/plot cut at the ground level. Subsamples of flag leaves and uppermost stem internodes were drawn from the biomass samples for total tissue nitrogen determination.

RESULTS AND CONCLUSIONS

The sites and grower practices used provided different N-supply and grain yield environments at each location. Anthesis-N applications did not affect grain yield or agronomic characteristics despite different yield potentials at each site and different amounts of soil nitrogen available both preplant and at anthesis (immediately prior to the application of anthesis-N) (Tables 1-3). Most of the data for the 2000/2001

Table 1. Preplant and Anthesis Soil Nitrogen Content, Anthesis-N Test Sites

Site	1999/2000		2000/2001	
	NO_3-N ppm	NH_4-N ppm	NO_3-N ppm	NH_4-N ppm
Preplant Samples - Kern Wheat Tests				
Butte Co	21.3	25.4	35.0	4.8
Colusa Co	28.9	10.5	34.5	24.1
UC Davis	16.3	11.4	53.7	4.5
Anthesis Time Samples - Kern Wheat Tests				
Butte Co	1.0	16.0	4.4	6.5
Colusa Co	0.9	6.8	4.2	6.8
UC Davis	2.1	7.4	3.9	4.8
Preplant Samples - Kronos Durum Wheat Tests				
Madera Co	42.4	44.0	21.6	19.2
Kings Co	23.9	37.4	23.8	35.4
Kern Co.	24.3	5.8	6.4	19.1
Anthesis Time Samples - Kronos Durum Wheat Tests				
Madera Co	0.6	2.8	5.8	2.2
Kings Co	5.6	6.5	5.9	20.6
Kern Co.	5.0	22.3	4.0	8.0

Sacramento Valley sites:
Chico State University Farm, Butte Co
Erdman Ranch, Colusa Co
UC Davis Agronomy Farm, Yolo Co

San Joaquin Valley sites:
Dupont Research Facility, Madera Co
J.G. Boswell, Corcoran, Kings Co
J.G. Boswell Kern Lake, Kern Co

season are being processed at the time of this report (August 20, 2001). Where available, means of treatments for the 2000/2001 season are presented along with results for the 1999/2000 season.

Average flag leaf N-content at anthesis (just prior to applying the anthesis nitrogen treatments) over all sites/seasons ranged from 2.9 to 4.2%, indicating inherent variability within and between sites (Tables 4-5). At the measured levels of flag leaf N-content at anthesis (all lower than 4% except for the Madera Co site in 2000/2001), responses of grain protein content to anthesis-applied nitrogen were expected. Average uppermost stem internode N-content at anthesis showed a similar level of within, and between site variability to flag leaf N-content. Flag leaf N-content and uppermost stem internode N-content at 14 days post-anthesis (14 days following application of the anthesis nitrogen treatments) generally were lower than those measured at the time of the application of the treatments. Flag leaf N-content, uppermost stem internode N-content, and flag leaf chlorophyll readings (SPAD readings were made with a Minolta SPAD-502 Chlorophyll Meter) taken 14 days post-anthesis were not consistently affected by the different rates of nitrogen applied at anthesis in 1999/2000. Tissue N-content and flag leaf chlorophyll may have peaked prior to the measurements and decreased by the time samplings and readings were taken due to translocation of nitrogen from flag leaf and stem tissues to the developing grain. There were significant correlations between SPAD readings and flag leaf N-content both at anthesis and 14 days post-anthesis at all sites in 1999/2000 except

Table 2. Effects of Anthesis-Time Nitrogen Applications on Yield and Agronomic Characters of "Kern" Wheat Sacramento Valley: Chico State University Farm, Butte Co; Erdman Ranch, Colusa Co; and UC Davis Agronomy Farm, Yolo Co

		1999/2000					2000/2001			
Site	Anthesis-N Rate (lb/acre)	Yield (lb/acre)	Test Wt (lb/bu)	1000 Kernel Wt (g)	Plant Ht (in)	Lodging (harvest)	Yield (lb/acre)	Test Wt (lb/bu)	1000 Kernel Wt (g)	Plant Ht (in)
Butte Co										
	0	5800 (02)	64.5	44.7	33	-	5060 (4)	63.4	46.9	35
	30 (as NH_4NO_3)	5540 (03)	64.4	43.8	33	-	5180 (3)	63.6	48.0	35
	60 (as NH_4NO_3)	5910 (01)	64.7	46.3	34	-	5410 (1)	63.6	48.3	36
	30 (as Foliar Urea)	5490 (04)	64.6	45.2	35	-	5220 (2)	63.5	47.2	36
	CV (%)	4.6	0.2	2.9	5.4		6.9	0.3	1.2	1.9
	LSD (.05)	ns	ns	ns	ns		ns	ns	0.9	1
Colusa Co										
	0	5240 (04)	62.3	49.8	-	1.3	5850 (2)	65.2	45.6	34
	30 (as NH_4NO_3)	5470 (01)	62.5	49.7	-	1.5	5830 (3)	65.1	45.7	34
	60 (as NH_4NO_3)	5310 (03)	62.7	50.8	-	1.5	5720 (4)	64.9	45.7	34
	30 (as Foliar Urea)	5460 (02)	63.1	49.9	-	1.3	6030 (1)	65.2	45.1	34
	CV (%)	5.0	0.2	0.9		36.4	4.9	0.2	2.3	2.9
	LSD (.05)	ns	0.5	ns		ns	ns	0.2	ns	ns
UC Davis										
	0	5560 (01)	64.9	46.7	35	1.8	6140 (3)	63.8	43.9	40
	30 (as NH_4NO_3)	5430 (04)	64.6	48.2	34	1.8	6120 (4)	63.3	43.5	37
	60 (as NH_4NO_3)	5530 (02)	64.4	47.3	34	1.5	6430 (1)	62.9	42.9	37
	30 (as Foliar Urea)	5490 (03)	64.8	46.2	36	1.8	6430 (2)	63.5	44.3	39
	CV (%)	5.6	0.2	1.6	2.9	31.6	6.4	0.4	2.0	4.7
	LSD (.05)	ns	ns	ns	ns	ns	ns	0.4	ns	ns
3-Location Summary (1999/2000)										
	0	5530 (02)	-	-	-	-	-	-	-	-
	30 (as NH_4NO_3)	5480 (04)	-	-	-	-	-	-	-	-
	60 (as NH_4NO_3)	5580 (01)	-	-	-	-	-	-	-	-
	30 (as Foliar Urea)	5480 (03)	-	-	-	-	-	-	-	-
	CV (%)	5.1								
	LSD (.05)	ns								

Rating scale for lodging: 1=0-3%, 2=4-14%, 3=15-29%, 4=30-49%, 5=50-69%, 6=70-84%, 7=85-95%, 8=96-100
Numbers in parentheses indicate relative rank in column.

Kings (significant correlation only at anthesis) and Kern. Excluding the Kings and Kern sites, correlation coefficients ranged from 0.71 to 0.93 at anthesis and from 0.55 to 0.85 at 14 days post-anthesis. Flag leaf chlorophyll of the durum wheat cultivar "Kronos" tended to be higher, by 5 to 10 SPAD units, than those of the common wheat cultivar "Kern" at similar flag leaf N-content (Tables 4-5). Different critical values for relating SPAD readings to nitrogen content (and ultimately to the need for anthesis-N topdressing to achieve target grain protein levels) may be needed for the different classes of wheat grown in California.

Grain protein content (12% moisture basis) for the 1999/2000 season (data not available for the 2000/2001 season at the time of this report) ranged from 10.0 to 11.6% at Butte, from 9.9 to 11.8% at Colusa, from 10.7 to 12.2% at UC Davis, from 9.2 to 13.6% at Madera, from 12.6 to 13.5% at Kings, and from 13.0 to 14.1% at Kern (Tables 4-5). Anthesis-N applications, even at the 60 lb/acre rate of N, were not successful in raising grain protein content of "Kern" wheat to the target level of 13.0% at the Sacramento Valley sites (Butte, Colusa, and UC Davis) under the crop biomass and nitrogen status environments there during the 1999/2000 season. Conversely, the anthesis-N applications generally were successful in raising grain protein content of "Kronos" durum wheat to the target level of 13.0% at the San Joaquin Valley sites (Madera, Kings, and Kern), although at the Madera site the 60 lb/acre rate of N was the only treatment that produced a grain protein content of 13.0%. Sin-

Table 3. Effects of Anthesis-Time Nitrogen Applications on Yield and Agronomic Characters of "Kronos" Durum Wheat San Joaquin Valley: Dupont Research Facility, Madera Co; J.G. Boswell, Corcoran, Kings Co;and J.G. Boswell Kern Lake, Kern Co

		1999/2000					2000/2001			
Site	Anthesis-N Rate (lb/acre)	Yield (lb/acre)	Test Wt (lb/bu)	1000 Kernel Wt (g)	Plant Ht (in)	Lodging (harvest)	Yield (lb/acre)	Test Wt (lb/bu)	1000 Kernel Wt (g)	Plantt Ht (in)
Madera Co										
	0	5650 (03)	63.4	64.5	38	1.0	4280 (2)	61.2	60.8	34
	30 (as NH_4NO_3)	6000 (01)	63.3	64.9	36	1.0	4330 (1)	61.4	60.7	33
	60 (as NH_4NO_3)	5910 (02)	63.0	66.1	36	1.3	4070 (4)	61.5	62.2	33
	30 (as Foliar Urea)	5580 (04)	63.4	63.1	36	1.3	4270 (3)	61.4	60.8	32
	CV (%)	11.4	0.4	5.3	1.6	33.1	11.3	0.4	3.3	3.7
	LSD (.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns
Kings Co										
	0	6390 (02)	62.6	63.9	35	6.5	5120 (1)	60.3	53.7	42
	30 (as NH_4NO_3)	6340 (03)	62.4	61.7	35	6.5	5050 (2)	60.4	53.0	41
	60 (as NH_4NO_3)	6510 (01)	62.4	62.9	34	6.5	4870 (4)	60.1	53.3	41
	30 (as Foliar Urea)	6250 (04)	62.3	63.4	35	6.5	4950 (3)	60.7	54.0	42
	CV (%)	7.5	0.7	3.7	1.7	6.3	7.2	0.7	2.7	1.4
	LSD (.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns
Kern Co										
	0	4110 (03)	58.1	49.0	-	8.0	6200 (2)	62.1	56.5	41
	30 (as NH_4NO_3)	4570 (01)	57.6	48.3	-	8.0	6040 (4)	61.9	56.4	41
	60 (as NH_4NO_3)	3780 (04)	58.0	46.5	-	8.0	6050 (3)	61.8	56.8	41
	30 (as Foliar Urea)	4310 (02)	57.7	47.8	-	8.0	6270 (1)	62.0	57.1	41
	CV (%)	16.7	1.4	3			3.7	0.4	2.5	1.8
	LSD (.05)	ns	ns	ns			ns	ns	ns	ns
3-Location Summary (1999/2000)										
	0	5380 (03)	-	-	-	-	-	-	-	-
	30 (as NH_4NO_3)	5640 (01)	-	-	-	-	-	-	-	-
	60 (as NH_4NO_3)	5400 (02)	-	-	-	-	-	-	-	-
	30 (as Foliar Urea)	5380 (04)	-	-	-	-	-	-	-	-
	CV (%)	11.4								
	LSD (.05)	ns								

Rating scale for lodging: 1=0-3%, 2=4-14%, 3=15-29%, 4=30-49%, 5=50-69%, 6=70-84%, 7=85-95%, 8=96-100.
Numbers in parentheses indicate relative rank in column.

gle-degree of freedom contrasts (orthogonal comparisons) between treatment means for the 1999/2000 season showed significant responses of grain protein content to anthesis-N applications. The ammonium nitrate treatments (30 and/or 60 lb/acre rates of N) significantly increased grain protein content at all locations except for Kings (which had the highest grain protein content with no anthesis-N application). The 60-lb/acre rate of N as ammonium nitrate resulted in higher grain protein content than the 30-lb/acre rate of N as ammonium nitrate only at the Butte and Madera sites. There were no significant differences in grain protein content between the 30-lb/acre rate of N as ammonium nitrate, and the 30-lb/acre rate of N applied as foliar urea.

Predictability of wheat grain protein content remains elusive. Further analysis of the data from the 1999/2000 and

Table 4. Effects of Anthesis-Time Nitrogen Applications on N-Tissue Content, Biomass, and Grain Protein of "Kern" Wheat Sacramento Valley: Chico State University Farm, Butte Co; Erdman Ranch, Colusa Co; and UC Davis Agronomy Farm, Yolo Co

	Anthesis				14 Days Post Anthesis				Harvest			
Anthesis-N Rate (lb/acre)	Flag Leaf SPAD	Flag Leaf N (%)	Stem N %	Biomass (g) (m-row)	Flag Leaf SPAD	Flag Leaf N (%)	Stem N %	Biomass (g) (m-row)	Flag Leaf N (%)	Stem N %	Biomass (g) (m-row)	Grain Pro % (12% mb)
Butte, 1999/2000												
0	40.3	3.4	1.4	217	42.5	3.1	1.2	212	0.9	0.8	280	10.0
30 (as NH_4NO_3)	40.7	3.5	1.5	218	43.8	3.4	1.5	217	1.0	0.8	274	10.8
60 (as NH_4NO_3)	40.4	3.5	1.5	216	43.8	3.3	1.4	187	1.3	0.8	286	11.6
30 (as Foliar Urea)	42.0	3.7	1.5	212	41.4	3.2	1.3	209	1.3	0.8	229	10.8
CV (%)	3.39	7.5	6.4	7.6	4.4	8.0	12.4	13.5	15.6	8.5	13.9	4.6
LSD (.05)	ns	ns	ns	ns	3.1	0.4	0.3	45	0.3	0.1	59	0.8
Butte, 2000/2001												
0	40.0	3.3	1.5	157	41.6	2.9	1.2	193	-	-	201	-
30 (as NH_4NO_3)	37.7	2.9	1.3	148	42.5	3.1	1.3	186	-	-	275	-
60 (as NH_4NO_3)	39.5	3.3	1.5	147	45.0	3.4	1.6	165	-	-	260	-
30 (as Foliar Urea)	40.8	3.4	1.5	180	42.0	3.0	1.3	176	-	-	231	-
Colusa Co, 1999/2000												
0	43.8	3.7	1.5	183	42.7	3.1	1.2	256	1.2	0.9	306	9.9
30 (as NH_4NO_3)	45.1	3.7	1.5	222	44.6	3.4	1.3	251	1.5	0.9	325	11.0
60 (as NH_4NO_3)	44.4	3.7	1.5	173	44.3	3.4	1.3	208	1.7	1.0	296	11.8
30 (as Foliar Urea)	44.2	3.8	1.6	194	45.8	3.6	1.3	241	1.3	0.9	328	10.7
CV (%)	4.19	5.7	7.5	19.0	3.5	6.0	5.7	13.6	9.4	10.2	16.2	6.4
LSD (.05)	ns	ns	ns	ns	2.5	0.3	0.1	52	0.2	0.2	81	1.1
Colusa Co, 2000/2001												
0	39.3	3.3	1.3	134	38.3	2.5	1.1	157	-	-	225	-
30 (as NH_4NO_3)	39.6	3.4	1.3	138	39.4	2.8	1.2	171	-	-	204	-
60 (as NH_4NO_3)	39.7	3.3	1.3	121	40.0	3.0	1.2	164	-	-	219	-
30 (as Foliar Urea)	40.9	3.6	1.3	129	39.8	3.0	1.2	142	-	-	225	-
UC Davis, 1999/2000												
0	43.4	3.6	1.5	195	42.6	2.9	1.1	207	1.2	0.8	329	10.7
30 (as NH_4NO_3)	42.4	3.3	1.4	173	44.6	3.5	1.2	195	1.2	0.9	323	11.6
60 (as NH_4NO_3)	41.7	3.2	1.4	176	43.9	3.4	1.2	230	1.3	0.9	288	12.2
30 (as Foliar Urea)	42.6	3.1	1.4	176	42.3	3.1	1.1	193	1.2	0.8	304	10.8
CV (%)	4.81	6.7	5.6	15.5	2.9	4.0	5.8	10.2	11.6	6.7	13.2	5
LSD (.05)	ns	0.4	ns	ns	1.6	0.2	0.1	34	0.2	0.1	65	0.9
UC Davis, 2000/2001												
0	43.9	3.6	1.6	138	43.5	3.4	1.5	174	-	-	293	-
30 (as NH_4NO_3)	43.4	3.6	1.5	127	44.2	3.6	1.6	170	-	-	266	-
60 (as NH_4NO_3)	43.4	3.6	1.5	129	43.7	3.5	1.7	158	-	-	300	-
30 (as Foliar Urea)	43.1	3.5	1.5	135	45.0	3.3	1.6	143	-	-	254	-

SPAD: Minolta SPAD-502 Chlorophyll Meter readings.

2000/2001 experiments will focus on investigating the relationship between total biomass and tissue (flag-leaf and uppermost stem internode) nitrogen content at anthesis with grain yield and grain protein content at harvest, as affected by the different rates of nitrogen applied at anthesis. Future work will include a time-course of SPAD readings and plant tissue nitrogen content determinations from prior to anthesis through 14-days post-anthesis to identify the optimum time for sampling and the highest correlation with final grain protein content. Future work also will focus on identifying predictive quick tests for use in fine-tuning anthesis-time nitrogen application rates.

Table 5. Effects of Anthesis-Time Nitrogen Applications on N-Tissue Content, Biomass, and Grain Protein of "Kronos" Durum Wheat San Joaquin Valley: Dupont Research Facility, Madera Co; J.G. Boswell, Corcoran, Kings Co; and J.G. Boswell Kern Lake, Kern Co

	Anthesis				14 Days Post Anthesis				Harvest			
Anthesis-N Rate (lb/acre)	Flag Leaf SPAD	Flag Leaf N (%)	Stem N %	Biomass (g) (m-row)	Flag Leaf SPAD	Flag Leaf N (%)	Stem N %	Biomass (g) (m-row)	Flag Leaf N (%)	Stem N %	Biomass (g) (m-row)	Grain Pro % (12% mb)
Madera Co, 1999/2000												
0	49.2	3.4	1.4	176	50.0	3.0	0.9	256	0.7	0.4	296	9.2
30 (as NH_4NO_3)	48.8	3.3	1.4	173	51.1	3.1	1.0	244	0.9	0.5	304	11.3
60 (as NH_4NO_3)	50.0	3.3	1.4	188	52.4	3.7	1.1	244	1.1	0.6	319	13.6
30 (as Foliar Urea)	45.5	3.1	1.2	171	50.5	3.4	1.1	238	0.9	0.5	290	10.5
CV (%)	5.14	10.1	8.3	12.9	6.4	12.2	13.9	12.7	19.4	21.8	13.2	9.1
LSD (.05)	ns	ns	ns	ns	5.2	0.7	0.2	50	0.3	0.2	64	1.6
Madera Co, 2000/2001												
0	57.3	4.2	1.6	118	57.1	3.1	1.2	152	-	-	209	-
30 (as NH_4NO_3)	57.6	4.2	1.5	130	58.4	3.9	1.5	138	-	-	186	-
60 (as NH_4NO_3)	57.0	4.1	1.5	103	58.1	3.8	1.7	120	-	-	192	-
30 (as Foliar Urea)	57.9	4.4	1.6	130	57.1	3.4	1.4	141	-	-	219	-
Kings Co, 1999/2000												
0	53.6	3.9	1.5	222	52.0	3.3	1.0	268	1.0	0.6	331	12.6
30 (as NH_4NO_3)	54.7	3.9	1.6	253	52.9	3.7	1.2	242	1.1	0.6	345	13.3
60 (as NH_4NO_3)	53.0	3.8	1.5	257	53.9	3.7	1.2	295	1.0	0.6	338	13.5
30 (as Foliar Urea)	54.0	3.7	1.6	237	52.7	3.6	1.1	278	1.3	0.6	357	13.2
CV (%)	2.43	5.1	5.2	10.9	1.8	6.6	16.1	14.4	12.2	11.7	17.7	4.8
LSD (.05)	ns	ns	ns	ns	1.6	0.4	0.3	62	0.2	0.1	97	1.0
Kings Co, 2000/2001												
0	46.6	3.4	1.4	116	51.4	2.7	1.0	200	-	-	277	-
30 (as NH_4NO_3)	48.1	3.4	1.4	196	52.7	3.0	1.1	224	-	-	320	-
60 (as NH_4NO_3)	48.2	3.5	1.5	94	51.1	2.8	1.3	188	-	-	405	-
30 (as Foliar Urea)	51.7	3.7	1.6	163	53.3	3.2	1.4	170	-	-	372	-
Kern Co, 1999/2000												
0	51.2	3.9	1.4	244	46.6	3.2	1.3	265.5	1.4	1.1	336	13.0
30 (as NH_4NO_3)	51.3	3.8	1.5	238	45.8	3.1	1.4	302.8	2.1	1.2	354	13.5
60 (as NH_4NO_3)	49.0	3.8	1.5	220	45.6	3.4	1.3	258.0	2.7	1.2	347	14.1
30 (as Foliar Urea)	50.8	3.8	1.4	239	48.0	3.4	1.3	312.2	1.6	1.0	373	14.1
CV (%)	4.57	5.0	8.1	11.7	4.6	6.7	9.6	15.0	23.0	11.5	15.5	4.8
LSD (.05)	ns	ns	ns	ns	3.4	0.4	0.2	68.5	0.7	0.2	88	1.1
Kern Co, 2000/2001												
0	53.3	3.6	1.3	182	48.6	2.2	1.0	226	-	-	415	-
30 (as NH_4NO_3)	53.3	3.5	1.3	182	50.9	2.5	1.0	287	-	-	412	-
60 (as NH_4NO_3)	51.9	3.6	1.3	165	51.3	2.5	1.1	279	-	-	464	-
30 (as Foliar Urea)	53.6	3.7	1.4	183	50.5	2.4	1.1	316	-	-	447	-

SPAD: Minolta SPAD-502 Chlorophyll Meter readings.

Development and Demonstration of Nitrogen Best Management Practices for Sweet Corn in the Low Desert

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INTRODUCTION

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 267 lbs/acre (300 kg N/ha). This project seeks to identify and demonstrate N best management practices (BMPs) for sweet corn. In 2000, we initiated N rate studies aimed at evaluating several diagnostic tools for efficient N management of sweet corn (Zea mays). Diagnostic tools evaluated include the traditional dry stalk nitrate-N test, the traditional soil nitrate-N test, and a quick soil test. Studies conducted in the spring and fall of 2000 were designed to evaluate the response of sweet corn to sidedress N fertilizer applications and test the effectiveness of various diagnostic plant and soil tests as predictive tools. We selected sites with two different grower cooperators in the Coachella Valley. Typically sweet corn is planted following lettuce, broccoli or cauliflower.

PROJECT OBJECTIVES

1. Evaluate and demonstrate efficient nitrogen (N) fertilizer practices for sweet corn, including the use of rate, timing, placement of N fertilizers to develop Best Management Practices.
2. Develop and demonstrate diagnostic tools for N management of desert-grown sweet corn.
3. Evaluate the effects of N management on post-harvest quality of sweet corn.

PROJECT DESCRIPTION

Four field experiments were conducted in 2000 to evaluate, and demonstrate to growers several diagnostic tools. The experiments in order were designated as 47D, 47E, 47F, 47G and were conducted in grower fields. We selected sites in the Thermal and Indio areas of the Coachella Valley.

The crop, planting date, final harvest and location of each experiment are shown below.

Experiment	Crop	Planting Date	Harvest Date	Location
47D	Sweet corn	02-04-00	05-19-00	Indio
47E	Sweet corn	02-22-00	05-23-00	Mecca
47F	Sweet corn	08-18-00	10-26-00	Thermal
47G	Sweet corn	08-28-00	11-16-00	Thermal

In all experiments sweet corn was seeded to a stand in single row beds. Individual plots in all sites were approximately 65m^2 (15.24 by 4.26 m) in size. All pest control and cultural operations were performed using standard practices. All stands were established using sprinkler irrigation. After stand establishment, water was applied by furrow irrigation.

Sweet corn growers have different cultural practices. Some growers typically apply three N fertilizer applications after planting (not including preplant application); experiments in these fields consisted of 8 treatments in a 2^3 factorial design.

Other growers typically apply two N fertilizer applications after planting (not including preplant application). In these fields experiments consisted of 4 treatments in a 2^2 factorial design.

Rates of N used in each sidedress application were those actually used by cooperating growers and ranged from 30 to 50 gallons per acre (gpa) of UN32 (approximately 70 to 118 kg N/ha).

Our intention was to collect stalk and soil samples prior to each sidedress fertilizer N application for evaluating diagnostic accuracy. In some cases the first sidedress occurred when the corn was too young for a first stalk sample. However, in all experiments we were able to collect stalk samples by the second sidedress. Individual basal stalks were dried, ground, and nitrate-N was determined using the method of Baker and Smith (1969).

Soil samples were also split into two subsets (A and B) of samples. For subset A, nitrate-N in field moist soil samples were determined using the quick test procedure developed by Hartz (1998). We determined weights and percent moisture of the soil added so that we could convert these values from mg/L to mg/kg. It is our objective to ultimately develop this test to be used without this conversion. The other soil subset (B) was air dried, extracted with KCl, and ammonium-N and nitrate-N was determined using steam distillation (Keeney and Nelson, 1982).

FIELD RESULTS

Studies conducted in 2000 were designed to evaluate the response of sweet corn to sidedress N fertilizer applications and test the effectiveness of various diagnostic plant tests as predictive tools. It is our intention to build a database sufficiently large, re-correlate, and re-calibrate plant (stalk) and soil tests if needed. We had no previous knowledge of the fields and we assumed that we would have N responsive sites. Unfortunately, most of the fields had high residual N values and positive responses to N fertilizer were minimal. Experiments 47D (sidedress 2), 47E (sidedress 3), 47F (sidedress 2), 47G (sidedress 2), shows an occasional positive response to N fertilization based on stalk values.

For stalk nitrate-evaluations, we initially used the critical values reported by Doerge et al. 1991. These values were 9000 ppm at the 3-leaf stage, 12,000-ppm at the six-leaf stage, 11,000-ppm at the 9-leaf stage, and 9000-ppm at the twelve-leaf stage. Some replications of 47D, 47E, 47F, 47G and 47E had stalk nitrate N concentrations that were above critical concentration. There were some positive responses to N fertilization. For example, with experiment 47D, we did diagnose some deficiencies but only saw a response in one replication. However, there were some errors in our diagnosis in predicting a positive response that did not occur. (Tables reporting much of this information are omitted for this report).

A comparison of predicted and actual response of sweet corn to sidedress N based on conventional soil values, our diagnosis of Exp. 47G (sidedress 1 and 2) indicated a deficient N condition. However, yield results indicated an error in diagnosis by predicting positive responses that did not occur. In some of the sidedress treatments we also predicted no response to N but a positive response occurred.

We used 20 ppm as a preliminary soil quick test critical level. For experiment 47G, we diagnosed an N deficiency in the second sidedress but there was no positive response to the sidedress N application. In experiment 47 (sidedress 2), 47D (sidedress 2), 47F (sidedress 2) and 47G (sidedress 2), the quick test predicted no response but a positive response was observed.

Because of the general lack of response to N fertilization we were not able to fully evaluate the efficacy of plant and soil tests as tools for managing N in the desert. During 2001, we hope to locate experiments on sites with low residual N so that we can more rigorously evaluate, and if necessary, modify plant and soil N tests for sweet corn.

POST HARVEST RESULTS

The samples from experiment 47D arrived very warm at the Mann Lab and only a few evaluations were done. For those that were evaluated, there were no differences found among the nitrogen sidedress treatments applied. The % soluble solids and % dry weight were 2-4% higher than values found in sweet corn from other experiments.

Sweet corn quality and maturity were uniform in 47E (Table 1). The pericarp was tougher (higher penetration force required) in kernels from sweet corn receiving no sidedress N. At 0 time, soluble solid contents were similar among the

Table 1. Quality of sweet corn (cv. Aspen) at harvest in relation to 8 fertilization treatments (Exp. 47E, 2000).

N Fert. treatment	Maturity[1]	Tip Fill[2]	Ear Fill[2]	Pericarp[3] toughness Newtons	Pericarp,[4] % Dry wt.
1. No sidedress N	2.0	2.4	3.0	5.69	2.32
2. First sidedress only	2.0	2.4	3.0	5.31	2.18
3. Second sidedress only	2.0	2.2	3.0	5.18	2.35
4. Third sidedress only	2.0	2.4	3.0	5.24	2.21
5. First & second sidedress	2.0	2.2	3.0	5.15	2.11
6. First & third sidedress	2.0	2.2	3.0	4.89	2.19
7. Second & third sidedress	2.0	2.1	2.9	4.96	2.34
8. First, 2nd & 3rd sidedress	2.0	2.2	3.0	5.24	2.31
Average	2.0	2.2	3.0	5.21	2.25
LSD .05	ns	0.2	ns	0.14	0.12

[1]Maturity: 1=immature, kernels small, 2=optimum maturity, 3=overmature, kernel sap milky; evaluation of 6 ears per rep × 3 reps.

[2]Tip fill and ear fill (kernel fill): 1=kernels not fill end or length of ear, 2=moderately well filled, 3=well filled; evaluation of 6 ears per rep × 3 reps.

[3]Pericarp toughness determined on 30 kernels per rep × 3 reps by measuring the resistance to penetration of a 2-mm flat cylinder probe on TA-XT texture analyzer, 2 mm deep.

[4]Pericarp content was determined as a percent on a dry weight basis; 3 determinations per treatment.

N treatments. With 6 and 12 days of storage, however, % soluble solids (SS) decreased in all corn from all N treatments, but the decrease was greatest in the corn receiving the least sidedress N. For example, treatment 8 (first, 2nd and 3rd sidedress N) has 14.9% SS after 6 days at 5°C (41°F) compared to 13.3% SS for treatment 1(no sidedress N). The differences in soluble solids among treatments and storage periods are consistent with the differences in direct measurements of sugars and the dry weight of the kernels. All 3 indicate the same thing: loss of carbohydrate during storage, but significantly less loss in corn from some of the sidedress treatments (especially treatments 7 and 8). Regarding changes in visual appearance of corn during storage, the main differences were due to time of storage; differences among N treatments for a given storage period were very small, and significant in only a few cases.

Sweet corn quality and maturity were uniform in 47F, with the exception of corn from treatment 3, which was slightly less mature. Again, the pericarp was tougher (higher penetration force required) in kernels from sweet corn receiving no sidedress N and less tough in 2 sidedress treatments (treatment 5).

Table 2. Quality of sweet corn (cv. ACX402W) from 4 fertilization regimes stored at 5°C for 0, 6 and 12 days (Exp. 47F, November 2000).

Fert. treatment	Days at 5°C (41°F)	Visual[1] Quality Husk	Visual[1] Quality Ear	Visual[1] Quality Silks	Decay on Silks[2]	% Dry weight	Pericarp toughness, Newtons	% Soluble Solids[3]	Sugar mg/g dry wt[3]
1	0	9.0	8.7	9.0	1.0	20.9	4.52	13.3	297
2	0	9.0	8.7	9.0	1.0	19.8	4.38	14.1	334
3	0	9.0	8.8	9.0	1.0	19.0	3.68	13.6	347
5	0	9.0	8.7	9.0	1.0	19.4	4.11	13.9	339
Average	0	9.0	8.7	9.0	1.0	19.8	4.17	13.7	329
1	6	7.5	4.9	7.2	3.2	19.1	4.20	10.6	242
2	6	7.8	4.8	8.4	3.0	19.8	4.35	11.3	267
3	6	7.3	5.5	7.8	2.9	19.4	3.95	11.4	268
5	6	7.1	4.7	7.6	3.3	20.0	4.09	11.7	255
Average	6	7.4	5.0	7.8	3.1	19.6	4.15	11.3	258
1	12	6.4	2.5	6.7	3.9	18.6	3.92	9.5	—
2	12	6.3	3.3	6.3	3.8	18.8	4.00	10.2	—
3	12	6.2	1.8	6.2	4.5	18.6	3.46	9.8	—
5	12	6.2	1.5	6.2	4.8	18.8	3.92	9.8	—
Average	12	6.3	2.3	6.3	4.2	18.7	3.83	9.8	—
LSD.05		0.6	1.1	0.7	0.5	0.8	0.2	0.6	28

[1]Visual quality of intact ear in husk, silks and husked ear was scored on a scale of 9 to 1, where 9=excellent, 7=good, 5=fair, 3=poor and 1=unuseable; a score of 6 is the limit of salability.
[2]Decay on silks, 1 to 5 scale, where 1=none, 2=slight, 3=moderate, 4=moderately severe, and 5=severe.
[3]Soluble solids were determined on 1 composite cleared juice sample per field rep on a temperature compensated refractometer; sugar determined on 1 composite sample per replicate.

Treatment 3 also had a tenderer pericarp, but this may have been due to small differences in maturity. A test evaluating pericarp toughness and maturity of sweet corn needs to be conducted to put these data into perspective. Also, the kernels should be cooked to determine if differences in toughness in the raw state persist after cooking.

Differences in storage quality of corn from different N treatments were again minimal. Decreases in quality due to time of storage were much more important than small differences among treatments. In this experiment, the silks had high levels of superficial decay, but the corn had been stored an additional 3 days before sending it to the lab. Pericarp toughness tended to decrease with time in storage (Table 2). Soluble solids were 2-3% lower than in May harvested corn and again decreased about 2% for every 6 days of storage. Treatment 1 (no sidedress N) has the lowest % soluble solids and sugar concentrations.

Sweet corn in Exp. 47G was slightly immature compared to the maturity of corn harvested in previous experiments. Less tip and ear fill indicates this immaturity. Stored ears showed changes in objective color values. L* values increased and hue values decreased, both consistent with loss of greenness. However, visual quality scores are still the most useful to estimate the overall "freshness" and appearance of corn. In this experiment, pericarp toughness was least in the corn receiving no sidedress N. Pericarp toughness decreased with 6 days of storage as also occurred in Exp. 47E.

Soluble solid contents were 2-3% lower than in corn harvested in May and this corresponded to about 25% lower sugar concentrations in these samples. Soluble solids and sugar concentrations were sometimes lower in treatments receiving lower N, but data are not as consistent as in Exp. 47E. Differences in soluble solids and sugars are small, although significant in some cases.

Interaction of Nitrogen Fertility Practices and Aphid Population Dynamics in California Cotton

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INTRODUCTION

The importance of the cotton aphid, *Aphis gossypii* Glover, as a mid-season pest in California cotton has increased since the late 1980's. This insect pest has joined lygus bugs, spider mites, silverleaf whitefly, and beet armyworms as the key arthropod pests of California cotton. The most significant cotton aphid outbreaks occurred in 1997 where an estimated 3.5% yield loss occurred, resulting in an estimated $34 million in crop loss, and an additional $38 million in control costs for "management" of this one insect pest. Aphid damage to cotton can occur in several ways. On young plants, severe aphid feeding can stunt plant growth and development. During the reproductive, and boll-filling stages, cotton aphids remove plant sap, and reduce the energy reserves of the plant. This inhibits the ability of the plants to produce and fill the cotton bolls. After boll opening, cotton aphids excrete honeydew on the exposed lint. This reduces the value (quality) of the lint, and can result in substantial monetary losses. Reasons for the upswing in pest status of cotton aphid are unclear. Changes in the aphid biology, cropping patterns, cotton species/varieties grown, agronomic practices, insecticide use patterns, and climate have all been proposed. Our previous work in 1999 (see 2000 CDFA/FREP conference proceedings) documented the correlation between nitrogen application levels and cotton aphid populations, and that high rates of nitrogen fertilizer can promote the build-up of aphid infestations. Additional field experiments were conducted in 2000 to further study aspects of cotton aphid biology, and the effects of cultural control measures at the individual, and population level. Balancing the amount of nitrogen needed for optimal cotton yield with the level required to mitigate cotton aphid population build-up is the goal of this project.

OBJECTIVES

1. Study the influence of cotton nitrogen fertilization practices on cotton aphid population dynamics and seasonal buildup in cotton.
2. Identify specific crop carbohydrate, and N status associated with higher aphid densities during specific crop growth stages.

PROJECT DESCRIPTION

Replicated field studies with differential nitrogen levels were established by University of California Cooperative extension personnel in grower fields. These studies were designed to evaluate the relationship between cotton nitrogen input and cotton yield and were set up as strip tests, generally 8 rows wide x the field length (up to 1/4 mile long) × 4 blocks. Target nitrogen rates in these studies were 50, 100, 150, and 200 lbs N/A; the lowest rate utilized the residual soil nitrogen and was 70-lbs/A nitrogen at one location. The three highest rates were the residual plus the appropriate amount of applied N. Field sites were located in grower fields in Tulare, Fresno, Kings, Merced, and Madera counties. Two University of California Research and Extension Centers were also utilized (Shafter and West Side). The row lengths were roughly 300 ft. at these two locations. Planting dates varied across locations but were generally in early April 2000. Nitrogen was generally applied in early to mid-June. Cotton aphid populations were sampled at weekly intervals from each plot from July to September. A twenty-leaf sample, fifth main stem node leaf from the top was used. Aphids were counted with the aid of 50× magnification. Aphid density, morph, and incidence of alates were recorded for each sample. This work was a repeat of the 1999 studies.

A manipulative experiment was conducted in an untreated 0.6-acre cotton field located at the University of California Cotton Research and Extension Center near Shafter for Objective 2. Acala cotton cv. 'Maxxa' was planted on May 6 with 40-inch row spacing. The field was divided into 4 rows × 46 ft plots with 10 different fertilizer regimes. The treatments were 0, 50, 100, 150, 200, and 250 lb/A nitrogen (ammonium sulfate fertilizer). There was also a treatment of 100 lb/A nitrogen + 100 lb/A K_20 and three other treatments of 200 lb./A nitrogen each, and different levels of K_20 added (100, 150, and 200 lb./A K_20, respectively). Treatments, when possible, were adjusted to soil residual nitrogen (20 lb./A) and were applied on June 22. Cotton aphids from a clonal colony (one genotype) were out-planted to eight plants in each plot on July 10. These aphids were enclosed in one-leaf mesh cages made of floating row cover (5 adults per cage) for 12 hours located on the 5th main stem leaf from the top of the plant. After this period, the adults were removed, and only one offspring produced by these females was left per cage. This cohort of aphids composed the first generation. These aphids were monitored and their generation time, fecundity, and survival recorded. A second cohort of aphids (second generation), the offspring of the first generation, was also monitored and their fitness factors assessed. Finally, a third cohort (third generation) was also monitored. In all cases, aphids with their cages were moved to new leaves every week to keep them at the same position within the plant (5th leaf from the top), and avoid drastic changes in the leaf physiology due to the cage. Naturally occurring aphid infestations were also monitored in these plots by taking 10-leaf samples (5th main stem node leaf from the top) from each plot at weekly intervals. The sampling period went from July 11 to September 5.

RESULTS AND CONCLUSIONS

In 2000, aphid populations were higher than in 1999 and developed earlier in the season. Averaging all seven fields, levels peaked in mid-August (Fig. 1). Populations were similar in the 50, 100, and 150 lbs nitrogen/A treatment and averaged about 32 aphids/leaf. In the 200 lbs N/ A treatment, populations averaged roughly 75/leaf. The percentage aphid-infested leaves responded weakly to nitrogen rate. These results differ slightly from the 1999 results in that the 150 lbs nitrogen/A treatment also inhibited aphid build-up in 1999. Populations in individual fields responded clearly to nitrogen level. A field located in Merced Co. showed a clear delineation of the aphid populations by nitrogen treatment. Populations peaked at 217 aphids/leaf in the 200-lb./A treatment compared with 50 aphids/leaf in the 50 lb./A treatment.

The detailed studies showed that aphids reared on plants fertilized with the highest nitrogen levels produced significant offspring (Fig. 2) and had shorter generation times than aphids from lower nitrogen plots. Generation times averaged from 7.9 days (0 lbs/A nitrogen [=20 lbs/A nitrogen residual]) to 7.1 days (250 lbs/A nitrogen), and the number of offspring per female ranged from 18.5 to 44.1 in the low and high nitrogen regimes, respectively for the first generation exposed to these conditions. This pattern of shorter generation time and higher fecundity on aphids that feed on highly fertilized plants is similar to that found in our previous study (1999). However, overall, the generation time was shorter,

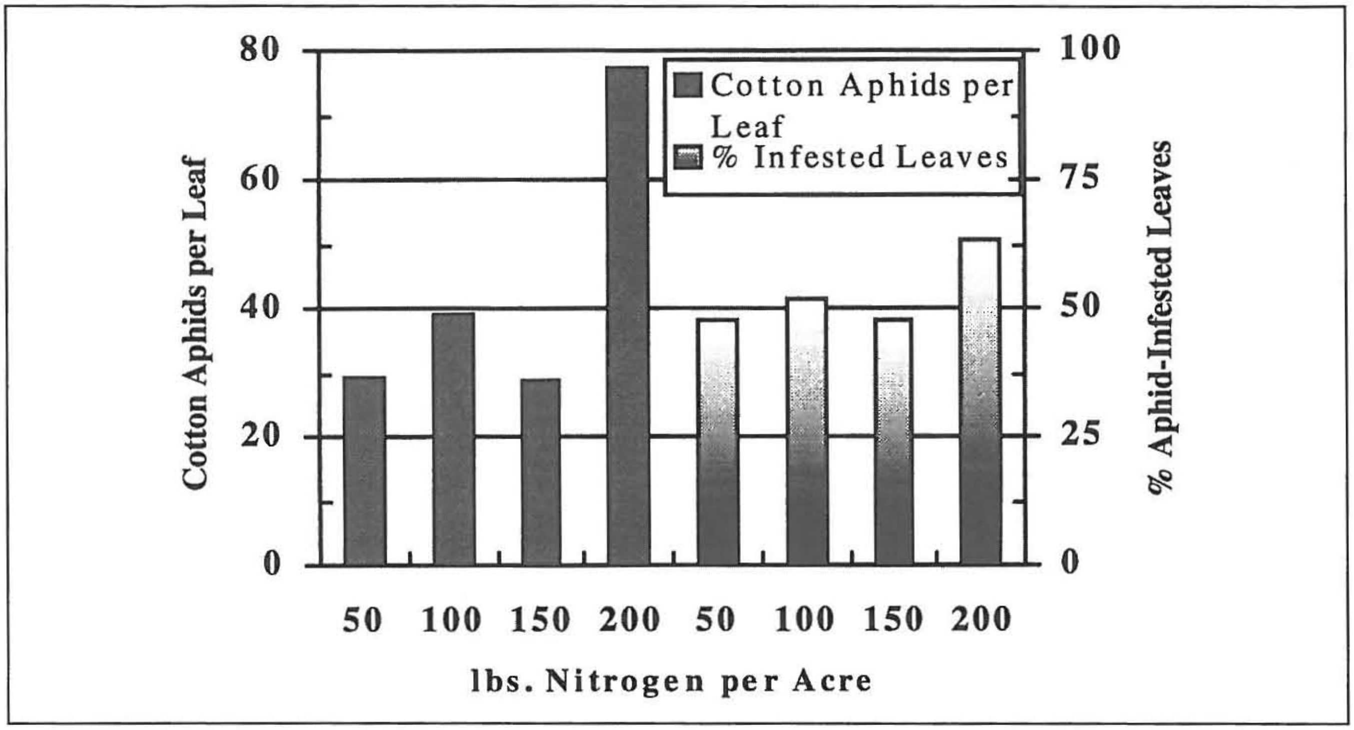

Figure 1. Effects of nitrogen rate on cotton aphid populations in studies conducted in grower fields. Data are the average of seven locations in the six county San Joaquin Valley cotton production area in 2000.

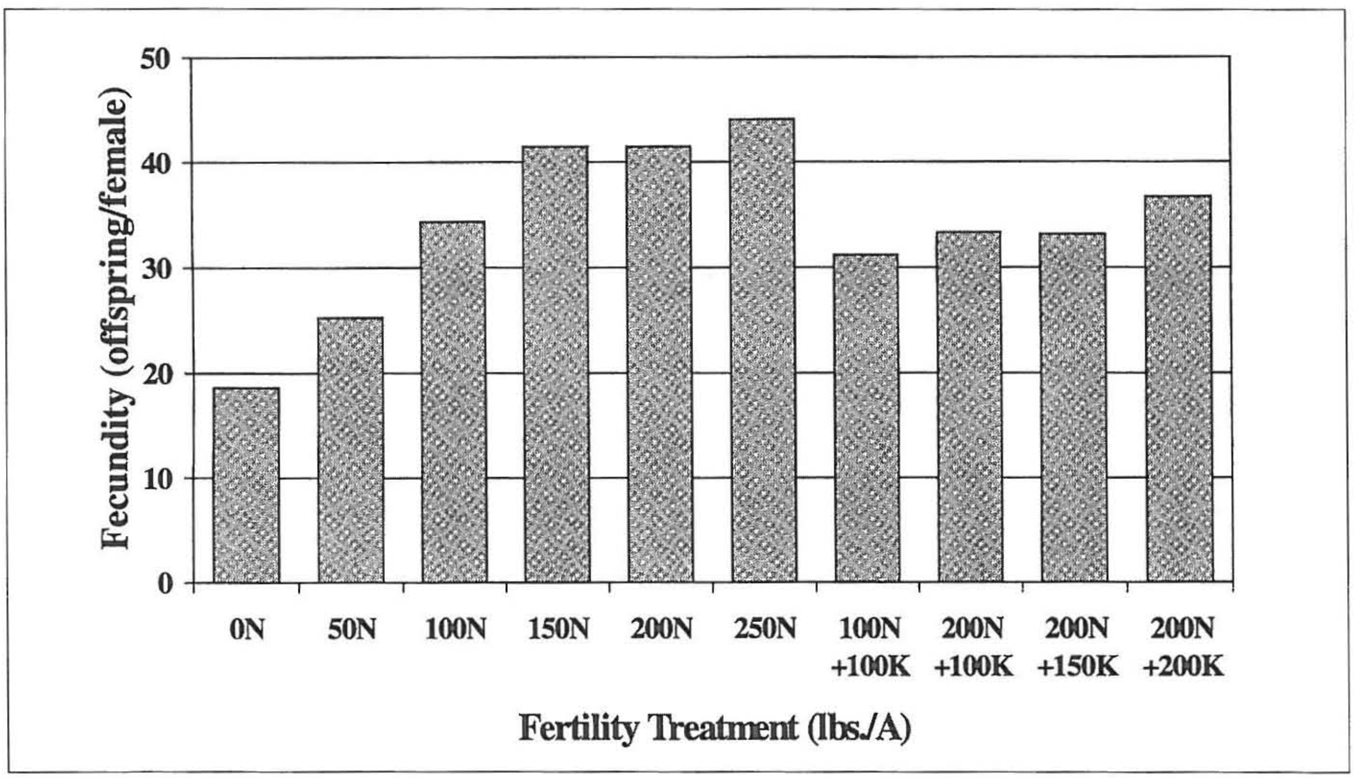

Figure 2. Effects of cotton fertility treatments on cotton aphid reproduction (fecundity), 2000.

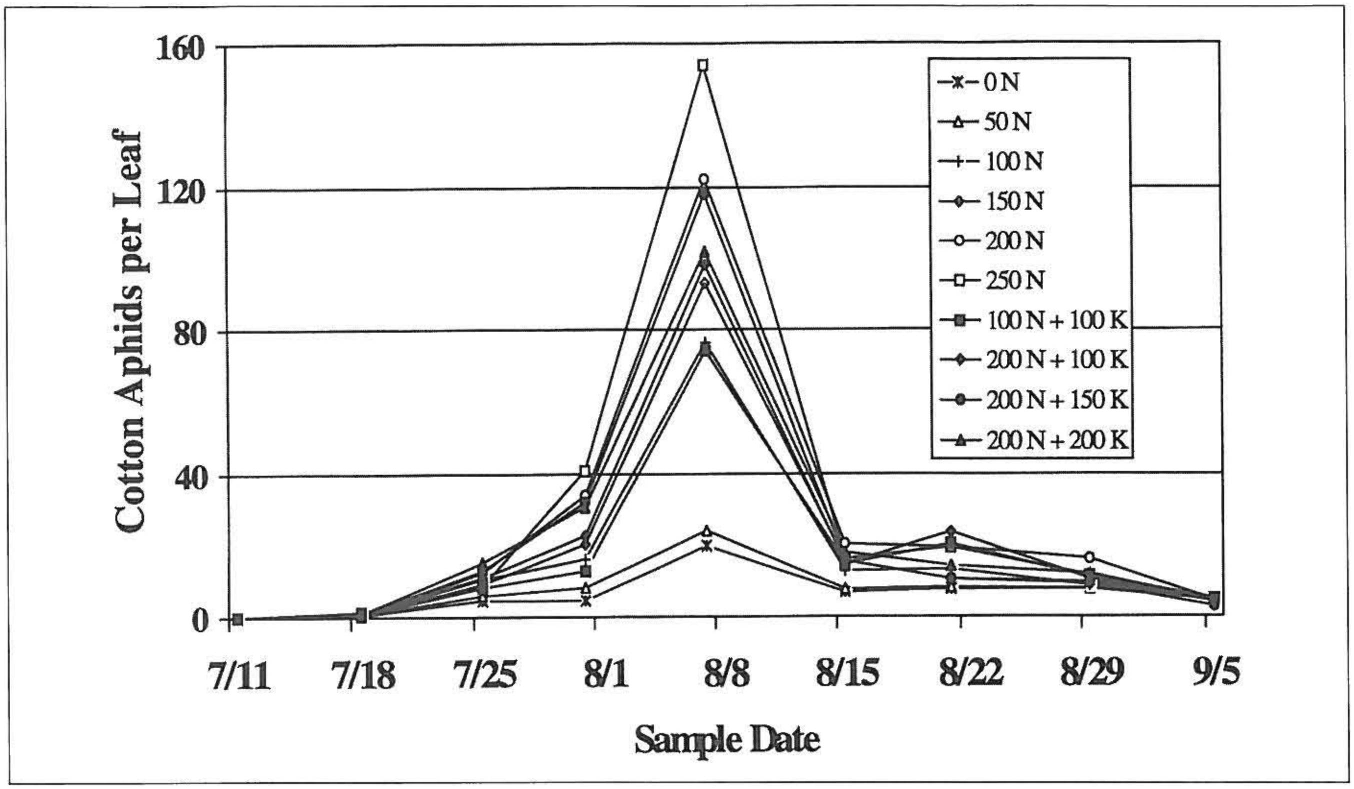

Figure 3. Effects of cotton fertility treatments on naturally-occurring cotton aphid populations, UC Cotton REC, 2000.

and the fecundity was much higher (at least 8 times more) in the 2000 study than the 1999 study. It seems that other factors (i.e., temperature) can interact with the nitrogen fertilizer affecting the fitness of this insect. Potassium seemed to have a negative impact on the aphid fitness lowering the fecundity, and increasing the generation time of the insect. This detrimental effect was not, nevertheless, as strong as the one observed in 1999. Results from the second and third generations of aphids were functionally the same as the first generation. Results from the population dynamics study (i.e., naturally-occurring aphid levels) supported our findings in the small cage experiment. Aphid populations in the highly nitrogen fertilized plots were more numerous than aphid densities in the low nitrogen plots, probably as a result of the positive effect of the fertilizer at the individual level (Fig. 3). Populations peaked at roughly 155 aphids per leaf in the 250 lbs treatment compared with roughly 20 aphids per leaf in the 0 and 50 lbs treatments. Thus, with the moderate-high aphid pressure experienced in 2000, the nitrogen rate of 100 lbs/A was an effective cultural method to keep the aphid infestations below the mid-season economic threshold of 75 aphids/leaf. Naturally occurring aphid populations were intermediate in the elevated potassium treatments, ranging from roughly 75 to 120 aphids per leaf. This positive effect of reduced nitrogen inputs must be balanced against the limitations of lint yield that may be imposed by this nitrogen input. This aspect, i.e., yield, was being investigated by Hutmacher, and others.

Potassium Responses in California Rice Fields as Affected by Straw Management Practices

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OBJECTIVES

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

INTRODUCTION

California legislation (AB 1378) leads to a phase down of rice straw burning over a ten-year period, which will change the way farmers manage rice straw. Although various options are available, it is likely that the incorporation of rice straw; (on-site disposal), will remain a major option for rice straw disposal. The average concentration of K in rice straw is around 1.4 %, but can range from as low as 0.6 % to as high as 1.8 %. The amount of straw removed by baling for off-site use is approximately 12 tons/ha, and hence, the amount of K removed in the straw after harvest in Californian rice fields can exceed 90 kg/ha. When straw is removed continuously, the available K levels in the soil are significantly affected. Preliminary data from the long-term straw rotation studies at the UC Rice Experiment Station 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 for 3 years. The current fertility guideline for rice is that about 87 ppm of extractable K should be present at time of seeding; otherwise K fertilization is recommended.

In the 2000 CDFA-FREP Proceedings, we reported on differences in grain and straw yield as affected by N and K fertilizer application in combination with straw removal and incorporation after one year of straw management. This year, we report on the relationship between pre-plant available soil K and yield after one and two years of straw removal and straw incorporation. The impact of straw management, and K fertilization will also be discussed.

DESCRIPTION

The second field season of this three-year field study was conducted at a field at the Mathew Farm, Marysville, CA which has historically shown a K deficiency. From half of the selected area (about 7 acres), the rice straw was removed whereas for the other half of the field, the rice straw was incorporated in the fall of 1998.

Soil samples were collected in the spring from the site where straw was removed or incorporated. Each year before fertilization, 15 random soil samples (150 g total weight) were collected from the area straw, and removed or incorporated. Soils were air-dried and extracted for exchangeable K using the traditional 1 M NH4OAC method.

For each growing season, three weeks before harvest, 40 representative whole stems from each experimental treatment were rated for aggregate sheath spot AgSS. Each plant was rated according to the following scale: 0=no presence of AgSS; <1 AgSS lesions below the third healthy leaf (counting from the top of the plant); 1= 3 healthy leaves; 2= 2 healthy leaves on stem, lesions below second leaf; 3= 1 healthy leaf on stem, lesions below first leaf (flag leaf); 4= all leaves dead. Decimals (0.1 to 0.9 added on to each integer rating) were equal to the portion of stem circumference affected by uppermost lesions located on stem between leaves. For example,

Table 1. Interrelationships between pre-fertilization available soil K content, available soil K content, midseason plant K content, and grain yield under different straw management practices.

Year	*Straw Management Practice*	*Pre-fertilization available soil K content (µg K g⁻¹ soil)*	*R² Value for: Midseason plant K content (%) content and grain yield*	*R² Value for: Available soil K (µg K g⁻¹ soil) and grain yield*
1	Incorporated	97.8	0.39	0.44
1	Removed	67.2	0.74	0.59
2	Incorporated	55.1	0.87	0.94
2	Removed	41.4	0.99	0.95

one healthy leaf with the uppermost AgSS lesion encircling half of the stem's circumference below this first leaf (flag leaf) would receive a rating of 2.5. All ratings were performed in the field immediately after sampling.

RESULTS AND DISCUSSION

Available soil K and grain yield

Available soil K content was determined by adding the amount of K applied (in µg K g^{-1} soil) for each level of K application to the pre-fertilization available soil K content. Throughout the duration of the study, as pre-fertilization available soil K content decreased, the R^2 value between midseason plant K content and grain yield increased (Table 1; Fig. 1). The study's highest pre-fertilization available soil K content value (97.8 µg K g^{-1} soil) in the first year's incorporated experiment had the study's lowest R^2 value (0.39) between the midseason plant K content and grain yield data of the same experiment (Table 1). The study's lowest pre-fertilization available soil K content (41.4 µg K g^{-1} soil) in the second year's removed experiment had the study's highest R^2 value (0.99) between the midseason plant K content and grain yield data of the same experiment.

Exchangeable K data collected using the 1 M NH_4OAc method.proved to be an excellent predictor of midseason plant K content and grain yield when K deficiencies became prevalent in the second year. However, measuring the pre-fertilization available soil K concentration using the 1 M NH_4OAc method could not predict responses to K fertilizer application in the first year following straw removal. Grain yield and straw yield significantly responded to K fertilizer addition when there was a pre-fertilization available soil K concentration of 67 µg g^{-1} in the first year. Neither grain yield, nor the straw yield responded to K application in the second year when straw was incorporated, and there was a pre-fertilization available soil K concentration of 55 µg g^{-1}

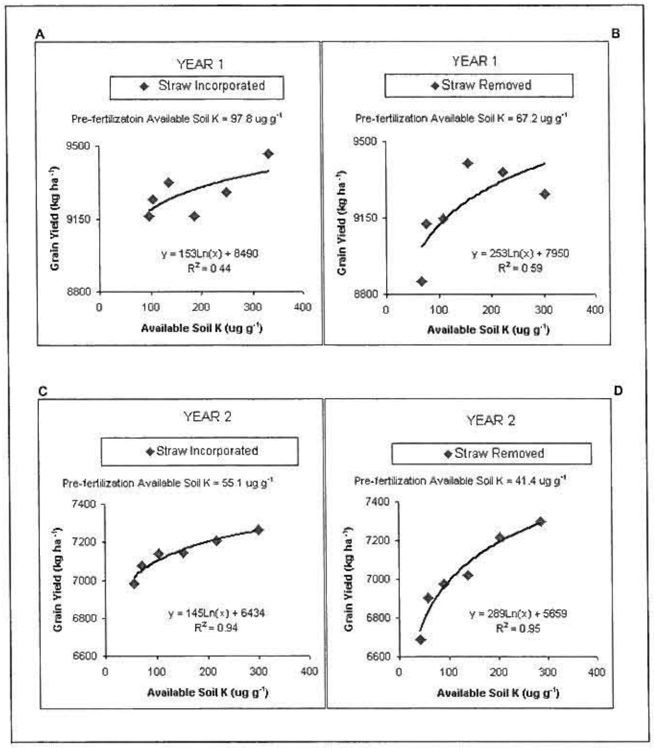

Figure. 1. The interrelationship between straw management, available soil K, and grain yield

(Table 1). This indicates that the incorporation of straw provided nutrients and/or improved soil physical properties that were beneficial to the overall grain yield but were undetectable by the NH_4OAc test. It cannot be concluded from this study that the NH_4OAc test cannot be used effectively on soils where straw is incorporated. The NH_4OAc test accurately predicted crop responses to various levels of K addition when pre-fertilization available soil K concentrations were below 60 µg K g^{-1} soil. This corroborates the critical level of 60 µg K g-1 soil for rice as determined in previous studies.

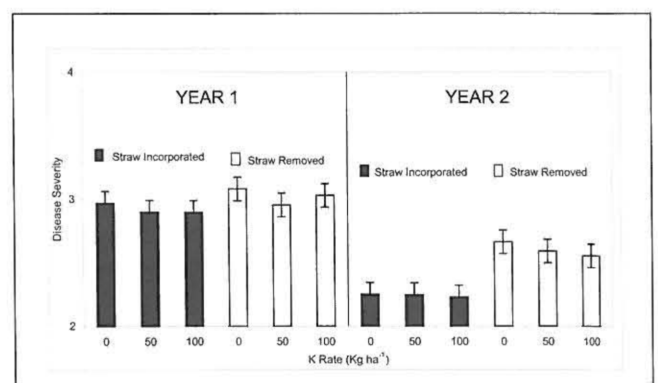

Figure 2. The annual effect of straw management and K application on the severity of Aggregate Sheath Spot. Error bars indicate the +/- standard error of the sample means for each treatment.

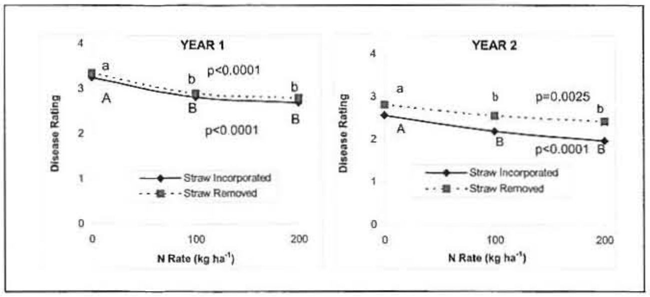

Figure 3. The annual effect of straw management and N application on the severity of aggregate sheath spot. Upper and lower case letters represent statistical t grouping of the data where straw was incorporated and removed, respectively.

The high correlation between pre-fertilization available soil K concentration (plus added fertilizer K) in predicting grain yield as soil K levels decreased (Fig. 1) indicates that no measurable amount of K fixation occurred in this study. Moreover, the high correlation between the grain yield and available soil K concentration (Table 1; Fig. 2) indicates that it is unlikely significant K losses occurred through leaching. Therefore, the K deficiency observed here was likely derived from a low K supplying capacity of the soil minerals. The NH_4OAc test appropriately predicted plant available K despite the drastic change in soil conditions upon flooding and the wet-dry cycle, both of which have shown to drastically affect the plant available soil K concentrations. The 1 M NH_4OAc measurement of pre-fertilization available soil K concentration can be successfully utilized to determine K fertilization recommendations in rice soils that have similar characteristics as the San Joaquin loam, and have pre-fertilization available soil K concentration levels below 60 µg K g^{-1} soil.

Aggregate Sheath Spot and Potassium

The non-significant effect of K fertilization on AgSS severity indicates that either sufficient available K when straw was incorporated and removed or that the severity of AgSS was not affected by the concentration of K in rice plants (Fig. 2). The midseason plant K content (at panicle initiation) was below the recommended 1.2% (i) under low levels of K application in the first year when straw was removed, (ii) under low levels of K application in the second year when straw was incorporated, and (iii) under all levels of K application except 125 kg ha^{-1} in the second year when straw was removed. These midseason plant K deficiencies correlated with yield responses to K application when straw was removed. Because K was not at sufficiently high concentrations for maximum yields in both years when straw was removed, it is likely that K would have been at insufficient levels for adequate AgSS resistance as well. Because AgSS severity was not significantly affected by any midseason plant K concentration, it is likely that an adequate plant K concentration existed for optimal AgSS resistance.

Aggregate Sheath Spot and Nitrogen

The application of N significantly decreased the severity of AgSS during both years of both experiments (Fig. 3). Moreover, the severity of AgSS continued to decrease up to the maximum amounts of N application. This indicates that N application continues to decrease the severity of AgSS even after yields have reached maximum yield. A decrease in the incidence of AgSS with increasing organic N applications as vetch was observed in an unpublished 1994 University of California Cooperative Extension study. Also, a recent study on a California rice soil has shown a significant decrease in the incidence of AgSS with 210 kg N ha^{-1} compared to 164 kg N ha^{-1}. It appears from these experiments that an increase in plant N concentration from N fertilizer application increases the resistance of rice to AgSS infection.

Aggregate Sheath Spot and Straw Management

Compared to two years of straw removal, two years of repeated straw incorporation reduced the severity of AgSS (Fig. 2). It should be noted here that the overall severity of AgSS decreased in the second year compared to the first year regardless of straw management practice. This is likely due to overall lower yields observed in the second year indicating less AgSS development.

The increased AgSS severity observed when straw was removed is possibly explained by a combination of two factors. First, the nutrient imbalance caused by the K deficiency when straw was removed may provide favorable conditions for the AgSS fungus to flourish in rice. Nutrient imbalance is a determining factor in the infection severity of a large number of diseases. However, no decrease in AgSS severity was observed upon K addition (Fig. 2). Therefore, it appears that the remaining stubble resulting from straw removal enables the efficient infection of the subsequent rice crop by *Rhizoctonia oryzae-sativae.* In contrast, the fall incorporation of rice straw reduces the AgSS severity of the subsequent crop compared to straw removal. These results may conflict with current management guidelines that ask for removal of AgSS-infected rice straw.

These seemingly conflicting data can be explained by the typical field operations associated with straw management practices in California where the major initial *Rhizoctonia oryzae-sativae* infection is located on the rice plant below the water line. The practice of straw removal entails mowing the rice plant at the water line in the fall. The remaining stubble is then disked underground during spring field operations. On the other hand, straw incorporation calls for fall incorporation before winter flooding, leaving the rice straw in full contact with the soil and the *Rhizoctonia oryzae-sativae* in competition with the indigenous microbial populations for survival. Therefore, straw removal may well favor the survival and subsequent crop infection of *Rhizoctonia oryzae-sativae* when compared to straw incorporation.

NITROGEN BUDGET IN CALIFORNIA COTTON CROPPING SYSTEMS

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INTRODUCTION

Microplots, labeled with 15N, have been established at two locations, one in Kings County and one in Fresno County, and have been used to trace the movement of N in cotton cropping systems. This report summarizes data on the growth and development of cotton as a function of N treatments monitored over a three-year period with Acala at both sites and with Pima for two years at the Fresno county site. Somewhat unique in these experiments is the maintenance of a cotton crop for up to three years, a practice not commonly used in California cotton production systems. A longer rotation period of a single crop as used in these studies is expected to provide a much more detailed analysis of the movement of N in that cropping system. The data reported in this summary provides a basis for determining the distribution of N in cotton, and its relation to yield. The intent of the overall project is to develop a nitrogen budget for cotton produced in the San Joaquin Valley, using the data presented in this report, and to integrate this information with data from a Valley-wide, five-year study of cotton response to N fertilizer. This report focuses on the plant and its response to applied N as preliminary to the ^{15}N study.

RESULTS

Growth and Development.

One aspect of the growth and development of cotton can be expressed as the development of leaf area index (LAI) over time in response to nitrogen. The two sites were compared as were the responses of Acala and Pima cotton (Figures 1 and 2). At both sites, there was little or no effect of 56 kg N per ha when compared with the control. However, LAI did increase at N levels of 168 kg N per ha. The time of the season when cotton achieved maximal LAI also varied. Maximal LAI occurred 20 days earlier in 1999 as compared to 1998 at the Kings County site (Figure 1). A similar LAI response was observed at the Fresno County site except in 1999 (Figure 2). In that year, an optimal response of LAI extended over a longer period. Pima cotton showed a positive response at all levels of applied N. Two possible differences between Pima and Acala are that Pima appears to develop maximal LAI ear-

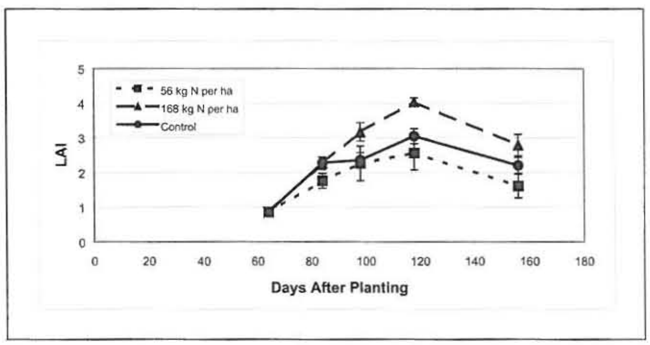

Figure 1a. Development of leaf area index (LAI) of Acala cotton over the 1998 season in response to N at the Kings County site.

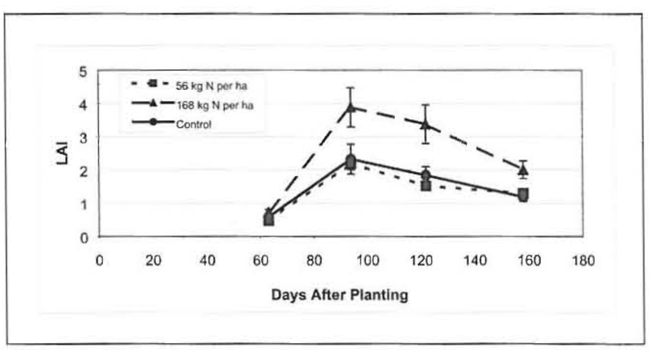

Figure 1b. Development of leaf area index (LAI) of Acala cotton over the 1999 season in response to N at the Kings County site.

Table 1. Pearson correlation coefficients for the relationships between various growth characteristics of Acala and Pima cotton grown at Fresno Co.

Variable		Acala Fresno Co.†						Pima Fresno Co.					
		TDM_g‡		FDM_g		Yield§		TDM_g		FDM_g		Yield	
		r											
LDM_g	S_1¶	0.70	***	0.64	***	0.43	**	0.39	NS	0.44	*	0.27	NS
LDM_g	S_2	0.91	***	0.88	***	0.81	***	0.89	***	0.84	***	0.77	***
LDM_g	S_3	0.87	***	0.82	***	0.75	***	0.87	***	0.85	***	0.82	***
LDM_g	S_4	0.97	***	0.92	***	0.61	***	0.89	***	0.84	***	0.78	***
LAI	S_1	0.55	**	0.55	**	0.32	NS	0.16	NS	0.21	NS	0.15	NS
LAI	S_2	0.75	***	0.74	***	0.87	***	0.87	**	0.74	*	0.71	*
LAI	S_3	0.85	***	0.79	***	0.62	**	0.88	**	0.80	*	0.75	*
LAI	S_4	0.93	***	0.88	***	0.41	*	0.75	*	0.54	NS	0.52	NS
LAD		0.88	***	0.84	***	0.81	***	0.89	**	0.77	*	0.73	*
TDM_g		1.00		0.99	***	0.72	***	1.00		0.92	***	0.86	***
FDM_g		0.99	***	1.00		0.74	***	0.92	***	1.00		0.92	***

*, **, *** Significant at the 0.05, 0.01,and 0.001 probability levels, respectively; NS is not significant.

† Correlations based on leaf area information for Acala reflect 1998 and 1999 data while those based on dry matter data include all three years of the study. Similarly for Pima, correlations of LAI and LAD only include 1999 data while those of LDM_g and TDM_g include 1999 and 2000 data.

‡ TDM_g = total dry matter at last sampling, FDM_g = fruit dry matter at last sampling, LDMg = leaf dry matter at respective sampling, LAI = leaf area index at respective sampling, LAD = leaf area duration.

§ Yield data from microplot plant samples, not yield from machine harvest.

¶ Sampling times S_1, S_2, S_3, and S_4 refer to samples at early square, early bloom, near peak bloom, and near defoliation.

lier in the season, and Pima is more vegetative and as a result shows more dependence on the level of N applied over the growing season.

Lint Yield

Figures 3 and 4 illustrate the lint yield in response to N treatments over years. The Kings county site showed no yield response over the first two levels of applied N (56 and 112 kg per ha), and then an increase in yield which leveled off at the higher rates of applied N. Comparison of yields over the three years in Kings County showed that in 1998, yields were lower than the following two years. Yields of lint increased at all levels of applied N at the Fresno County site

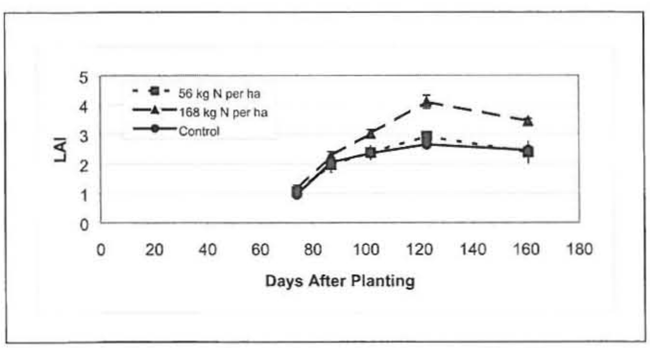

Figure 2a. Development of leaf area index (LAI) of Acala cotton over the 1998 season in response to N at the Fresno County site.

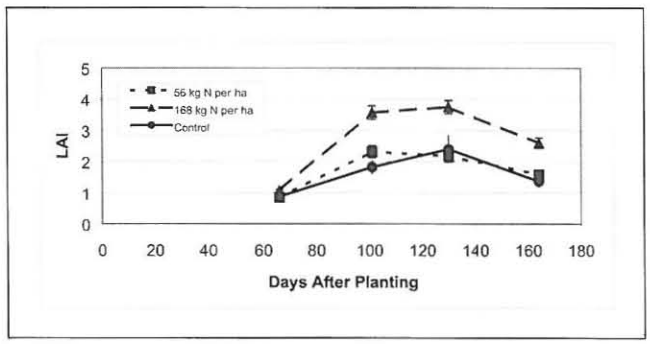

Figure 2b. Development of leaf area index (LAI) of Acala cotton over the 1999 season in response to N at the Fresno County site.

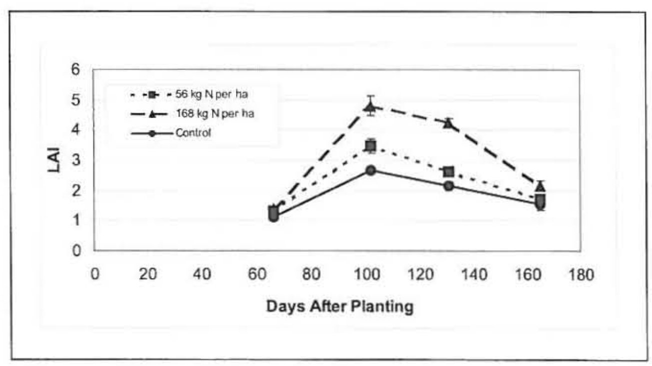

Figure 2c. Development of leaf area index (LAI) of Pima cotton over the 1999 season in response to N at the Fresno county site.

Table 2. Pearson correlation coefficients for the relationships between various growth characteristics of Acala cotton grown at Kings Co.

Variable		1998 *TDMg*†		1998 *FDMg*		1998 *Yield*‡		1999 *TDM*$_g$		1999 *FDM*$_g$		1999 *Yield*	
		r											
LDM$_g$	S[1]§	0.22	NS	0.36	NS	-0.07	NS	0.74	**	0.68	*	0.78	**
LDM$_g$	S[2]	0.65	*	0.60	*	0.75	**	0.69	*	0.59	*	0.77	**
LDM$_g$	S[3]	0.72	**	0.64	*	0.53	NS	0.82	**	0.74	**	0.61	*
LDM$_g$	S[4]	0.90	***	0.69	*	0.67	*	0.84	***	0.74	**	0.51	NS
LAI	S[1]	0.19	NS	0.34	NS	-0.20	NS	0.73	**	0.66	*	0.72	**
LAI	S[2]	0.50	NS	0.49	NS	0.63	*	0.62	*	0.50	NS	0.80	**
LAI	S[3]	0.81	**	0.73	**	0.52	NS	0.77	**	0.71	**	0.52	NS
LAI	S[4]	0.89	***	0.70	*	0.63	*	0.92	***	0.80	**	0.52	NS
LAD		0.88	***	0.78	**	0.63	*	0.81	**	0.70	*	0.71	**
TDM$_g$		1.00		0.93	***	0.53	NS	1.00		0.97	***	0.62	*
FDM$_g$		0.93	***	1.00		0.37	NS	0.97	***	1.00		0.57	NS

*, **, ***Significant at the 0.05, 0.01,and 0.001 probability levels, respectively; NS is not significant.
†TDM$_g$ = total dry matter at last sampling, FDM$_g$ = fruit dry matter at last sampling, LDM$_g$ = leaf dry matter at respective sampling, LAI = leaf area index at respective sampling, LAD = leaf area duration.
‡Yield data from microplot plant samples, not yield from machine harvest.
§Sampling times S_1, S_2, S_3, and S_4 refer to samples at early square, early bloom, near peak bloom, and near defoliation.

over all years. Pima was grown for two years at the Fresno County site as comparison with Acala. As shown in Table 5, yields of Pima responded to 56 and 112 kg ha^{-1} N, however, at 168 kg ha^{-1} and higher, there was no further response to applied N.

Table 1 provides correlation on the relationship between various growth characteristics, including yield of Pima and Acala cotton at the Fresno County site. Leaf dry matter (LDM) development in Acala showed a strong, positive correlation with all the growth characteristics measured at all stages of development. Pima also showed positive correlation with these characteristics except at early square formation. LAI development in Acala was also strongly correlated with ontogeny. LAI of Pima was not strongly correlated, particularly during initial development of the canopy.

The relationship between growth characteristics of Acala in Kings County is shown for two years, 1998 and 1999 in Table 2. Cotton grown in 1998 showed a less positive interaction of growth characteristics. This may be related to the lower yields observed during that season.

DISCUSSION

The results presented are part of a comprehensive data set that will be used to develop fertilizer guidelines for California cotton. The growth and development of cotton in response

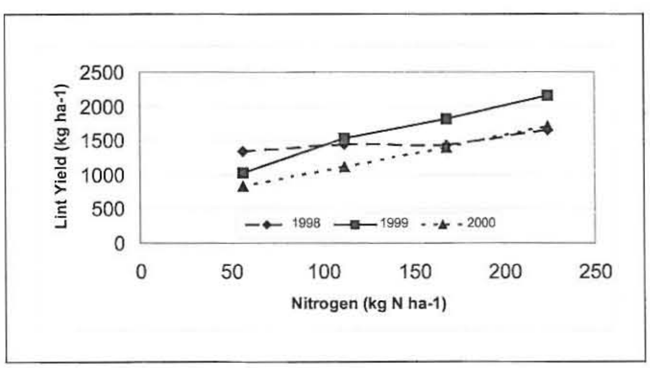

Figure 3a. Lint yields of Acala cotton over three seasons at the Fresno County site.

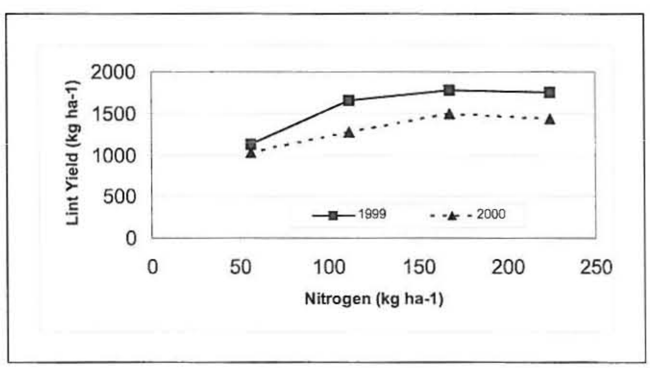

Figure 3b. Lint yields of Pima cotton over two seasons at the Fresno County site.

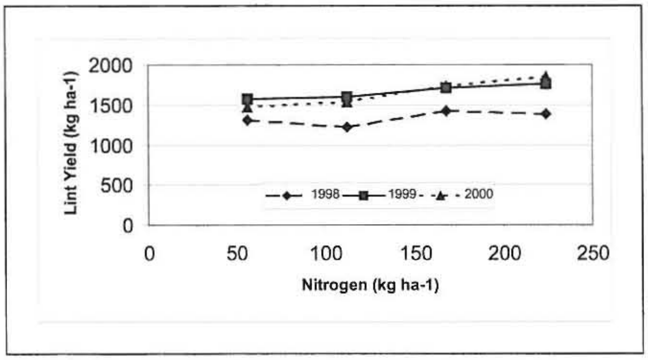

Figure 4. Lint yields of Acala cotton over three seasons at the Kings County site.

to N fertilization rates is being defined. Uptake, distribution, and redistribution of N in response to applied N is being documented. These data will be compared across locations and years. Within the larger field sites, we have located ^{15}N sites. The information collected from the experiments described in this report will provide the basis for interpretation of the ^{15}N experiments. Crop maturity and quality will be evaluated. All of these parameters will be correlated with fiber yield.

The data collected will be available for development of a model, which will be used in interpretation of the long term, multi-site research project currently being conducted in the cotton production systems in the San Joaquin Valley.

Results from the two sites have provided the following information:

- Vegetative development of Acala cotton is more closely linked to yield than is Pima cotton.
- Environmental factors affecting yield reduces the linkage with vegetative development more in Pima cotton than in Acala.
- Vegetative development of Pima cotton is more responsive to N than is Acala.

The information presented above provides a better understanding of the responses of current cotton varieties to N. These data will be added to the body of information accumulated over the last five years, will provide the basis for improving the N-use efficiency of cotton, and will assist in establishing guidelines for N fertilization of this crop.

Field Evaluations and Refinement of New Nitrogen Management Guidelines for Upland Cotton: Plant Mapping, Soil and Plant Tissue Tests

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INTRODUCTION

Incentives to consider adjusting nitrogen management practices for cotton arise based upon several concerns. High N levels can delay harvest, have negative impacts on ease and costs of defoliation, and can increase problems with late-season pests with impacts on lint quality. Higher than desired N levels during bloom/early boll fill can also promote vegetative development at the expense of fruit retention. A significant additional concern in recent years has been the potential fate of nitrogen applied in excess of crop requirements. Many cotton fields in California are grown in a rotation sequence that includes crops such as alfalfa, processing tomatoes, corn or silage crops, and vegetables. These are all crops which can contribute N (alfalfa), or have typical N applications that exceed applied N in cotton or in the more traditional small grains rotation systems.

The drive for greater efficiency in fertilization practices in cotton will require improved evaluations of: (a) soil fertility level on a field-by-field basis; (b) a means to evaluate and deal with field-by-field variation in crop growth and nutrient status conditions [nutrient status (i.e. petiole nitrate), some measure of vigor and fruit retention that is adjusted for stage of growth]; and (c) an understanding of the required timing for split fertilizer applications in meeting critical plant needs. In this type of system, adjustments in nutrient applications are made depending on levels of residual soil N, irrigation water N, and crop condition. Silvertooth (1991) and Unruh and Silvertooth (1996) have referred to this type of nutrient management as a "feedback" approach to fertilizer N management. This is in contrast to a "scheduled" approach where fertilizer N is applied more on a routine basis determined by stage of growth or month. The "feedback" approach should have improved potential to reduce losses, improve nutrient use efficiencies, and provide more specific guidelines for use in making N management decisions.

Growers typically express significant interest in evaluation of any viable approach to reduce production costs, but despite evidence of potential for improvement in any of these areas of efficiency, they frequently reject recommendations that involve reductions in applied N rates. Reasons for this general response are undoubtedly many, but include concern for unreasonable economic risks. Grower concerns can be that direct savings can be relatively small when compared with potential revenue losses associated with inadequate available N to sustain high yields. More grower awareness is needed for the facts that while direct savings resulting from more judicious N applications may be small, excess N applications can also result in other management problems (more difficult balance of vegetative/reproductive growth balance, some links to increased aphid and lygus pressure, delays in maturity, more difficult defoliation).

OBJECTIVES

A field-based research and demonstration project was initiated to provide further evaluation of the concepts developed in recent University of CA nitrogen management studies in cotton and to begin evaluation of the potential to integrate rapid laboratory tests for better estimates of mineralizable N. Goals are to improve grower appreciation of an integrated N management system still based upon soil and plant N status measurements, but incorporating: (1) estimates of crop growth and yield potential; (2) lower initial N applications to reduce potential for leaching losses; and (3) use of split soil N applications and/or foliar applications when plant sampling indicates good enough yield potential to warrant additional N supply.

DESCRIPTION

N Management Field Studies.

The 2001 growing season was the first year of this three-year field study. Studies were set up at four locations representing a range of initial soil residual nitrogen levels and soil types:

- Sandy loam soil site at the Shafter Research and Extension Center in Kern County, with cotton following a cotton crop
- Silty loam soil site in Kern County, cotton following forage alfalfa and cotton
- Clay loam soil site in Kings County, cotton following prior crop of processing tomatoes
- Clay loam soil site in Fresno County, cotton following processing tomatoes and wheat

The three basic N application treatments at each location in 2001 included the following:

1. A one-time (early vegetative growth) baseline application of fertilizer N (about 100-125 lbs applied N/acre depending upon application equipment and grower);
2. A one-time treatment receiving a full 180-200 lb N/acre application; and
3. A treatment receiving an initial 100-125 lbs N/acre application, with subsequent need for additional N applications (water-run or foliar) assessed based upon measured soil N, yield potential assessed by plant mapping, and in consideration of early and mid-bloom petiole NO_3-N

Field sites selected for the experiment differ in soil types and in estimated effective rooting depth, but were selected to represent the difficult management range of "low" to "intermediate" in soil residual N in the upper 2 feet versus 4 feet of profile, where the ability of soil nitrate tests to accurately predict plant-available N carries more risk to potential yields. Pre-season soil samples to a depth of four feet were collected for analysis of residual soil NO_3—N levels, PO_4-P, exchangeable-K, Zn and mineralizable N. Soil NO_3-N analyses on air dry soils were performed within a few days of sample collection at a commercial testing laboratory in the San Joaquin Valley. These samples were analyzed to develop estimates of available N used in determining applied N rates for the study. Duplicate samples were sent to the Division of Agriculture and Natural Resources State Testing Laboratory (KCl extract NO_3-N, PO_4-P, Exchangeable-K, Zn).

Samples were collected at all sites to a depth of four feet for initial NO_3-N and mineralizable N tests to allow for the comparison of residual N made in the upper 2 feet, upper 3 feet and upper 4 feet of the profile. The reason for this is that two foot sampling depths are commonplace among advisors and agronomists, while recommendations for pre-season or early-season soil sampling to 3 or 4 feet depths would require some convincing evidence that it significantly improves estimates. In addition, in both the spring (early post-plant) and again near harvest in the fall, soil samples will be collected to a depth of 8 feet in one-foot increments and analyzed for soil NO_3-N, Cl-, exchangeable K and PO_4-P. The soil NO_3-N and Cl- data will be used in combination with irrigation water NO_3-N and Cl- to estimate leaching loss potential at any sites where irrigation water Cl- levels are high enough to allow these calculations. Exchangeable K and PO_4-P data will be used to determine if levels of K and P are limiting at any research sites. Soil water contents will be determined on all soil samples collected both in spring and fall sampling dates in order to estimate depths of water extraction, and in combination with applied water amounts, will be used to estimate (by water balance approach), the potential for deep percolation losses. Irrigation water samples will be taken and analyzed for NO_3-N, and the timing and amounts of applied water estimated to allow calculation of irrigation water contributions to applied N.

Soil Mineralizable Nitrogen Evaluations.

One of the primary problems with soil N tests is the general uncertainty many agronomists, soil scientists and consultants express in assessing the accuracy, and adequacy of soil nitrate tests to explain the likely dynamics of plant-available N. Since NO_3-N is just part of the soil N pool, and ammonium-N tests are highly variable and of limited value in many of our western soils, there remains interest in other tests that might be better correlated with plant-available N. Gianello and Bremner (1982) developed a "hot KCl" method to assess potentially available organic N in the soil, and showed the superiority of this test to other chemical laboratory analyses, and the much-reduced time needed for the analysis. The procedure is very simple, involving air-dried soil samples that are heated with 2M KCl to 100C for a 4-hour period, followed by cooling and determination of ammonium-N.

Most biological laboratory methods for soil N assessments are based upon incubation tests of 14 day to over 30-week duration, depending upon the specific approach. Recently, Franzluebbers et al (1996) developed a protocol for potential N mineralization based upon a 24-hour incubation. Briefly, the procedure is as follows: air-dried, sieved soil samples are placed in airtight tubes, water is added to 50% water-filled pore space, and a 24-hour incubation is done at 25° C. After this period, the amount of CO_2 evolved is determined by titration. Initial evaluations of these two approaches were compared on soil samples collected from an earlier (2000 growing season) nitrogen research site, which represented a range of soil types and initial levels of soil residual NO_3-N. Initial evaluations were done on these samples since the mineralizable N estimates could then be compared with previously determined data on soil nitrate, ammonium and total N. Following these evaluations, efforts in late summer and fall of 2001 will be directed toward evaluation of 2001 growing season samples.

RESULTS AND CONCLUSIONS—FIRST YEAR

Field Nitrogen Management Studies

In the four field test sites, residual soil NO_3-N analyses done on soil samples collected within 3 to 6 weeks following planting yielded the following average quantities in the surface two, three and four foot depths of the soil profile.

Depth of soil sampled (inches)	*2001 Field Study Sites — Average Soil NO_3-N (lbs N/acre as NO_3-N on soil dry wt basis)* — *Site A (Kern)*		*Site B (Shafter)*		*Site C (Kings)*		*Site D (Fresno)*	
	Avg.[1]	S.E.	Avg.	S.E.	Avg.	S.E.	Avg.	S.E.
0-60	69	7	41	3	113	17	58	9
0-90	104	14	61	8	128	22	72	11
0-120	149	17	107	7	176	23	97	10

1Avg. = average; S.E. = standard error across samples

Based upon our prior five-year study, preliminary recommendations for nitrogen fertilization for this study (based upon spring soil nitrate data in the upper two feet of the soil profile) would be:

- if less than 55 lbs N as NO_3-N/acre, then fertilizer application recommended at 125-175 lbs N/acre unless low yields predicted due to late planting or field history
- if between 55 and 100 lbs N as NO_3-N/acre, then reduce fertilizer application recommendation to 100 to 125 lbs N/acre, consider use of plant mapping and petiole nitrate analyses to assess yield potential and plant N status
- if over 100 lbs N as NO_3-N/acre in the upper two feet of soil profile, lower fertilizer recommendation to 75 lbs N/acre or less, consider use of plant mapping and petiole nitrate analyses to assess yield potential and plant N status

As has been seen in prior studies with cotton in the San Joaquin Valley, there is considerable variation across sites and within fields in spring soil NO_3-N levels depending upon soil types, prior management, and crop rotation. The data shown above also indicates the dilemma facing anyone who tries to use soil test data just collected for the upper two feet of soil profile. For the four sites shown above, the percent of total soil NO3-N in the upper four feet of the profile accounted for if sampling was restricted to just the top two feet ranged from about 40 to slightly over 60 percent. As in prior analyses, if a crop (such as cotton) is expected to have roots active in water and nutrient uptake down below two feet, there is an advantage in collecting deeper soil samples in order to attempt to account for deeper, potentially available N. An additional advantage to early post-plant information on deeper (to three or four feet) soil NO_3-N would be that it provides some incentive to avoid application of large amounts of early-season irrigation that could leach soil nutrients. Based upon these results and earlier UC nitrogen studies in cotton, it often would significantly improve nutrient management information to collect soil samples to a depth of three or four feet, instead of only one or two feet.

It is important to note, however, that since soil nitrate losses can occur and since there are other potential sources of N represented in the soil N pool, identification of potential soil NO_3-N reserves will still not fully represent plant-available N for making fertilization decisions. This is where estimates of crop yield potential (from plant mapping) and plant nutrient status (from petiole nitrate analyses) can play an important role. Ranges of petiole NO_3-N from 2001 field sites for specific dates were as follows:

Date of petiole sampling (by growth stage)	2001 Field Study Sites Petiole NO_3-N (mg/kg x1000 as NO_3-N on dry wt basis) *data from treatment #3 only (low initial N/supplemental N treatment) Site A (Kern) mg/kg x 1000		Site B (Shafter) mg/kg x 1000		Site C (Kings) mg/kg x 1000		Site D (Fresno) Mg/kg x 1000	
	Low[1]	High	Low	High	Low	High	Low	High
Early bloom (first bloom +/- 5 days)	14.7	18.9	13.3	15.2	13.0	18.4	12.2	14.1
15-20 days after first bloom	7.7	12.9	9.1	11.5	7.3	11.6	7.7	10.5
28 to 35 days after first bloom	6.3	8.8	4.5	6.9	5.7	9.3	6.0	7.4

[1]Data shown shows the range of values for averages within reps of the treatment; low = low average; high = high rep average

Plant mapping data will be summarized at a later date, but was used to help interpret the petiole data for use in recommendations for supplemental nitrogen. Yield potential estimates at the different sites based upon within-season plant mapping data indicated relative yield potentials and timing of the crop as: (a) Kern — moderate yield potential/early and mid-season fruit set most important; (b) Shafter — low yield potential / early and mid-season fruit set most important; (c) Kings — moderate to high yield potential/well-balanced fruit set; and (d) Fresno — moderate to high yield potential/ well-balanced fruit set. The petiole data and yield potential estimates were used to assess the need for a supplemental fertilizer application, resulting in a fertilizer application on the Kern, Kings and West Side REC location in treatment #3.

Yield and fiber quality will be determined at all locations in fall, 2001. Soil sampling in all treatments to a depth of a minimum of 4 feet (8 feet if possible) will be conducted after harvest.

Mineralizable Nitrogen Analyses

In this current project, evaluation of these methods for mineralizable N determination were begun in a UC Davis laboratory in 2001, starting with analysis of soil samples collected in 2000 from multiple sites of the earlier cotton nitrogen rate study. The advantage to beginning with these soil samples is that a broad range of soil test data is already available on these samples from prior work done at the UC-DANR lab, allowing comparison with prior soil nitrate, ammonium, and total N analyses. Preliminary analysis of the results has shown good correlation between mineralizable N estimates using the hot KCl and incubation methods. However, it must be acknowledged that these analyses have to date, been primarily on low organic matter soils with silty clay loam, and clay loam textures. Other soil types are represented in some of the other soil samples as yet unanalyzed in this project. Some results and comparisons should be available to be summarized by late 2001 or early 2002. The next phase in the mineralizable N analyses will be evaluation of soil samples from 2001 project sites, and this will commence in fall, 2001.

Location of Potassium-Fixing Soils in the San Joaquin Valley and a New, Practical Soil K Test Procedure

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INTRODUCTION

In 1997, UC published a bulletin (#21562, UC Division of Agriculture and Natural Resources, Oakland) describing methods for diagnosis of K deficiency in soils and cotton plants and recommending K fertilization rates for cotton. Included was the recommendation to apply very high rates of K fertilizer – up to 400 lb K_2O/acre – where soils have a very high K-fixation capacity. The economic consequences to cotton growers of applying such high K rates where they are not needed or of failing to meet the soil fixation capacity where K is needed are severe. High soil K fixation capacity in San Joaquin Valley soils with micaceous/vermiculitic mineralogy was reported by A.L. Page and other soil scientists at UC Riverside in 1963. We expect that soils derived from Sierra Nevadan parent material, particularly those that have significant amounts of their sand and silt fractions derived from biotite mica, will have a high potential for fixing K compared to soils on the west side of the San Joaquin Valley derived from non-granitic Coast Range parent material. Our rationale is that biotite weathers fairly quickly to vermiculite in the coarser fractions. Vermiculite has the potential to trap K in mineral interlayers following K-fertilization and drying of the soil. We expect that soils formed from geologic materials from the Coast Ranges, and other fine-textured soils formed from rocks containing biotite, will not contain much vermiculite and will be less likely to fix K.

OBJECTIVES

We will produce a map of the San Joaquin Valley in digital and paper format that identifies those lands used for cotton production that have soil with potentially high-K fixation capacity.

We also will test on soils collected from the San Joaquin Valley a recently published laboratory method for estimating plant-available K over a wide range of K fixation capacity – the modified sodium tetraphenyl boron method. The 1997 UC bulletin does not recommend a method for estimating K fixation capacity, and the methods currently available through commercial agricultural laboratories are labor-intensive and involve lengthy incubations. These tests are relatively expensive and are only used after the standard exchangeable K test shows a low level of available K.

Results of this project and a recommendation for soil testing will be made available to agricultural laboratories, crop advisers, fertilizer suppliers, and cotton growers in the San Joaquin Valley.

Funding for this project is being provided by the CDFA FREP and the California State Support Committee of Cotton, Inc.

DESCRIPTION

We obtained three databases for use on the mapping part of this project:

- Pink Bollworm California Cotton maps from 1999 and 2000 and California Cotton Acreage files for 1998-2000.

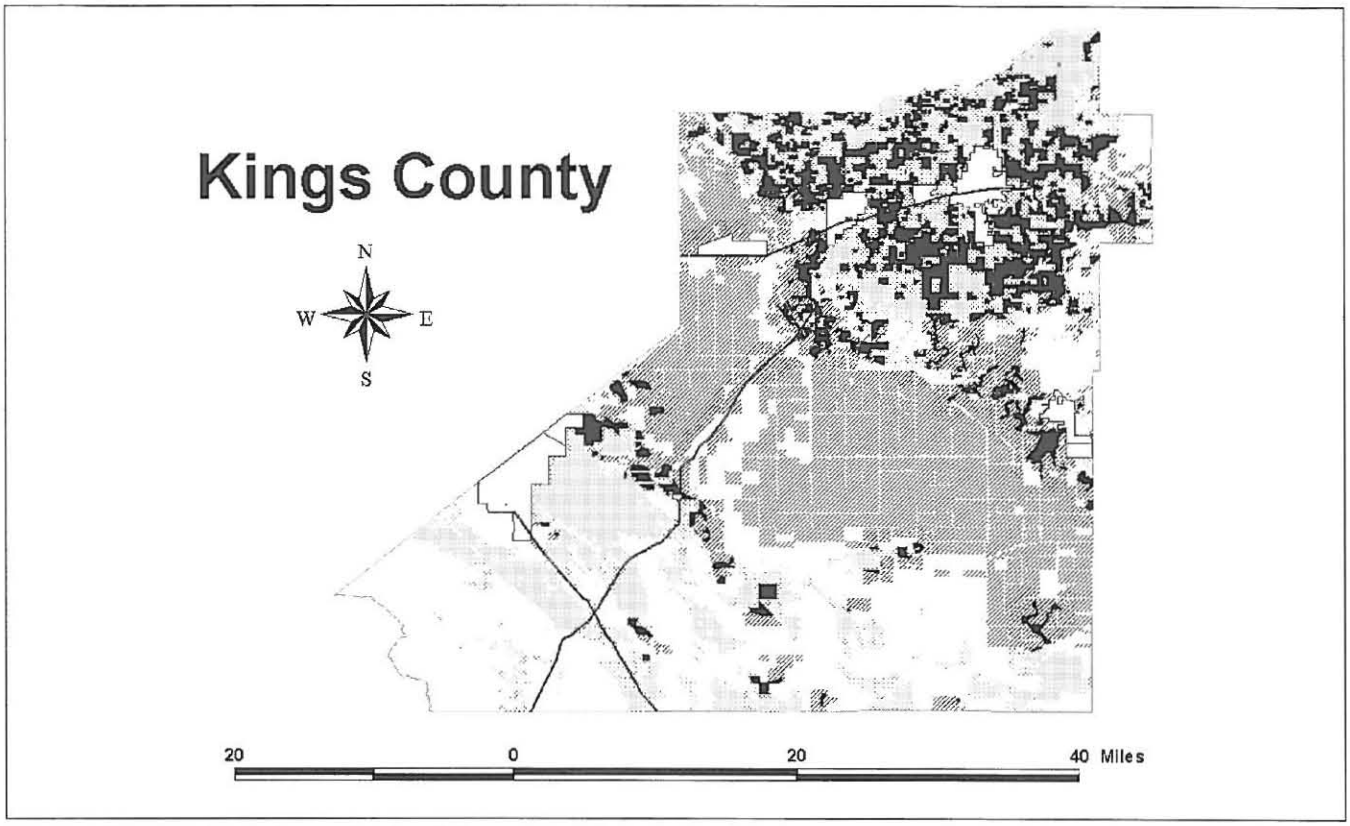

Figure 1. Simplified map showing land used for cotton production and soil classification at the family level. ***Black****—coarse-textured soils on cotton land;* ***Medium gray****—finer-textured soils on cotton land;* ***Light gray****—coarse-textured soils on non-cotton land. Soils data from USDA SSURGO database. Cotton data from California Dept. of Food & Agriculture pink bollworm database combined over years 1998-2000.*

These files include all cotton acreage in Fresno, Kern, Kings, Madera, Merced, and Tulare counties. The resolution of these maps is about five acres. These were provided to us by Jim Rudig, supervisor of the California Department of Food & Agriculture's Integrated Pest Control Branch, in both MapInfo® and ArcView® GIS formats.

- SSURGO, a USDA-NRCS soils digital database, which contains soils information at the scale of the typical county soil survey. SSURGO coverage is not available for Fresno County, Western Part and for portions of Kern Co. Kerry Arroues, USDA-NRCS, allowed us to use field sheets from the Fresno Co., Western Part, soil survey, which is currently in preparation.
- STATSGO, a USDA-NRCS soils database that has larger mapping units suitable for multi-county or state maps.

Soils are currently being collected from 20 sites, representing three categories:

1. Coarse loamy or fine loamy with coarse surface texture soils derived from granitic, Sierra Nevadan parent material;
2. Coarse loamy family or fine loamy with coarse surface texture derived from coastal, non-granitic parent material;
3. Finer-textured soils;

To be selected for this study, soils must have low exchangeable K and not have recently been manured or fertilized. Samples are being collected from the 6-18 inch depth as recommended by UC Bulletin 21562. Full profile descriptions and samples will be collected at sites meeting all criteria.

RESULTS AND CONCLUSIONS

Using MapInfo®, UC Davis soil science graduate student Craig Rasmussen, produced preliminary maps of the San Joaquin Valley based on soil family-level characteristics contained in the SSURGO and STATSGO databases. The STATSGO database is unsuitable for this project, lacking in resolution at the county level. Individual mapping units within STATSGO contain too great a diversity of texture to allow us to map K-fixation potential. A gray-tone example compiled from SSURGO data is shown in Fig. 1. We have also added county roads and township-range-section as data layers to make the maps more useful for identifying a farm or even a farm field.

The map displays soils information overlain with cotton land use information. "Cotton land" is defined as that which was planted or replanted to cotton in at least one year during the 1998-2000 period. The map also shows locations of soils that are classified at the family level as (i) coarse loamy or (ii) fine loamy with coarse surface texture. This family-level classification is based on texture of the soil "control section", which for most soils is the 10-40 inch depth, not the surface layer. These maps show extensive areas of cotton production within the areas hypothesized to have a high potential K-fixing capacity. However, it is further hypothesize that coarse-textured soils derived from Sierra Nevadan granitic parent materials, which is high in biotite mica, are much more likely to fix K than coarse-textured soils from non-granitic (e.g., Coast Range) parent material. This distinction is not shown in the map.

Research planned for the next year (through December, 2002) consists of a full chemical, mineralogical, and physical characterization of the collected soil samples and several fertilizer experiments in grower cotton fields in the San Joaquin Valley.

Improving the Diagnostic Capabilities for Detecting Molybdenum Deficiency in Alfalfa and Avoiding Toxic Concentrations for Animals

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During the mid-1980's, molybdenum deficiency in alfalfa was identified in several intermountain valleys of Northern California by plant tissue analysis and the generally recommended pound of sodium or ammonium molybdate per acre (0.4 lb Mo/acre) based on some research in Washington gave adequate growth and high yields of alfalfa. Since the mid-1990's, numerous samples of alfalfa coming from the same areas have shown lower levels of molybdenum (<0.5 ppm). Over the past 10-15 years many laboratories have changed a number of analytical procedures and instruments, which do not provide reliable analyses of molybdenum at concentrations in the range of 0.1-2 ppm. Several surveys of alfalfa and other forage species as well as animal blood samples have indicated that copper concentrations are minimally adequate to deficient in many of the same locations where molybdenum were made, even at the low rate of just 1 lb/acre sodium molybdate (0.4 lb Mo/acre) the higher molybdenum would cause severe animal nutrition problems.

OBJECTIVES

The objectives of proposed project are to:

1. Characterize the relationship between plant tissue molybdenum and copper concentrations and alfalfa yield response where molybdenum is applied at several rates.
2. Develop a broader ranged diagnostic capability by assessing plant tissue molybdenum concentrations at different stages of alfalfa growth where several rates of molybdenum have been applied.
3. Provide standard forage samples for distribution to analytical laboratories by collecting large quantities (20-50 lbs) of two alfalfa samples having molybdenum concentrations in the range of 0.1-0.3 ppm and 0.5-0.7 ppm.

RESULTS AND DISCUSSION

Two sites have been established, one in Shasta County several miles north of Burney, CA, and a second in Siskiyou County several miles west of Fort Jones, CA, in Scott Valley. The Shasta County Site was initiated on March 31, 2000 when the treatments listed in Table 1 were applied. Individual plots were 10 ft by 25 ft in size, and the field trial design was a randomized complete block with 3 blocks or replications. Several alfalfa fields on the ranch were sampled in August 1999, and indicated top 1/3 of plant concentrations of molybdenum were in the 0.1 – 0.3-ppm range. Plant tissue samples also indicated that phosphorus, potassium, sulfur, and boron were in the adequate range.

Early plant growth stage samples were taken at 6 inches height and again at 12 inches. All of the plant material of the samples collected at the 6-inch growth stage and only the top 6 inches of the 12-inch high plants will be analyzed for molybdenum concentrations to develop the relationships be-

Table 1. Alfalfa yield during 2000 and molybdenum concentration in the top 1/3 of plant samples on May 25, 2000 as influenced by molybdenum and lime treatments.

Treatment	*Mo (lbs/A)*	*Lime (tons/A)*	*May 25 Yield (tons DM/A)*	*July 8 Yield (tons DM/A)*	*Aug 11 Yield (tons DM/A)*	*Sept 29 Yield (tons DM/A)*	*May 25 Mo Conc. (ppm)*
1. Control	0	0	2.27 cd	1.45	2.00	1.02	0.23 e
2. Mo	0.2	0	2.53 ab	1.49	2.01	0.98	0.67 de
3. Mo	0.3	0	2.44 bc	1.49	2.19	1.03	0.87 cd
4. Mo	0.4	0	2.48 abc	1.46	2.14	1.08	1.40 c
5. Mo	0.6	0	2.60 ab	1.57	2.23	1.04	2.43 b
6. Mo	0.8	0	2.68 a	1.53	2.12	1.09	2.33 b
7. Mo	1.2	0	2.50 ab	1.57	2.15	1.03	5.07a
8. Lime	0	2	2.21 d	1.57	1.97	0.97	0.47 de
$LSD_{0.05}$			0.222	NS(0.120)	NS(0.386)	NS(0.154)	0.63

tween growth stage and molybdenum concentration. The first harvest was collected at the early bud stage of plant development on May 25, 2000. The yield results are given in Table 1 along with the molybdenum concentrations of the top 1/3 of plant samples (equivalent to the top 6 inches of the plant). It can be noted that there is a significant increase in alfalfa yield and molybdenum concentration with the increase in the rate of molybdenum application but no response to lime. Maximum yield was achieved with 0.6 – 0.8 lbs Mo/A. The 1.2 lbs Mo/A rate resulted in an average molybdenum concentration of just over 5 ppm in the plant which is well above the desired plant level for maximum yield, and approaches the problem range for animals, particularly if copper concentrations are below the 8 – 10 ppm range. Phosphorus (PO4-P), potassium, sulfur, and boron were all in the adequate range while zinc (19-33 ppm), manganese (24-47 ppm), iron (62-104 ppm), copper (6.1-10.2 ppm), and cobalt (0.1-0.2 ppm) would be considered to be adequate while selenium for animals would be slightly in the deficient range, 0.023 – 0.145 ppm. As is sometimes the case, yield differences were not significant in the 2nd, 3rd, or 4th harvests during 2000 (Table 1).

In 2001, early plant growth stage samples were taken at 6 inches height, and again at 12 inches, and pre-bud growth stage prior to each harvest. All of the plant material of the samples collected at the 6-inch growth stage, only the top 6 inches of the 12-inch high, and pre-bud plants will be analyzed for molybdenum concentrations. The first harvest for the second year of this trial was collected at the early bud stage of plant development on May 25, 2001. Yield results given in Table 2 indicate a small but significant yield increase in response to molybdenum additions for the first harvest but inconsistent for both the 2nd and 3rd harvests. As is often the case, the application of lime at the rate of 2 tons/A gave a similar alfalfa yield response to that of most of the applied molybdenum treatments of the three harvests during the second year after application. The early plant growth stage samples as well as the harvest plant part samples are currently being processed for laboratory analyses.

The Siskiyou County site was initiated when the treatments given in Table 3 were applied, lime on March 9, 2001, and boron and molybdenum on March 10, 2001. Individual plots were 10 ft by 25 ft in size, and the field trial design was a randomized complete block with 3 blocks or replications. The alfalfa field proposed for a trial was sampled on June 21, 2000 and found to have low concentrations of molybdenum (0.2 – 0.3 ppm) and boron (6 ppm). Plant tissue samples also indicated that phosphorus (>2700 ppm midstem PO_4-P), potassium (>4.5 % midstem total K), and sulfur (>1250 ppm midstem leaf SO_4-S) were in the above adequate range.

Early plant growth stage samples were taken at 6 inches height (May 4, 2001) and at 12 inches height (May 14,

Table 2. Alfalfa yield during 2001 as influenced by molybdenum and lime treatments applied on March 31, 2000.

Treatment	*Mo (lbs/A)*	*Lime (tons/A)*	*May 25 Yield (tons DM/A)*	*July 6 Yield* (tons DM/A)*	*Aug 13 Yield* (tons DM/A)*
1. Control	0	0	1.76 b	1.39ab	0.93
2. Mo	0.2	0	1.91ab	1.37ab	1.02
3. Mo	0.3	0	1.88ab	1.48a	1.06
4. Mo	0.4	0	1.89ab	1.24 b	0.99
5. Mo	0.6	0	1.96ab	1.37ab	0.97
6. Mo	0.8	0	2.00a	1.48a	0.94
7. Mo	1.2	0	1.89ab	1.29ab	1.01
8. Lime	0	2	1.92ab	1.51a	1.12
$LSD_{0.05}$			0.228	0.235	0.217

* Estimated at 20% dry matter.

Table 3. Alfalfa yield during 2001 as influenced by molybdenum, boron, and lime treatments applied on March 31, 2001.

Treatment	*Mo (lbs/A)*	*B (lbs/A)*	*Lime (tons/A)*	*May 18 Yield (tons DM/A)*	*July 2 Yield* (tons DM/A)*	*Aug 13 Yield* (tons DM/A)*
1. Control	0		0	1.56ab	2.34 c	1.92
2. Mo plus B	0.2	4	0	1.57ab	2.75a	2.07
3. Mo plus B	0.3	4	0	1.65ab	2.55abc	1.99
4. Mo plus B	0.4	4	0	1.76a	2.50abc	2.00
5. Mo plus B	0.6	4	0	1.71ab	2.70ab	2.02
6. Mo plus B	0.8	4	0	1.66ab	2.50abc	2.00
7. Mo plus B	1.2	4	0	1.68ab	2.51abc	2.03
8. Mo	0.4	0	0	1.65ab	2.40 c	1.99
9. Mo	0.8	0	0	1.60ab	2.49abc	1.97
10. B	0	2	0	1.68ab	2.36 c	1.95
11. B	0	4	0	1.72a	2.39 c	2.05
12. Lime	0		2	1.46 b	2.37 c	2.04
13. Mo + B + Lime	0.2	4	2	1.61ab	2.43 bc	1.99
14. Mo + B + Lime	0.4	4	2	1.69ab	2.48abc	2.03
LSD0.05				0.260	0.281	NS(0.225)

* Estimated at 20% dry matter.

2001) as well as the pre-bud prior to each harvest. All of the plant material of the samples collected at the 6-inch growth stage, only the top 6 inches of the 12-inch high, and pre-bud plants will be analyzed for molybdenum concentrations. The first harvest was collected at the pre-bud stage of plant development on May 18, 2001. The yield results are given in Table 3. It can be noted that there is a slight trend for molybdenum, boron, or a combination of molybdenum and boron to increase the first harvest alfalfa yields. Observations of the trial just prior to harvest indicated the control plots as well as those receiving molybdenum alone had slightly chlorotic tops of the plants because of boron deficiency. This slightly chlorotic appearance of the tops of the plants caused by boron deficiency seldom results in vegetative yield decreases but could reduce seed yields by 25 to 50% or more. Second harvest (July 2) yields show a somewhat similar trend but with slightly less response from boron or lime alone treatments. Third harvest (August 13) yields show only a slight trend for improvement from applied treatments. The early plant growth stage samples as well as the harvest plant part samples are currently being processed for laboratory analyses

To accomplish objective two, plant samples are being collected at 4 growth stages: 1.) six inches of plant height, 2.) twelve inches of plant height with only the top 6 inches used for analysis, 3.) pre-bud (when only 2 – 5% of the plants have a small ball indicating the bud is beginning to form), and 4.) the standard 1/10 bloom stage. In some cases, the growers will be harvesting prior to 1/10 bloom so samples taken at harvest will be characterized as to stage of growth.

To accomplish objective three, to develop standard forage samples for distribution to analytical laboratories having molybdenum concentrations in the range of 0.1-0.3 ppm and 0.5-0.7 ppm, all of the top 1/3 of plant samples remaining after subsamples are submitted to the laboratory for analyses are being retained. As laboratory analyses are completed, these samples will be combined based on the molybdenum concentration ranges mentioned above.

SITE-SPECIFIC VARIABLE RATE FERTILIZER APPLICATION IN RICE AND SUGAR BEETS

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OBJECTIVES

The overall objective is to determine whether variable rate nitrogen application is economically justified in California and if so, to determine a practical method for implementing it. Specific objectives are:

1. For specialty rice, determine whether the spatial distribution of crop nitrogen demand can be forecast with sufficient precision on a site-specific basis using aerial photographs, yield monitor data, or other data readily obtainable by the farmer.
2. If the spatial distribution of crop nitrogen demand can be adequately forecast for specialty rice, determine whether the improvement in quality and/or yield is sufficient to offset the increased cost of the variable rate technology.
3. For sugar beets, determine whether crop nitrogen demand can be forecast with sufficient precision using electrical conductivity, soil texture, remotely sensed images from the previous crop, or other available data.
4. If the spatial distribution of crop nitrogen demand can be forecast for sugar beets, determine whether the improvement in quality and/or yield is sufficient to offset the increased cost of the variable rate technology.
5. If economically justified, develop a set of practices for implementing variable rate nitrogen application on these crops. Produce a technical manual on variable rate nitrogen application targeted to fertilizer companies, precision agriculture companies, and growers.

DESCRIPTION

Large fields are rarely uniform, yet they are farmed as if they were. New management technologies are being developed, however, which allow variable application rates of fertilizers, soil amendments, seed, and pesticides. These make use of satellite-based global positioning system technology (GPS) to locate places within a field that may vary in some important soil property like nitrogen content, water holding capacity, or salinity. Such practices are generally termed site-specific management or precision agriculture.

One of the most promising site-specific management practices is variable rate input application. In particular, variable rate application of fertilizers, especially fertilizer nitrogen, has been extensively studied in Midwestern cropping systems. The potential for variable rate fertilizer application to increase profit and resource use efficiency has not been investigated scientifically for California's diverse irrigated cropping rotations. Many laser-leveled, surface-irrigated fields in California display a high level of spatial variability in yield. Therefore, the potential for improved economic and resource use efficiency of fertilizer exists, either by adding fertilizer to areas in which yield is limited by mineral nutrients, or by reducing fertilizer rates in areas where yield potential is sufficiently reduced that high rates are unwarranted.

To maximize its economic impact, an initial variable-rate nitrogen management research program should focus on systems for which a substantial economic advantage accrues to the use of site-specific management. Maximum economic payoff is obtained in those crops for which there is a relatively large economic penalty for both under- and over-fertilization, and a relatively narrow range of optimal fertilizer rates. Two crops that meet these criteria are specialty rice (*Koshihikari* and *Akitakomashi*) and sugar beets. While these crops are not major contributors to California economically, they are ideal for an initial test of site-specific fertilization. For both of them, the primary economic penalty associated with over-fertilization is in quality reduction. In the case of specialty rice, increases in nitrogen levels have been identified with increased protein content, which in turn has been associated with poor flavor. In the case of sugar beets, high levels of soil nitrate are associated with reduced sugar concentration. In both crops, the factor causing a reduction in quality is readily quantifiable, and therefore, subject to rigorous analysis. The questions we are addressing include the following: Will the money saved by applying fertilizer at variable rates, for example, cost less than the assessment and equipment needed for such work? Will crop yield be improved? Or at a minimum, will these technologies allow farmers to comply better with increasingly restrictive environmental regulations? No one can answer these questions knowledgeably at present.

Soil salinity is an important management factor for many sugarbeet growers in the Imperial and San Joaquin Valleys. Salinity can inhibit seedling emergence and limit crop growth. Salinity or texture assessments can be carried out quickly and relatively cheaply, and used prior to planting to guide management for the upcoming growing season. The salt content of soils also is correlated with soil physical characteristics like water holding capacity. There may also be other useful correlations with soil properties that are much more difficult to map accurately, like nitrate content. One of the most perplexing problems for sugarbeet production in the San Joaquin Valley is low sugar content. Residual soil nitrate at depth in the profile may be a factor contributing to low sugar content. It is very difficult to assess a field's variation in nitrate even when only the surface one and one-half to three feet of soil are sampled. The complexity of the problem is increased greatly when nitrate in the second three feet is included. Sugarbeets are deep-rooted and take up some water and nutrients from the four to six foot depth (and sometimes deeper) in many soils, especially near the end of the growing season. Like salts, nitrates are soluble in water and move downward in the profile as soils are leached by irrigation and rainfall. Unlike salts, nitrates have an active role in plant growth and soil biology, and so are subject to plant uptake and transformation by soil organisms. Nevertheless, nitrate and salt may be sufficiently well-correlated to allow mapping for salinity, which is relatively simple and reliable, to be used as an indicator of potential nitrate hot spots deeper in the profile. These areas could be tested to six feet, and if confirmed, fertilizer application rates may be adjusted accordingly in those portions of the field.

RESULTS AND CONCLUSIONS

Sugar Beets/Imperial Valley site

Previous yield maps and a new electrical conductivity survey were carried out, and used to develop a variable rate gypsum treatment plan for the Imperial Valley site. Gypsum, at the rate of two tons per acre) was applied to the tops of beds in 20 plots (four 30" rows, 60 feet long) chosen using the ESAP v2.01 software created by Scott Lesch. These twenty sites represent the range in salinity conditions found in the field. Supplemental nitrogen fertilizer (at the rate of 100 lb N per acre, applied in addition to the baseline rate of 150 lb N per acre) was applied to half of the twenty sites, which were divided to reflect an approximate balance between each group of ten plots with respect to salinity conditions.

Prior to planting and irrigation, soil cores were collected to three feet at each of the twenty sites, and analyzed for salinity and clay content for calibration with the conductivity maps made earlier by Corwin and Lesch. An additional set of soil samples to six feet was collected at harvest in late May, and is being analyzed for salinity, clay content, and nitrate. Seedling emergence was counted at each of the twenty sites two weeks after initial irrigation. Soil samples were taken at each site on the same day at the two to three inch depths, and are being analyzed for salinity and sodium content. Petiole samples were collected at most of the plot sites during the spring and at harvest to follow changes in plant nitrate content and see if those changes are related to soil conditions. At harvest, which took place in June 2001, a yield monitor was used to map sugarbeet yields. Those yield maps will be combined with the previous year's maps for sugarbeet, wheat, and soil electrical conductivity to evaluate the effects of soil variability, including residual and applied N on crop performance. Hand harvests were taken at the twenty plot sites and analyzed for yield, quality, root characteristics, and root NO_3 content. All data are being combined and analyzed.

El Nido site:

In the spring of 2000, an EM 38 survey was carried out on a 60-acre site in El Nido, California by Dennis Corwin. Following the survey, soil samples were collected at 16 sub sample locations chosen using the ESAP v2.01 software. Samples are being analyzed for salinity, texture and nitrate. Sugarbeets were planted at the El Nido site in May 2001. They will be harvested in spring 2002. Stand counts were made and will be correlated with soil properties. Supplemental fertilizer applications at rates of 50 or 100 lbs N per acre were side dressed to young beets before canopy closure. Two 50 rows were fertilized at each of 16 sub sample locations. Sites were divided into two approximately equal groups, half receiving the larger rate, and half the smaller. Results will be compared to neighboring rows using hand harvests at each location. Background variation in soil residual N, and the variable surface amounts applied will be used to assess crop fertilizer response.

Rice

Nitrogen trials were established in three commercial rice fields in the Sacramento Valley; *Koshihikari, Akitakomashi,* and M-202. This gives us the opportunity to observe how the interaction of nitrogen with rice quality differs between Japanese and American varieties. All fertilizer applications are being carried out by the growers as a part of their regular operations. The experimental layout has been designed to account for the realities of commercial rice production. Therefore, the trials are not laid out in a randomized, replicated manner. Rather, they consist of three large individual blocks (un-replicated) in which nitrogen fertilizer is applied at 50%, 100%, and 150% of the normal rate the grower uses in that field. Blocks will be measured using a yield monitor at harvest, and data will be analyzed using multivariate regression techniques. Grain samples will be hand-harvested on a regular grid for grain nitrogen analysis. Other primary data will include yield maps of the harvest. Remotely sensed aerial images are being collected, and these will be used to infer a measure of vegetative N demand. Figure 1 shows an aerial image of one of the trial fields. The light colored area near the center of the field contains very shallow soil and has historically poor yielding. The nitrogen trials run in a north-south direction through this field. The high nitrogen trial can be seen as a band of darker color.

Figure 1. Aerial image of one of the rice fields in which nitrogen rate trials are being conducted.

Precision Agriculture in California: Developing Analytical Methods to Assess Underlying Cause and Effect of Within-field Variability

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INTRODUCTION

Precision farming or soil-specific management (SSM) is not a new concept. Yet, recent technological advancements in multiple disciplines are revolutionizing the potential for the application of SSM concepts in large scale, industrialized agriculture. This new potential for more efficient and environmentally-friendly agriculture has revitalized many of the traditional agricultural sciences by posing the new challenges of describing, understanding, and predicting spatial agro-ecological patterns with high resolution at landscape scales.

The challenge, however, will not be on how to collect and transfer the data into maps that reflect the spatial patterns of features of interest but on how to interpret the data and make predictions on the impact of variable management practices across a farmer's field. This cannot be achieved without a thorough understanding of the underlying mechanism that causes the variability of key processes across the field to occur in the first place.

This project aims at integrating state-of-the-art tools for collecting, geo-referencing and mapping spatial data with thorough characterization and modeling of the fundamental processes causing spatial variability. This project, dealing with field-scale variability, is part of a larger, multi-scale research effort dealing with spatial variability in Californian rice agroecosystems.

OBJECTIVES

1. Initiate a case study to quantify the underlying mechanisms that control the spatial variability of grain yield in rice fields.
2. Determine how the efficiency of collecting information across a farmer's field can be optimized using state-of-the-art geostatistical techniques.
3. Develop a predictive model for yield and perform sensitivity analysis to assess the main factors controlling its spatial variability.
4. Test the economic feasibility of SSM by varying treatments across the field.

DESCRIPTION

As part of the first-season activities of a three-year study, a rice field was selected at Josiassen Farm, near Oroville, California. The field has been under rice cultivation for the last five years, and rice straw has been incorporated each year during the winter. Within the field, four transects of 1200 feet were randomly selected for our study. Two of those tran-

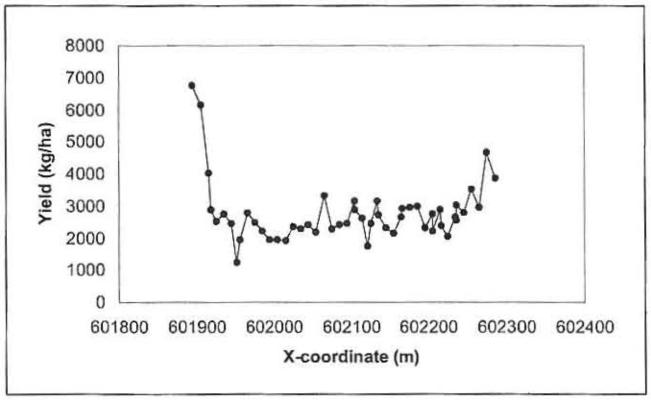

Figure 1. Yield along the unfertilized transect No. 1.

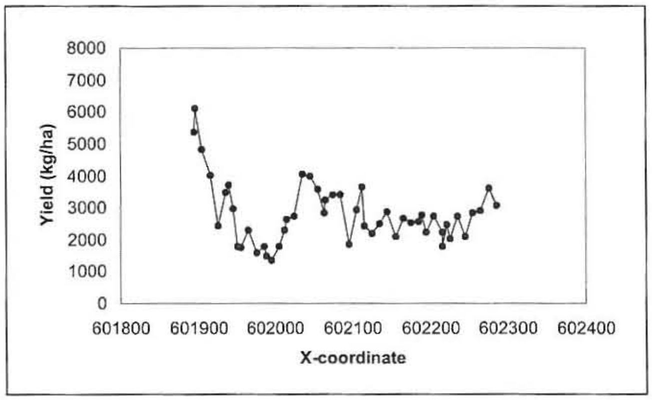

Figure 2. Yield along the unfertilized transect No. 2.

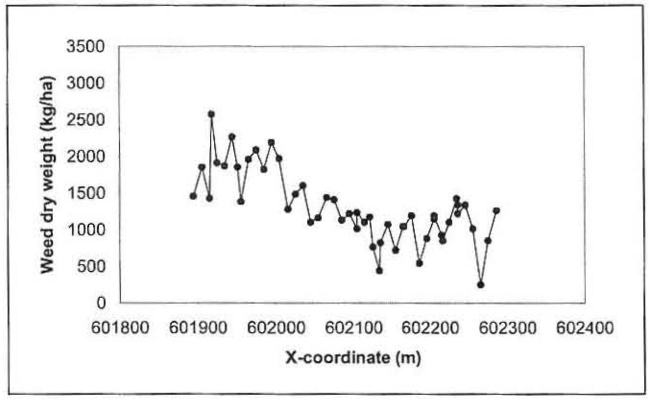

Figure 3. Weed dry weight along transect 1.

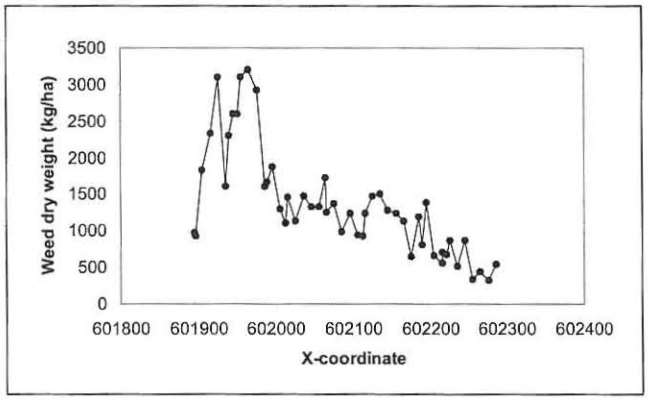

Figure 4. Weed dry weight along transect 2.

sects were selected to be left unfertilized, in order to quantify natural variability of soil fertility. Unfertilized transects were used for assessment of variability of natural soil fertility.

In the spring of 2000, 50 soil samples were collected for each transect. Samples were dried and stored using standard methodology. Analyses were carried out for Olsen-P, total N, total C, ^{15}N natural abundance, ^{13}C natural abundance, cations and texture. The field was planted on May 25th. Two of the transects, 30 feet wide, were left unfertilized. The rest of the field was fertilized with aqua ammonia. At plant establishment, and a month later, infrared images were taken. At harvest, whole plant samples (including roots) were collected from all locations. In addition, the weed weight was quantified. Harvest maps across the transect were made using a yield monitor, and were calibrated using hand-harvested plots across the transects.

RESULTS AND DISCUSSION

Yields and weeds

All experiments were geo-referenced using a real-time differential GPS. In the spring of 2000, 50 soil samples (40 with a spacing of 30 feet, 10 random) were collected for each transect, yielding a total of 200 samples Figs. 1 and 2 show yield variability along the two unfertilized transects. Average yield along the unfertilized transects was 2800 kg ha^{-1} with a minimum and maximum yield of 1260 kg ha^{-1} and 6760 kg ha-1, as collected on 0.5 square meter plots. Yield variability seemed to be slightly higher on the second transect. Both transects show a marked increase in yield near the sides of the field, especially the west side, (left side of Figs. 1 and 2).

Figs 3 and 4 show above-ground weed biomass for both unfertilized transects. Weed species were mainly Ricefield Bolrush, with smaller densities of Watergrass and Redstem. As collected on 0.5 square meter plots, average below-ground yield biomass was 1300 kg ha^{-1} with minima and maxima of 250 kg ha^{-1} and 3200 kg ha^{-1}, respectively. On both transects, there was a marked increase in weed density near the west side of the field (left side of Figs. 3 and 4).

Aerial photographs were made at mid-season and just before harvest, and will be linked to the measured yield data on the ground the coming months.

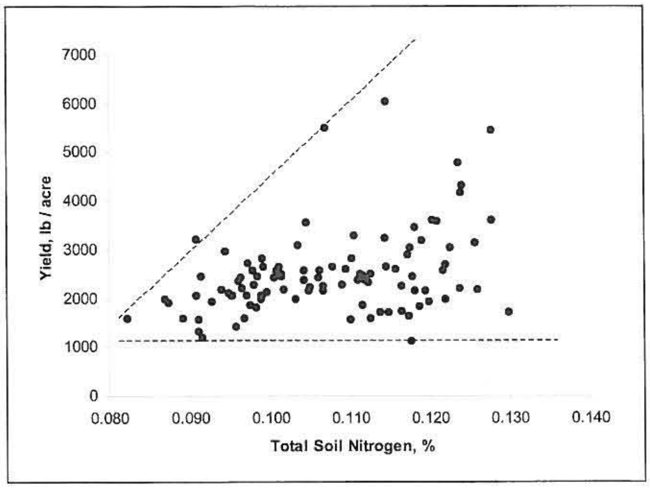

Figure 5. Soil Nitrogen vs. yield on both transects.

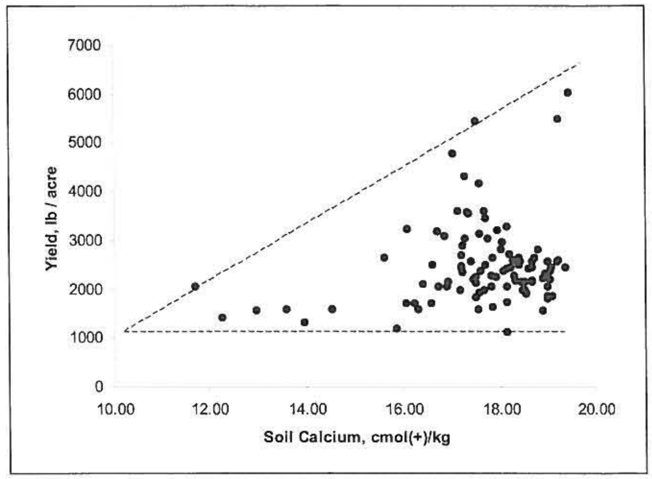

Figure 7. Soil Ca vs. yield on both transects.

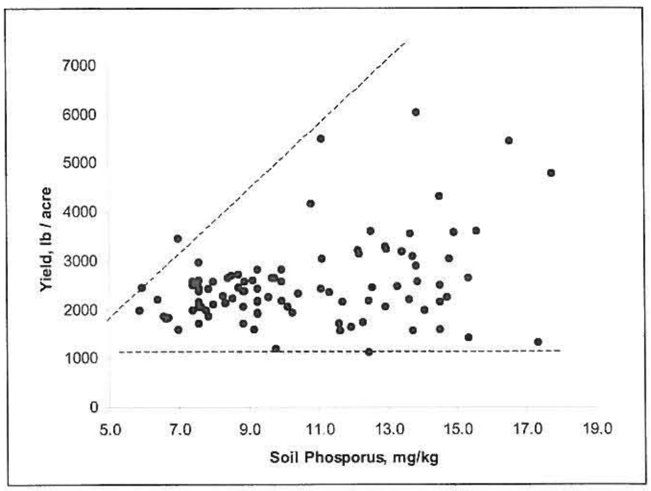

Figure 6. Olsen-P vs. yield on both transects.

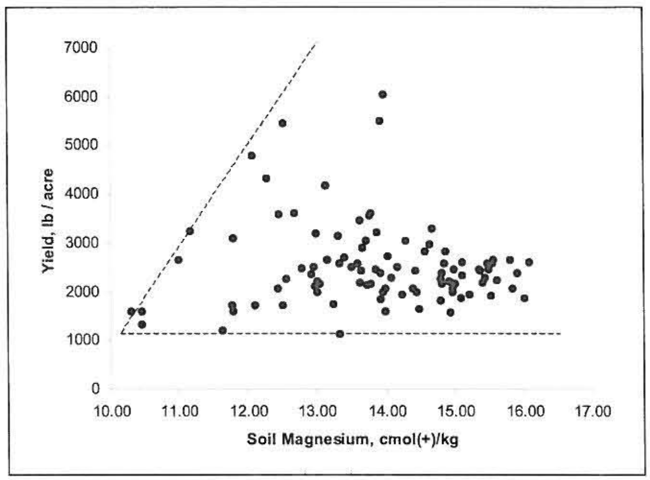

Figure 8. Soil Mg vs. yield on both transects.

Soil parameters

Total soil N varied from 0.08 % to 0.13 %, with average values of 0.11 % (Fig. 5). Total N varies smoothly across the field, and is related to the yield maps of Figs. 1 and 2. Both yield and total N show peaks at the west side of the field, and a smaller peak in the middle of the second transect. Clearly, N is limiting in the crop (Fig. 5). Total soil C is closely related to total soil N, with C/N ratios between 9.5 and 13.0.

Olsen-P (Fig. 6) shows a very similar pattern, and is also limiting crop growth indicating a general pattern in soil fertility that is expressed in yield, nitrogen, carbon, and phosphorus numbers. Olsen-P ranges from 5.8 to 17.7, with an average value of 10.5 mg/ kg.

The cations show a distinctly different pattern, with extractable soil Ca and Mg (Fig. 8) relatively high on all parts of the transect, except for the west side of transect #2. This is probably due to leveling of the field, which moved topsoil from east to west, resulting in higher soil organic matter in the western part, and more exposed subsoil (with cations) in the eastern part. In addition to N and P, Ca and Mg are also limiting in parts of the field.

Agricultural Baseline Monitoring and BMP Implementation: Steps Toward Meeting TMDL Compliance Deadlines Within the Newport Bay/San Diego Creek Watershed

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INTRODUCTION

Agricultural production in the Newport Bay Watershed is considered one of several sources of nutrient loading to San Diego Creek, the main tributary for the Newport Bay. Due to the ecological importance of the Newport Bay, San Diego Creek was placed on the state's 303(d) list for impaired waterbodies, a listing that requires the development of a Total Maximum Daily Load (TMDL). The goal of the TMDL is to return the waters to a condition where it's beneficial uses are no longer impacted by the identified pollutant(s). The process to reach this goal is both costly and time-consuming. A TMDL developed without adequate funds, and time comprises the goal of ultimately improving the quality of the waterbody.

The development of a sediment and nutrient TMDL for the Newport Bay Watershed proceeded rapidly in response to litigation. As a result, the Santa Ana Regional Water Quality Control Board (SARWQCB) was forced to estimate nitrogen and phosphorus loads in agricultural surface runoff. Agricultural baseline flow and nutrient data were limited to that collected by three large wholesale nurseries to meet their waste discharge requirements. The timeline required for TMDL development was not sufficient, however, for baseline monitoring of surface runoff from agricultural fields. In order to address this problem, SARWQCB utilized a phased approach that allows for incremental reductions in loads over several years as well as the opportunity to revisit loads previously set when new information becomes available. Currently, load reductions have been established for the end of 2002, 2007, and 2012. The final goal is to reduce total nitrogen and phosphorus loading by 50% in 2012.

Agricultural producers in the Newport Bay Watershed, in order to meet the goal of a 50% reduction by 2012, will need to implement additional Best Management Practices (BMPs) that specifically address the movement of nitrogen and phosphorus compounds in surface runoff. This project seeks to establish baseline loads of nitrogen and phosphorus in surface runoff from agricultural fields. The data will then be used to evaluate the effectiveness of implementing BMPs that aim to improve the quality of surface runoff from both row crops and nurseries.

OBJECTIVES

1. Establish a water quality monitoring program for several representative agriculture sites in the Newport Bay Watershed in order to determine the baseline loads of total nitrogen and phosphorus in surface runoff.
2. Develop and conduct meetings that focus on current TMDL development and provide an opportunity for agricultural producers, nursery operators, and consultants to interact with SARWQCB and UC Cooperative Extension staff in an informal setting.
3. Develop and conduct a series of management workshops that provide hands-on demonstrations and seminars that

Table 1

Site	*Plot*	*Crop(s)*[1]	*Flow*[2]	*Sampling*	*BMP Implementation*
A	R-1 (control)	S	March 2000-present	Weekly if present	None
	R-2	S	March 2000-present	Weekly if present	PAM, tensiometers
B	R-3 (control)	S	March 2000-present	Weekly if present	None
	R-4	S	April 2000-present	Weekly if present	PAM, tensiometers
C[3]	R-5 (control)	C, B, S	Feb 2000-present	Weekly if present	None
	R-6	C, B, S	Feb 2000-present	Weekly if present	PAM, tensiometers
D[4]	R-7 (control)	S	October 2000-present	Weekly if present	None
	R-8	S	October 2000-present	Weekly if present	PAM, tensiometers
E	N-1 (upstream)	CN	June 2000-present	Weekly if present	None
	N-2 (downstream)	CN	July 2000-present	Weekly if present	Vegetative filter

[1]Crop letter codes: B=Bean, C=Celery, CN=Container Nursery, and S=strawberry.
[2]Flow is monitored at sites under production when surface runoff is present.
[3]Site was relocated in March 2000 (following celery harvest) to a field currently used for strawberry production.
[4]Site was relocated in October 2000 from an orchard where surface runoff was absent to a field currently used for strawberry production.

focus on new technologies and cultural practices that will assist agricultural producers, nursery operators, and consultants in minimizing nutrient movement in surface runoff.

DESCRIPTION

The initial phase of the project involved the selection of agricultural sites that accurately represent the various types of production occurring in the Newport Bay Watershed. Other selection criteria included the following: the accessibility of site; the ability to install flow monitoring and water sampling equipment without drastic changes in a grower's existing drainage design; and the willingness of a grower to implement BMPs following the collection of baseline data.

Each site consists of two plots, a control plot and a treated plot. A monitoring program was initiated on both plots to collect both baseline flow data and nutrient concentrations. The monitoring program will continue through the end of 2000. The implementation of BMPs on treated plots will begin in 2001 following an evaluation of the baseline flow and nutrient data.

The baseline-monitoring program consists of the placement of automatic water samplers in the field once a week to sample surface runoff for a 24-hour period. Surface runoff flow is measured continuously with an area-velocity flow meter thus allowing for the estimation of nitrogen and phosphorus loads. Conditions when monitoring equipment cannot be utilized such as during field preparation, monitoring is replaced with grab samples if surface runoff is present. Water quality parameters consist of pH, electrical conductivity (EC), $(NO_2 + NO3)$-N, NH_4-N, TKN, PO_4-P, and total-P. All nutrient analyses are being conducted by Irvine Ranch Water District's EPA approved water testing laboratory while EC and pH measurements are completed in the field.

The educational component of this project is composed of a series of forums and workshops. A forum will consist of an informal meeting between agriculture operators, nursery growers, UCCE project staff, and representatives from the SARWQCB. The meetings will provide the opportunity for updates on this project as well as interaction between the agency developing TMDLs and those that are directly affected by it.

Workshops will focus on management strategies that are useful to both agriculture and nursery operators in reducing nutrient loads in surface runoff. The meetings will be held twice a year focusing on specific topics such as nutrient and irrigation management. New technologies will be demonstrated in an effort to expose growers to equipment available to assist them in making sound nutrient management decisions.

RESULTS AND CONCLUSIONS

I. Development of a Water-Quality Monitoring Program

Specific characteristics of the sites included in the baseline-monitoring program are described in detail in Table 1. One particular difficulty in establishing a monitoring program is the unforeseen changes in land use that occur frequently in the Newport Bay Watershed as a result of urbanization. Changes in land use have resulted in the loss of the original site C after two months of monitoring, and a delay in establishing monitoring stations at Site D. Flow and nutrient monitoring were resumed following relocation of Site C to another site.

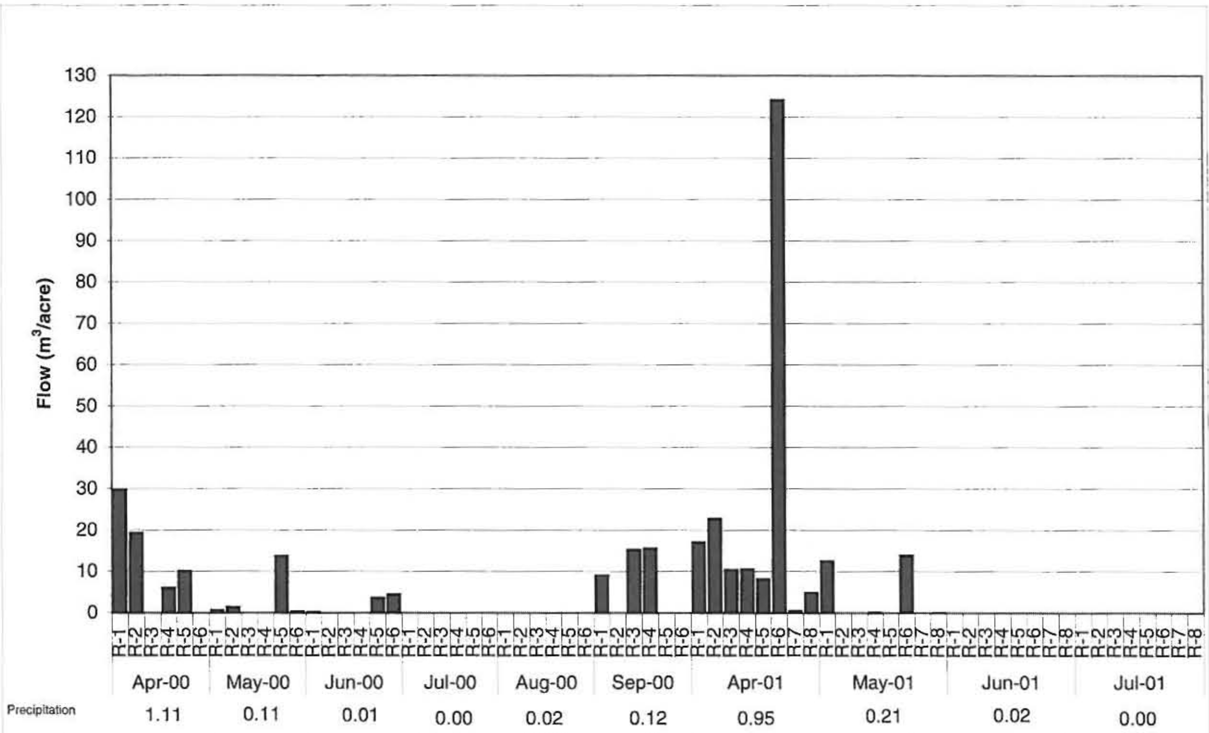

Figure 1. Monthly flow during dry season (April-September).

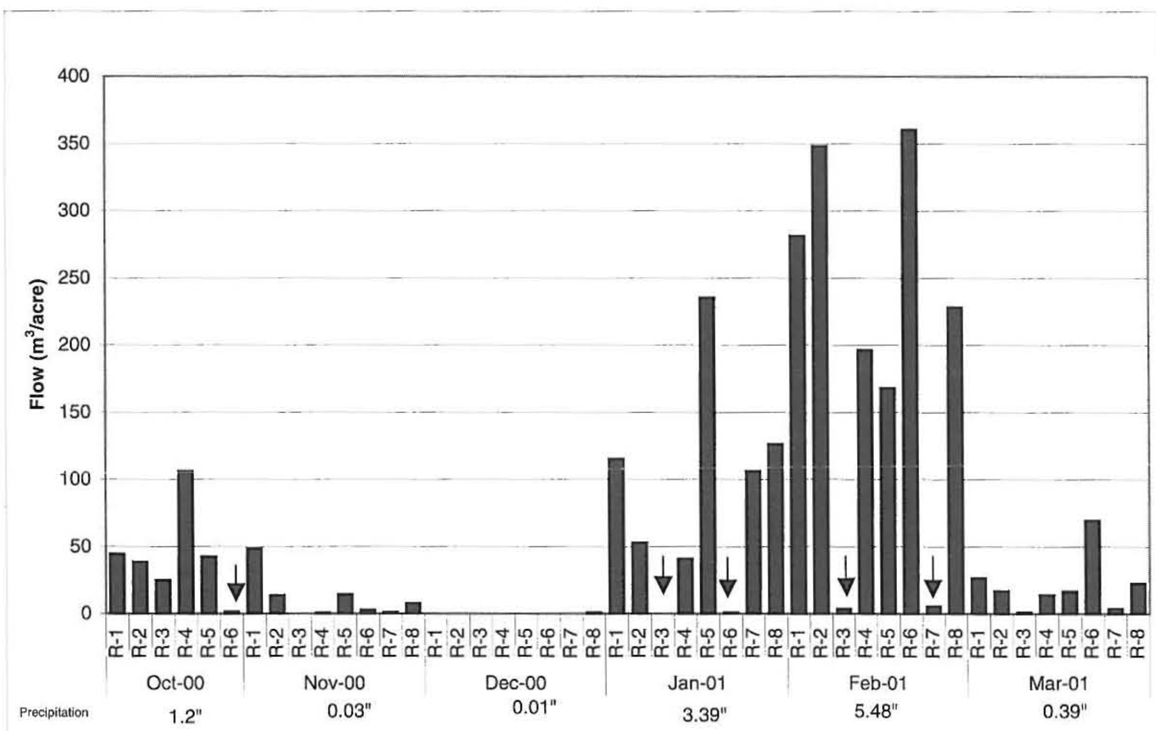

Figure 2. Monthly flow during wet season (October-March).

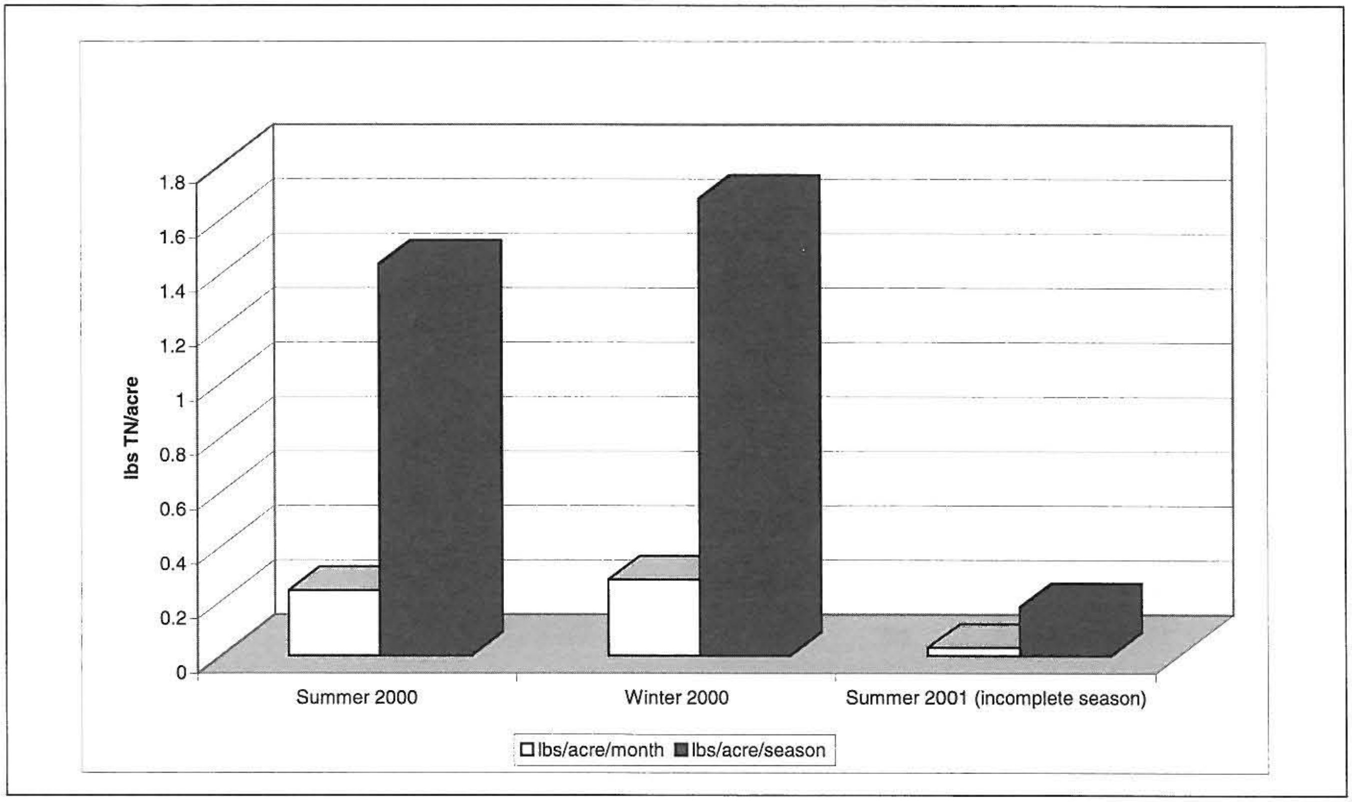

Figure 3. Average total nitrogen loading from monitoring sites

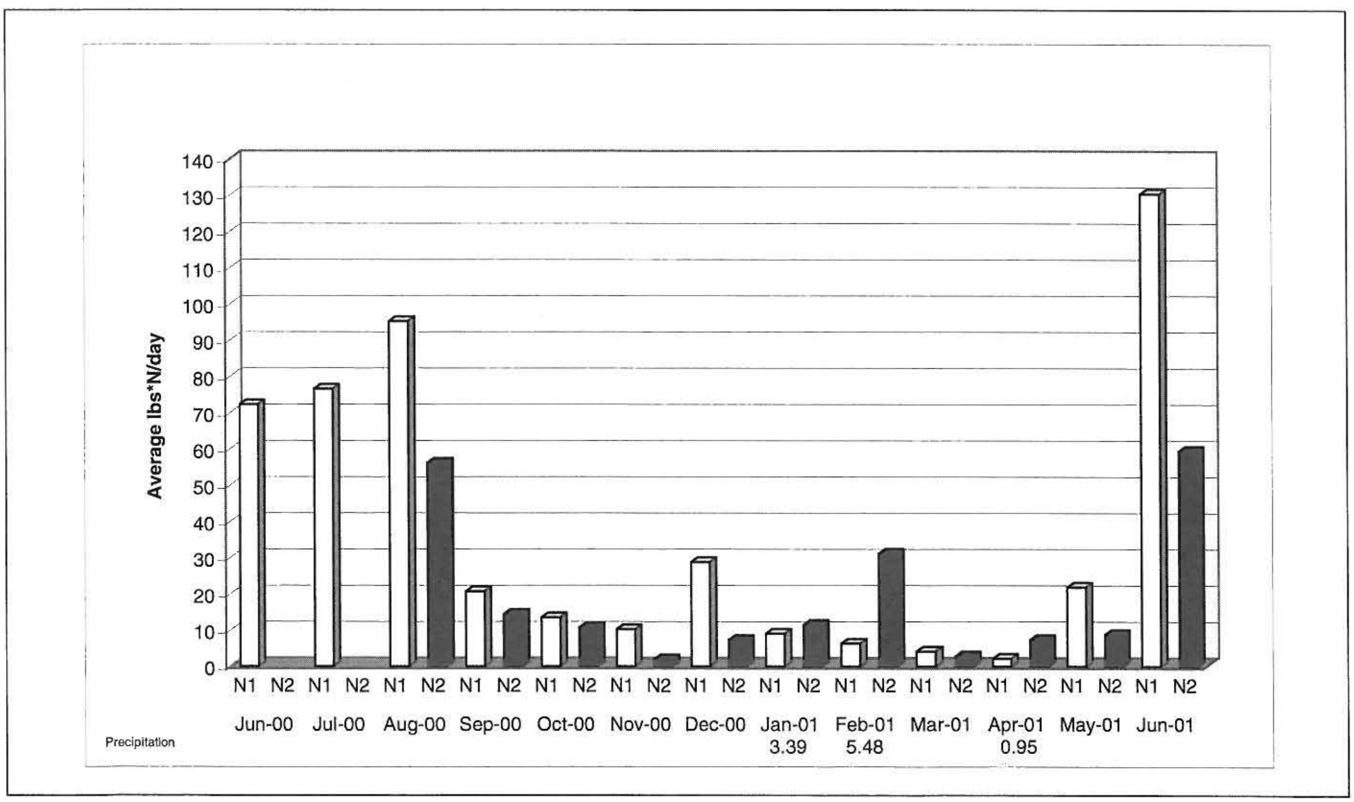

Figure 4. Surface runoff sampling site comparison. Upstream(N1) vs. Downstream(N2)

Control and treated plots were chosen based on similar acreage and drainage patterns when possible. The ability to collect baseline data provides information on the differences in flow and nutrient movement between plots prior to BMP implementation on the treated plot.

II. Baseline Flow and Nutrient Loading Results

Total flow measured from row crop fields during both the summer season (April – September) and the winter season (October – March) beginning April 2000 to the present are shown in Figures 1 and 2. The majority of flow occurs during the winter season, and during the establishment of strawberry transplants in September and October when overhead sprinklers are used to irrigate. The utilization of drip irrigation following transplant establishment results in no surface runoff, if managed correctly, for a majority of the growing season. Surface runoff present during the summer season can be attributed to excessively long run times for leaching, leaking systems, or the use of overhead irrigation to produce beans, although this occurs on a very small percentage of the total acreage. Rainfall levels greater than 1/4" were characterized by substantial sediment loads that interfered with flow monitoring. Arrows over bars indicate errors in flow readings due to equipment failures caused by sediment.

Monitoring of row crop sites for approximately one year shows that nitrogen and phosphorus loading occurs primarily during the winter season with the exception of storm events that occurred during the summer season in April 2000 and 2001 (Figure 3). The Nutrient TMDL established in 1999 specifies a 2002 summer allocation for agricultural runoff at 22,963 lbs/season Total Nitrogen (TN) for approximately 11,000 acres. Agricultural acreage in 2000 consisted of approximately 4,000 acres in row crop production, 2,000 in orchard production, and 1,000 in nursery production. Figure 3 shows both the average lbs/acre/month of TN leaving row crop fields during the summer season and the total lbs/acre/season. During the summer 2000 season, surface runoff from row crops fields carried an estimated 5760 lbs of TN.

The Nutrient TMDL also establishes phosphorus load allocations for agricultural runoff, but on an annual basis. The 2002 annual phosphorus load allocation for agricultural runoff is 26,196 lbs/year. A complete dataset for phosphorus will be available at the end of 2001 in order to calculate an estimate of phosphorus loading by agricultural runoff in the Newport Bay Watershed. The reduction of phosphorus loading is mainly dependent on the ability to control sediment movement during storm events as well as under conditions when overhead irrigation is required, such as Santa Ana wind conditions and frost.

III. Implementation of BMPs

Sites A, B, C, and D are currently all planned for strawberry production for the 2001-2002 growing season. Best Management Practices will focus on reducing surface runoff during the establishment of strawberry transplants in September and October. With the cooperation of the growers at each site, tensiometers will be installed directly into the beds at 6" and 12". Depending on layout of the overhead irrigation design, the grower will be advised to schedule irrigations for the control plot utilizing previous methods, while irrigation on the treated plot will be based on a predetermined soil tension. Due to the crucial nature of transplant establishment, and the tendency to over irrigate as a safety margin, project personnel will need to remain in close contact with the grower in order to establish a comfortable soil tension level. The goal of utilizing tensiometers is to establish a soil moisture range that results in maximum transplant rooting and survival while reducing the amount of surface runoff.

In addition to employing the use of tensiometers, polyacrylamides (PAM) will be utilized on the treated plots to reduce the amount of sediment moving off-site. Depending on the site, various formulations of PAM will be tested ranging from an emulsifiable concentrate to dry formulations that are broadcast in furrows.

Due to an existing Waste Discharge Requirement, BMP implementation at Site E was initiated immediately. Preliminary water quality data collected by the nursery provides a baseline to gauge the success of the vegetative filter strip. A vegetation filter was installed in a concrete-lined channel with flow measurements and water sampling occurring upstream (N-1) and downstream (N-2) of the filter. The vegetation filter acts both as a biological active filtration system as well as a source for the production of plant material. In order to improve the efficiency of the filter, its design was modified from that described in the 2000 FREP Conference Proceedings. The channel is currently divided into eight basins containing 578 plastic mesh baskets with two to three Canna lily plants (tubers) per basket. Dividing the channel into smaller basins allows for harvesting one basin every eight weeks with the goal of maintaining the vegetative filter with a significant portion of mature plants. The baskets are set into each basin on approx. 0.6 m centers covering 186 m^2.

During the summer season, the vegetative filter strip is effective in reducing the average lbs. TN/day leaving the nursery. The concentration of nutrients in the runoff remains fairly constant from inflow to outflow monitoring stations, but the overall flow is significantly less at N-2 compared to N-1 resulting in lower nitrogen loading at N-2. Plant density and runoff resident time will be further increased in order to maximize the exposure of plant roots to the surface runoff. During the winter season, rainfall and cooler temperatures reduce the effectiveness of the vegetative filter. Inputs other than irrigation runoff, such as direct rainfall into the channel and drainage from roads, results in higher flows and nutrient loads measured at N-2 compared to N-1.

IV. Education Outreach

On January 19th, 2001, a frost protection forum was held at the South Coast Research and Extension Center. Several of growers expressed interest in improving their knowledge about using irrigation for frost control. Dr. Rick Snyder, a UC Davis biometeorologist, presented growers with basic information on frost and how irrigation can be utilized to protect plants from frost damage. The format allowed growers to pose questions relevant to their own situations. Eighteen growers attended the forum.

The first in a series of workshops was held on November 16, 2000 at the South Coast Research and Extension Center in conjunction with California Certified Crop Advisors, Orange County Farm Bureau and the South Coast Resource Conservation & Development Area. Focusing on nutrient management and attended by 66 agricultural operators, PCAs, nursery operators, and certified crop advisors, the workshop's goal was to present an overview of nutrient management for various crops as well as provide hands-on demonstrations of soil and tissue nutrient testing equipment and techniques. All attendees received a handbook containing information on TMDLs, a copy of the ANMP, speaker handouts, and a catalog of University of California Cooperative Extension publications relating to water and nutrient management.

The second workshop, held on February 20th, 2001, focused on irrigation management. The workshop was held in conjunction with the Southern California Chapter of Certified Crop Advisors, Orange County Farm Bureau, and the South Coast Resource Conservation & Development Area. The morning session consisted of presentations by experts from the University of California on irrigation scheduling, efficiency, and technology. Hands-on demonstrations were conducted in the afternoon on proper use of soil moisture monitoring equipment, new irrigation technologies, and injection mechanics. Forty-one growers, PCAs, and consultants attended the workshop. Each attendee received a handbook containing speaker handouts, relevant research literature, and additional information on irrigation

A self-appraisal workshop for row crop growers in the Newport Bay Watershed was held on July 25th at the South Coast research and Extension Center. Growers prior to attending a summary meeting completed a self-assessment survey with the assistance of project staff. The survey included areas of irrigation, fertilization, and cultural practices that impact the quantity and quality of surface runoff. At the summary meeting, growers were given their individual results as well as a presentation on the overall results of growers in the Newport Bay Watershed. The goal of the workshop was to have each grower assess their current practices to determine the areas where they need to make improvements in order to minimize surface runoff contamination. The second half of the meeting allowed growers and project staff to discuss the logistics and economical feasibility of suggested BMPs. Currently, a similar self-assessment and summary meeting is being planned for the nursery growers in the watershed. Ninety percent of the growers in the Newport Bay Watershed completed the survey and attended the summary meeting.

Development of Fertilizer and Irrigation Practices for Commercial Nurseries

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INTRODUCTION

Container-grown woody plants are an important agricultural commodity in California, accounting for most of the $1.99 billion farm gate for nursery products in 1999. California nurseries contribute over 20% of the nursery crops produced in the U.S. Production is intensive, usually involving daily application of water and high concentrations of fertilizers—especially nitrogen. Because of their high demand for nitrogen, the potential for nitrogen pollution from runoff and leaching losses in nurseries is great. Commercial nurseries have addressed this problem by improving methods of applying nitrogen and water. A practice of long standing has been to apply soluble nitrogen in irrigation water (liquid feeding), either by overhead irrigation, using impact sprinklers, or through emitters placed in each container. Liquid feeding offers the advantage of management over nutrient supply, since the grower can control fertilizer concentration, form of nutrients applied, and the composition of nutrients in the liquid feed. However, it suffers from the disadvantage of fertilizer waste because of the combined effects of a limited soil volume in containers, and the need for frequent irrigation, and fertilization. Application through overhead irrigation is particularly inefficient, since as much as 75% of the applied water is not intercepted by the containers.

Nurseries have responded to this problem with three major changes in fertilizing and irrigating; 1) Many nurseries have installed drainage systems that allow for capture and reuse of runoff. This has the advantage of permitting continued use of overhead irrigation, but the installation cost is high and retrofitting established nurseries is problematic; 2) Liquid feeding through drip irrigation systems has replaced use of impact sprinklers in many nurseries. This is more efficient, and can reduce N losses substantially, provided appropriate amounts of N, and water, are applied. Unfortunately, the water requirements of individual nursery crops can vary greatly, and the water and nutrient requirements of most nursery species are not well known. As a result, it is likely that excessive application of water, and fertilizer occurs, leading to leaching, and runoff of nitrogen. Another drawback to drip systems is that installation is labor intensive and not usually cost effective for small container sizes; 3) The third method in common use is application of encapsulated, controlled-release fertilizers, and irrigation with clear water rather than a liquid feed. This approach can be effective, but there is still the potential for leaching losses due to over fertilization, and over irrigation. In addition, crops in large containers (5 gallons or larger) typically require multiple applications of fertilizer, which can result in a substantial labor expense.

A hybrid method of fertilizing has been proposed, in which a slow-release form of N is applied in a liquid feed. Some have argued that this method results in low leaching losses of N, while avoiding the need for labor-intensive multiple applications of fertilizer. This project was undertaken to test this proposed method, and to document the fertilizer, and irrigation needs of large nursery stock.

OBJECTIVES

1. Determine water use of seven tree species grown in 5-gallon containers. The species, chosen to include both deciduous and evergreen species that are widely used in California, were *Magnolia grandiflora, Pistacia chinensis, Platanus racemosa, Prunus ilicifolia, Quercus agrifolia, Quercus lobata,* and *Sequoia sempervirens.* The common names of these species are Southern magnolia, Chinese pistache, California sycamore, hollyleaf cherry, California live oak and California white oak respectively.

2. Determine nitrogen uptake, and leaching losses for these trees, and compare nitrogen use efficiency of three methods of fertilizer application (liquid feeding with nitrate and ammonium, liquid feeding with polymethylene urea and surface application of controlled release fertilizer).

3. Determine dry weight gain of trees.

DESCRIPTION

Two-inch liners of *Magnolia grandiflora, Pistacia chinensis, Platanus racemosa, Prunus ilicifolia, Quercus agrifolia, Quercus lobata,* and *Sequoia sempervirens* were obtained from commercial nurseries in Spring 2000, and 15 replicates of each species were planted into 5-gallon containers on June 1. The container medium contained equal amounts by volume of sphagnum peatmoss: redwood sawdust: medium sand. It was chemically amended with dolomite (5 lb yd^{-3}), superphosphate (2 lb yd^{-3}), and Micromax (1 lb yd^{-3}).

The containers were arranged on raised benches in the University of California, Davis Environmental Horticulture experimental nursery. Each fertilizer group was irrigated through a separate drip irrigation system controlled by a solenoid valve and a timer. One supplied tap water to plants fertilized with controlled release fertilizer (designated as CRF treatment), and the other two used a Smith injector to introduce one of two fertilizer solutions into tap water, and deliver a final N and K concentration of 100 mg/L. One of the fertilizer solutions contained polymethylene urea (Growth Products' Nitro-30), and potassium sulfate (designated as MU treatment); the other solution contained a standard liquid feed solution of calcium nitrate, potassium nitrate, and ammonium nitrate, with 25% of the N supplied as ammonium (designated as SLF). Controlled release fertilizer (Osmocote 24-4-9) was applied to the surface in the appropriate treatment at the recommended rate (100 g/container). Irrigation water was applied through adjustable emitters to provide the different species with the volume of water necessary to produce a 0.25 leaching fraction.

Volumes leached were measured gravimetrically every 6 to 10 days. Plant water use was calculated as the difference between applied and leached volumes. Values of water use were compared to ET_0, reference evapotranspiration obtained from the Davis CIMIS site. Leachate samples were collected for measurement of different forms of N.

Trees were harvested at the end of October, when defoliation of deciduous trees started. All plants were separated into leaves, wood, and roots. Final fresh and dry weights of leaves, wood, and roots were measured, and their N content was determined.

RESULTS AND CONCLUSIONS

Plant dry weight differed among species, and was affected by fertilizer treatment (Table 1), but there was no interaction between species and fertilizer. The total dry weight of plants from the SLF, and the CRF treatments was greater than that of plants in the MU treatment. The SLF treatment resulted in a higher leaf dry weight than in the other two treatments, and roots made up a larger portion of dry weight among plants fertilized with the controlled-release fertilizer.

Table 1. Tree dry weight, in grams, as a function of fertilizer treatment.

Fertilizer	*Leaves*	*Wood*	*Roots*	*Total*
SLF	36.8a	45.8a	48.4ab	131.0a
MU	26.2b	32.6b	36.5b	94.5b
CRF	30.2b	40.1ab	56.4a	126.8a

Values followed by different letters are significantly different at P=0.05.

Leaf N varied with species, and fertilizer treatment, with a significant interaction (Table 2). The SLF resulted in a higher leaf N concentration than in plants fertilized with MU, or CRF. This difference was most pronounced in *Platanus,* and *Q. lobata.* The fast-growing *Platanus* plants had a significantly lower leaf N concentration if they were fertilized with CRF. In other species, the differences among the three fertilizer treatments were not large. Total N uptake by plants during the experiment was affected mostly by species, but there was also a significant effect of fertilizer treatment (Table 3). *Platanus* plants took up far more N than any other species, and the SLF treatment resulted in greater N uptake than either other fertilization method. The benefit of SLF treatment on N uptake was most pronounced on *Magnolia, Platanus, Q. lobata,* and *Sequoia.*

Table 2. Effect of species and fertilizer treatment on leaf N concentration, expressed as a percentage of dry weight.

Species	*Leaf N*
Magnolia	1.77a
Pistacia	2.10b
Platanus	2.12b
Prunus	2.42c
Q. Agrifolia	1.96d
Q. Lobata	2.55e
Sequoia	1.56f

Values followed by different letters are significantly different at P=0.05.

Fertilizer	*Leaf N*
SLF	2.26a
MU	1.97b
CRF	1.98b

Values followed by different letters are significantly different at P=0.05.

Table 3. Effect of species and fertilizer treatment on total N uptake, expressed in grams.

Species	*Tissue N*
Magnolia	1.24a
Pistacia	1.85b
Platanus	4.40c
Prunus	0.32d
Q. Agrifolia	0.42d
Q. Lobata	0.65e
Sequoia	1.83b
Fertilizer	*Tissue N*
SLF	2.95a
MU	1.27b
CRF	1.27b

Values followed by different letters are significantly different at P=0.05.

Leaching losses of N were greatest among species that received the SLF treatment, and the CRF treatment resulted in significantly lower N leaching losses than the other treatments did (Table 4). Nearly all of the leachate N in the SLF and CRF treatments was in the form of nitrate-N. In the MU treatment, over 40% of the leachate N was polymethylene urea. Nearly one-third of the N applied in the SLF treatment was lost to leaching, whereas only 2% of N applied as CRF was lost to leaching (Table 5). A large portion of the applied N was present in a soluble form in the soil at harvest, especially among plants that received CRF. N use efficiency in this experiment was expressed as the ratio N uptake/ N leached (Table 6). The N efficiency of the CRF treatment was significantly greater than that of the SLF, and MU treatments. Leachate N concentration after the first few days was less than 100 ppm for all fertilizer treatments (Figure 1). Concentrations were highest in the SLF, and MU treatments (averaging 82 and 53 ppm, respectively), and only 6-ppm for the CRF treatment.

Table 4. Cumulative N leached, in grams, from application of three fertilizer treatments to seven tree species.

Species	*N leached*
Magnolia	1.95a
Pistacia	2.62b
Platanus	2.79b
Prunus	1.77a
Q. Agrifolia	2.11a
Q. Lobata	1.94a
Sequoia	1.95a
Fertilizer	*N leached*
SLF	3.50a
MU	2.49b
CRF	0.50c

Values followed by different letters are significantly different at P=0.05.

Table 5. Percentage of applied N that was leached from application of three fertilizer treatments to seven tree species.

Fertilizer	*%N leached*
SLF	32.2a
MU	24.3b
CRF	2.1c

Values followed by different letters are significantly different at P=0.05.

Table 6. N use efficiency of three fertilizer treatments, expressed as the ratio N uptake: N leached.

Fertilizer	*N uptake/N leached*
SLF	0.70a
MU	0.66a
CRF	3.74b

Values followed by different letters are significantly different at P=0.05.

Cumulative water use varied widely among species, from 9.5 gal (36 L) for *Prunus* to 35.4 gal (134 L) for *Platanus*. The cumulative water use of most of the species was between 9.5-13 gal. There was a substantial amount of variability in water use within species. As expected, daily water use was greater in summer months than in spring (Figure 2).

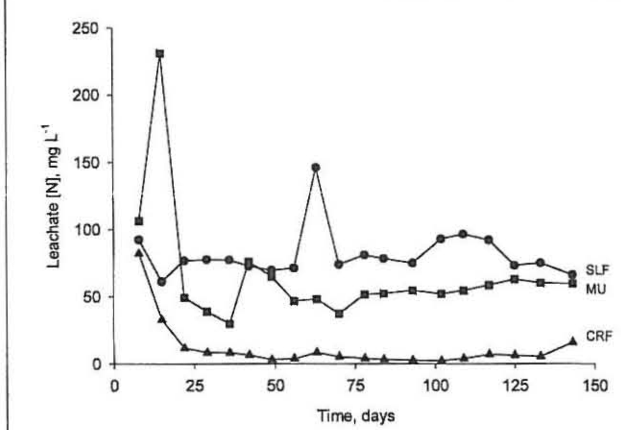

Figure 1. Leachate N concentrations among fertilizer treatments.

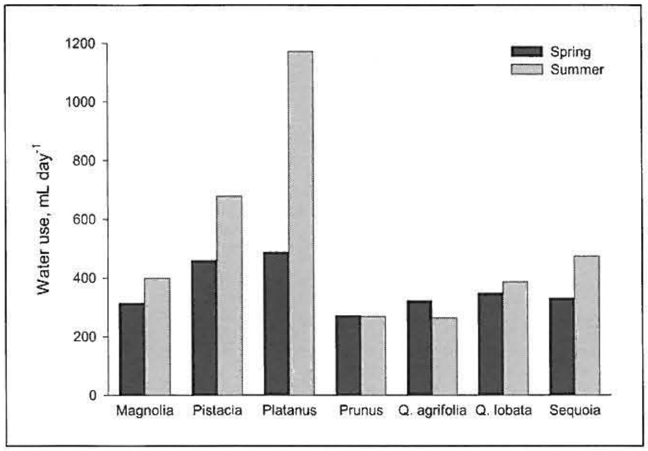

Figure 2. Average daily water use in spring and summer months for seven tree species growing in 5-gallon containers.

Fertilization of 5-gallon trees with controlled-release fertilizer was much more efficient than fertilizing by liquid feeding with either a traditional soluble N source or a slow-release source, such as polymethylene urea. Nitrogen demand, and fertilizer release rate appeared to be well matched in the case of CRF, so that even containers that received a high leaching fraction did not have high losses of N. Liquid feeding resulted in substantial leaching losses of N. The leaching fraction is not easily controlled under typical commercial nursery conditions because micro-sprinkler emitters may not maintain a uniform rate of delivery, and because water use within, and between species can vary widely.

Table 7. Ratio of N uptake to water use (in ppm) for seven tree species growing in 5-gallon containers.

Species	*N uptake/water uptake*
Magnolia	89
Pistacia	71
Platanus	135
Prunus	29
Q. Agrifolia	32
Q. Lobata	47
Sequoia	127

Average daily water use during the summer ranged from 200-1200 mL. Even the highest values of water use are less than half the volume that we estimate is typically delivered to plants of this size in commercial nurseries. The problem of leaching losses in a liquid feed system could be alleviated greatly by applying the appropriate amount of N, and water. By dividing total N uptake, in mg, by cumulative water use, in L, we can estimate the ideal concentration of applied N in ppm. For the slow-growing species in this study, a concentration of 30-50 ppm would meet this ideal (Table 7). Only the fastest-growing species should need a liquid feed N concentration in excess of 100 ppm.

Development of Irrigation and Nitrogen Fertilization Programs on Tall Fescue to Facilitate Irrigation-Water Savings and Fertilizer-Use Efficiency

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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 1997 estimate of $2.1 billion spent annually on turfgrass maintenance in California also is 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 best management practices (BMPs) also is important for the responsible use and protection of natural resources. Currently, there is considerable interest in developing and implementing turfgrass BMPs for addressing the following issues:

1. Water conservation.
2. The potential contamination of runoff water and groundwater with applied nutrients, especially NO_3-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 non-target organisms.
6. The potentially toxic effects of applied chemicals to non-target plants and animals.
7. The potential loss or degradation of native habitat during construction and turfgrass maintenance.
8. The reduction of landscape waste, including grass clippings that are 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 the importance of crop-water management and fertilizer-use efficiency, we developed a research and education project concerning 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 most likely range from 80% reference evapotranspiration (ET_0) per unit landscape area (AB325) to 100% ET_0 per unit landscape area.
2. Fertilization of turf grasses, according to established cultural strategies, presents a negligible potential for nutrient elements to pass through the root zone and into groundwater, or be transported by runoff water into surface waters. This has been confirmed by a number of earlier studies and 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 plant 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 NO_3-N leaching, this situation would be less likely to occur during the implementation of annual landscape water-use budgets of 80% to 100% ET_0 per unit landscape area.

In light of these assumptions regarding the management of tall fescue, we believe a valuable water management/N-fertility use efficiency project would involve the development of a balanced irrigation and N-fertility program. This research will take into consideration landscape water-use budgets and optimal annual N rates for tall fescue performance in terms of visual turfgrass quality and drought stress tolerance, growth, and N uptake.

OBJECTIVES

1. Test irrigating tall fescue at a defined annual amount (80% historical ET_0 plus rain) with increased irrigation during the warm season to improve turfgrass performance, and then proportionally adjusting the cool-season irrigation amount downward to make up for the additional warm-season irrigation. These treatments are compared to irrigating tall fescue at a constant rate of 1) 80% historical ET_0 plus rain and 2) 80% ET_0 (real-time) plus rain.
2. In conjunction with irrigation treatments, test the influence of the annual N-fertility rate on tall fescue performance.
3. Quantify the effects of irrigation and N-fertility treatments on visual turfgrass quality and drought stress tolerance, growth (clipping yield), and N uptake, along with treatment effects on soil water content and soil N status.
4. Develop BMPs for tall fescue relating to turfgrass water conservation and N-fertilizer use efficiency, which provide optimal performance in terms of visual turfgrass 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.

DESCRIPTION

This project involves the study and development of best management practices (BMPs) for landscape water conservation and N-fertility efficiency on tall fescue, currently the most widely planted turfgrass species in California. This 3-year field study investigates irrigation treatments that are designed to test irrigating tall fescue at a defined annual amount (80% historical ET_0 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 additional warm-season irrigation. These treatments are being compared to irrigating tall fescue at a constant rate of 80% historical ET_0 plus rain, and 80% ET_0 (real time) plus rain. In conjunction with the irrigation treatments, this study investigates N-fertilizer treatments designed to test optimal annual N rates for tall fescue performance in terms of visual turfgrass quality and drought stress tolerance, growth (clipping yields), and N uptake. We are also determining the influence of irrigation and N-fertilizer treatments on soil water content and soil N status. A detailed description of treatment, measurement, and plot-maintenance protocols was provided in the 1999 CDFA/FREP Conference Proceedings.

In the course of the study, we are also conducting outreach activities, including trade journal publications and oral presentations, reflecting both the ongoing research, and the importance of turfgrass BMPs in general. The presentations will evolve with the ongoing research and from audience evaluations. This will include an assessment of the current turfgrass management practices of the target audience, so that these practices can be modified in order to meet the requirements of generally accepted BMPs for turfgrass irrigation and N fertilization. Upon completion of this project, we hope to be able to provide the necessary information for maintaining acceptable tall fescue, complying with landscape water-use budgets, and efficiently applying N fertilizers. Considering that water use is the top environmental issue in California, and that tall fescue is currently the most widely planted turf grass in the state, there is a high potential that BMPs developed from this project will have immediate, and widespread adoption, by professional turf grass managers, personnel involved in the fertilizer industries, educators, consultants, and home-lawn owners.

RESULTS AND CONCLUSIONS

Several preliminary and general observations can be made concerning the data collected from Apr. 1998 to Dec. 2000.

In terms of irrigation, we are testing three treatments that are set at 80% historical ET_0 plus rain and one treatment set at 80% ET_0 (real time) plus rain. The former treatments require four irrigation clock changes per year, while the latter treatment requires 52 (weekly) clock changes per year. Our 80% historical ET_0 plus rain and 80% ET_0 (real time) plus rain treatments are comparable in the industry to 100% historical ET_0 plus rain and 100% ET_0 (real time) plus rain, respectively, because the distribution uniformity (DU) of our 12 irrigation cells (DU≈0.87) is probably 20% higher than DUs of typical landscapes. Thus, our irrigation treatments are consistent with current irrigation water budgets that range from 80% to 100% ET_0 (real time).

Irrigation and N-fertility treatments are significantly affecting the data. However, irrigation treatments are the dominant influence and actually mute the N-fertility influence (benefit).

Basically, no irrigation treatment has been successful in producing visual turfgrass quality and color ≥6.0 (1 to 9 scale; 1=worst, 5=minimally acceptable and 9=best visual turfgrass quality or color) during all four of the 3-month quarters. Generally, turfgrass performance was better during the January to March and April to June quarters than the July to September and October to December quarters.

Our data show that our 80% ET_0 plus rain amount (comparable to 100% ET_0 plus rain in the industry) is not sufficient irrigation to maintain tall fescue at a visual turfgrass quality of ≥6.0 for 12 months per year when grown in Riverside, Calif., on 100% of the landscape area. Obviously, most landscapes are not planted in 100% tall fescue.

The N-fertility rate treatments significantly affected visual turfgrass quality and color with higher ratings associated with higher N rates. Though our data has been dominated by irrigation-treatment effects, our N-fertility data show that N rate and source will be important factors in maintaining proper shoot growth and plant vigor while achieving 80% to 100% ET_0 landscape irrigation water budgets.

Minimizing Nitrogen Runoff and Improving Nitrogen and Water Use Efficiency in Containerized Woody Ornamentals

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OBJECTIVES

Determine the water and nitrogen (N) uptake of commercially important container-grown woody plants in relation to plant habit, developmental stage, and environmental conditions.

Determine the fate of ammonium (NH_4^+) and nitrate (NO_3^-) from granular control release fertilizers (CRF) and liquid fertilizers (LF) in containerized woody ornamentals growing in acid (5.0) or neutral (7.0) pH media during an 11-month period.

Develop fertilization and irrigation guidelines based on research results. Actively distribute guidelines to growers, CE advisors, consultants, fertilizer companies, and educators through workshops, field days, seminars, lectures, and publications.

DESCRIPTION

Horticulture is a 2.2 billion dollar industry in California. Over 70% of ornamental production is located in the coastal regions of Southern California, an area of the state where urban communities, agricultural developments, and protected wetlands are in close proximity to each other. Due to these geographical constraints, along with the high use of fertilizer and water by the industry, NO_3^- leaching from agricultural lands continues to threaten local drinking water supplies and the neighboring ecosystems. In an effort to prevent N contamination from different sources of pollution, the Total Maximum Daily Loads (TMDL) process and other regulations derived from the Clean Water Act have been enforced by local agencies, reducing the maximum allowable NO_3^- levels from 10 mg N/L to 1.0 mg N/L in some cases. Unless fertilization and cultural practices are restructured, many nurseries will be unable to comply with the new water quality control programs that have been implemented in recent years.

Nitrate leaching is a serious problem in the nursery industry because of several cultural practices. Production standards such as containerization (growing in containers), porous planting media, and high irrigation and fertilization rates are conducive to nitrification of ammonium (NH_4^+) and fertilizer leaching. Because of the limited root systems in container-grown plants, crops must be irrigated and fertilized frequently so that the small root volume can provide sufficient water and nutrients to the relatively larger shoot canopies. Consequently, N and water usage per acre by the nursery industry is often more than any other horticultural or agronomic crop, sometimes exceeding 500 lb /A per year in N fertilization, and 6 times the reference evapotranspiration (ET_0) for irrigation.

Nitrate runoff from nursery systems can be reduced in several ways:

1. *Plant Health* - optimize nutrient uptake into plants by maintaining healthy, and properly functioning root system.
2. *Media Quality* - optimize nutrient binding capacity of media so that fertilizers are not easily leached from the media.
3. *Fertilizer Source* - optimize nitrogen availability from fertilizers so that nutrients are available to the plants when needed.
4. *Irrigation* - optimize water availability so that the needs of the plant are met without excess water leaching from the media.

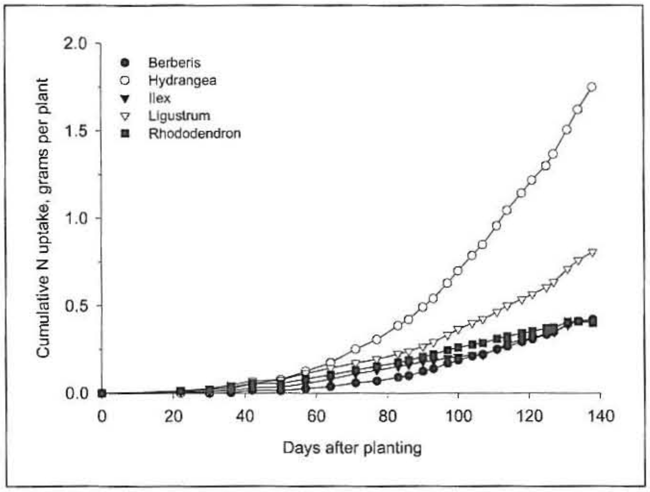

Figure 1. Cumulative N uptake.

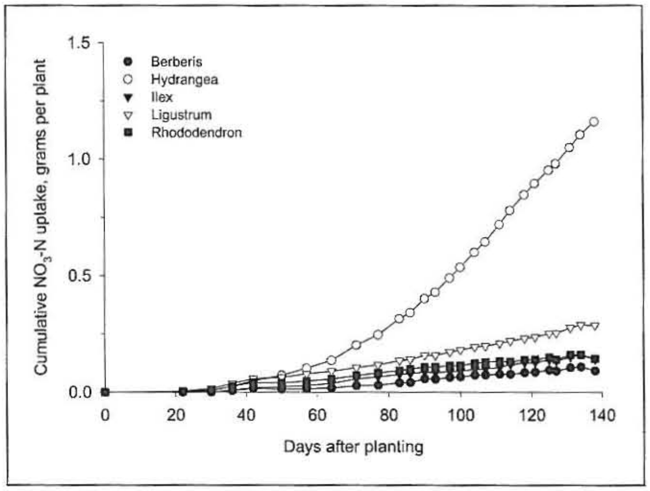

Figure 2. Cumulative NO_3-N uptake.

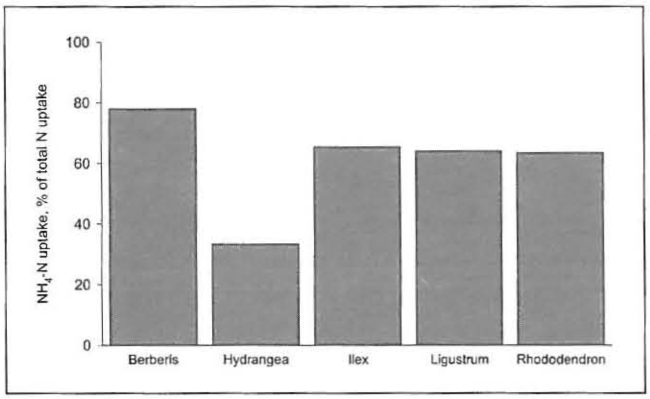

Figure 3. NH_4-N uptake as a percentage of total N uptake.

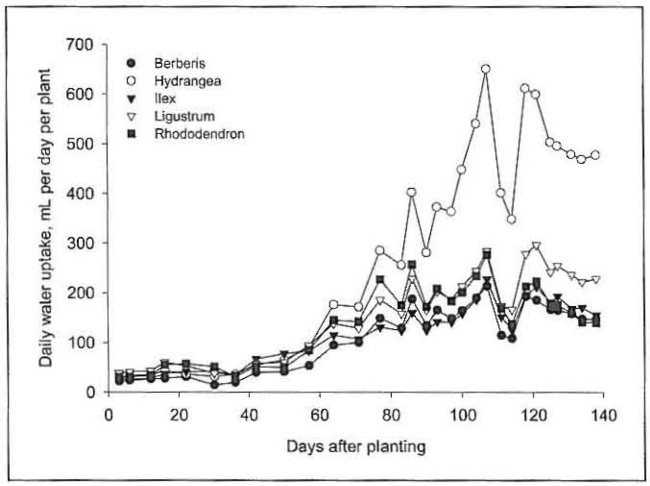

Figure 4. Daily water uptake rates.

Our projects are focusing on the last two objectives, fertilizer types and irrigation practices, since these programs can have a direct and immediate impact on NO_3^- leaching. The first study, being conducted at the University of California in Davis, will elucidate the N and water requirements of five different woody ornamentals. The second study, conducted at the University of California in Riverside will characterize the dynamics of N release and utilization from seven different fertilizer formulations: four granular controlled release fertilizers, and three liquid fertilizers. Based on the data from these two studies, we will be able to develop fertilization and irrigation programs that will optimize plant growth while simultaneously minimizing NO_3^- leaching.

RESULTS AND CONCLUSIONS

Project 1: Determining Nitrogen and Water Requirements

Five woody ornamental species *(Berberis thunbergii, Hydrangea macrophylla, Ilex aquifolium, Ligustrum lucidum, and Rhododendron sp.)* were used in the trial. These species are commonly known as barberry, hydrangea, English holly, privet and azalea, respectively. The plants were obtained in Spring 2001 as 2-inch liners, planted into 4-L static solution culture containers, and placed on benches in a lath-house at the UC Davis, Department of Environmental Horticulture. The composition of the nutrient solution used during most of the experimental period was 2 mM $MgSO_4$, 1 mM K_2SO_4, 1 mM KH_2PO_4, 2 mM NH_4NO_3, $CaSO_4$ at 0.43 g/L, and micronutrients at full-strength Hoagland's solution concentrations. Acidity was adjusted to pH 6, and solutions were changed every 3-4 days to maintain sufficient amounts of water and nutrients in the containers. From day 128 to day 138, the solution for half of the plants of each species was maintained between pH 4.5-5.

The weight of the nutrient solution in each container was determined before and after each solution change for calculation of water use and N uptake. The concentration of NO_3^-

Table 1. Average daily uptake of N (in mg), water (in mL), and the ratio of total N uptake to water uptake, in mg/L.

	mg N	mL water	mg N/L
Berberis	6.4	160	39.9
Hydrangea	25.3	470	54.0
Ilex	5.1	169	30.2
Ligustrum	11.0	226	48.7
Rhododendron	4.4	187	23.3

N and NH_4-N in the nutrient solution was determined before and after each change by the diffusion-conductivity method. Plant fresh weight was determined at each nutrient solution change after lightly blotting the roots to remove excess nutrient solution water.

Cumulative total N uptake varied greatly by species (Fig. 1). Total N uptake by *Hydrangea* was twice as great as uptake by any other species. This difference was even more pronounced for NO_3-N uptake (Fig. 2). With the exception of *Hydrangea,* all of the species under study took up more NH_4-N than NO_3-N (Fig. 3). Lowering the solution pH did not significantly affect plant preference for NH_4-N or NO_3-N.

During the first 50 days of growth, average daily water uptake of all five species was 50-75 mL per day (Fig. 4). After about 3 months of growth, average water uptake rates for most of the species were between about 160-225 mL per day (Table 1). The exception was *Hydrangea,* for which the average had increased to 470 mL per day. These rates of water use are lower than estimated irrigation application rates at most commercial nurseries.

The ratio of N uptake to water uptake yields a value for the ideal nutrient solution N concentration for a liquid feed system (Table 1). The highest ratio occurred in *Hydrangea* (54 mg/L) and the lowest in *Rhododendron* (23 mg/L). All of these values are substantially lower than the liquid feed N concentrations applied in most commercial nurseries.

The growth habits and soil preferences of the species studied are representative of the range typically found in commercial nurseries. The results will be useful to growers who seek finer adjustment of application rates of N and water, as well as to fertilizer companies and others who wish to match N application rates or release rates to woody ornamental crop needs.

Table 2. Fertilizer treatments for Project 2, which will determine nitrogen use efficiency from different fertilizer types.

Treatment	Fertilizer Rate	Fertilizer Type
1	100 ppm N as NH_4^+	LF
2	100 ppm N as NH_4NO_3	LF
3	100 ppm N as NO_3^-	LF
4	2.4 lb N/yd^3	Osmocote 17-7-12
5	2.4lb N/yd^3	Apex 17-5-11
6	2.4 lb N/yd^3	Multicote 17-5-11
7	2.4 lb N/yd^3	Nutricote 18-6-8

Project 2: Nitrogen Use Efficiency From Granular Controlled Release and Liquid Fertilizers During an 11 Month Growing Period

This study, conducted in Riverside, is currently in progress. Two plant systems: ligustrum growing in neutral pH (7.0) media and azalea growing in acid pH (4.5) media are being studied. There are seven treatments for each plant type (Table 2).

Leachates are being collected weekly to determine NH_4^+ and NO_3^- leaching. Five replications of each treatment are being harvested monthly to determine total N uptake into plants, and total N remaining in media.

Based on the combined data from these two projects, new information will be learned regarding N and water requirements of the crops as well as the dynamics of N cycling in media, N uptake into plants, and N leaching, with comparisons being made between different fertilizer sources. This information will be used to develop fertilizer and irrigation protocols that will reduce NO_3^- leaching and improve N use efficiency in the nursery industry.

Nitrogen Mineralization Rate of Biosolids and Biosolids Compost

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PROJECT OBJECTIVES

1. Determine the short- and long-term N mineralization rates of dewatered, air-dried or composted biosolids.
2. Determine if short-term incubation assays, or laboratory analytical procedures, are predictive of field mineralization rates.

PROJECT DESCRIPTION

The disposal of biosolids is one of California's vexing environmental problems. Application on agricultural land represents the most beneficial use of this nitrogen-rich material. However, without a sound understanding of N mineralization behavior of the common biosolids products (dewatered, air-dried or composted), it is impossible to determine appropriate field application rate to supply the desired agronomic benefit without creating a nitrate pollution hazard. Information on N availability from biosolids under central California field conditions is extremely limited. This project proposes to develop short- and long-term N availability estimates for representative biosolids products and through field studies and laboratory assays, to examine the effects of soil type, cropping system, and loading rate on N mineralization dynamics. Furthermore, the ability of laboratory analytical procedures, or short-term incubation assays to predict N mineralization behavior will also be investigated.

A total of 104 microplots were established at UC Davis in early June 2000. These microplots were filled with either a sandy loam or a clay loam soil from fields under standard row crop rotations. These microplots were amended with various biosolids materials collected from waste treatment plants in several metropolitan areas of California. The biosolids materials used were:

a) air-dried biosolids, from a Central Valley city

b) air-dried biosolids from a Sacramento Valley city

c) digested, dewatered biosolids from a Central Valley city

d) digested, dewatered biosolids from a Bay Area city

e) composted biosolids from a North Coast city

f) composted biosolids from a Los Angeles basin city

The air-dried and dewatered samples were applied to the microplots on June 8, 2000, at a rate equivalent to a field application of 8 dry tons per acre. Due to the lower N content, and assumed slower mineralization rate, the composts were applied at a rate equivalent to 16 dry tons per acre. Initial N and moisture contents are listed in Table 1. Immediately following application, the samples were manually incorporated into the soil to simulate disking in the field.

On June 14, 'Piper' sudan grass was sown in 76 of the microplots. An automated irrigation system was constructed to maintain the microplots between field capacity and approximately 70-centibar tension. All leachate was collected for analysis of mineral N concentration (NH_3-N and NO_3-N).

On August 24, the aboveground sudan grass biomass was harvested, and oven-dried. Total N concentration in the sudan grass was determined by a standard laboratory technique. The sudan grass was allowed to regrow until October 25, when it was harvested again and biomass N content again determined.

The remaining microplots were allowed to remain fallow until November 9, 2000, when they were planted with "Yolo'

Table 1. Initial biosolids characteristics.

Biosolids sample	*Type*	*%N (dry wt basis)*	*Initial % moisture (dry wt basis)*[z]
A	Air-dried	5.7	28
B	Air-dried	4.6	41
C	Dewatered	3.9	410
D	Dewatered	4.8	380
E	Composted	2.2	60
F	Composted	0.9	108

[z]calculated as [(initial wet weight–dry weight)/dry weight]*100

Table 2. Apparent N availability from biosolids samples in the sudan grass bioassay.

Soil	Biosolids sample	Total biomass (dry g/plot)	Biomass N (g/plot)	Leachate N (g/plot)	Apparent biosolids N availability (% of initial N)[z]
Sandy loam		465	5.1	0.4	
	A	522	8.8	0.9	21
	B	575	8.2	0.5	20
	C	588	8.9	0.6	29
	D	608	10.1	0.5	30
	E	554	7.2	0.4	13
	F	425	5.0	0.7	3
Clay loam		191	1.9	0.1	
	B	466	5.0	0.2	19
	D	540	7.0	0.1	30
	F	198	2.1	0.1	2

[z]sudan grass biomass N + leachate N, minus those quantities from plot of unamended soil

wheat. A rain exclusion shelter was constructed over these microplots to allow for control of soil moisture status. These microplots will be kept moist and the wheat allowed to grow to crop maturity in early summer, 2001.

RESULTS

Sudan grass growth and biomass N accumulation differed substantially between soil types (Table 2). Whether this was due to inherent differences in soil N fertility or in soil physical characteristics (structure, aeration, etc.) was unclear. However, the degree of apparent N availability from the biosolids samples was very consistent between soil types. The average apparent N availability from the three biosolids samples used with both soil types (samples B, D, and F) averaged 18% and 17% of initial N content in the sandy loam and clay loam soils, respectively.

The three types of biosolids products (air-dried, dewatered, and composted) behaved quite differently. Dewatered biosolids (samples C and D) showed apparent N availability of approximately 30% of initial N content, compared to an average of 20% for air-dried products and only 8% for composts. The clear trend was for greater N availability with the 'fresher' products. The two samples of dewatered biosolids

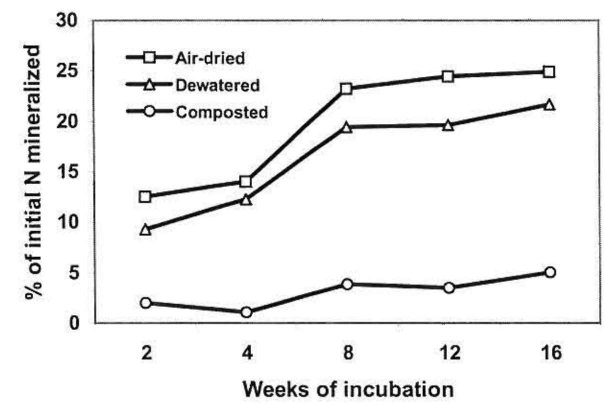

Figure 1. Net N mineralization of various biosolids materials in 16 weeks of laboratory incubation.

behaved virtually identically, as did the two samples of air-dried material. The substantial difference in the behavior of the two compost samples was predictable from their initial characteristics. Sample E had relatively high N content for compost (2.2%), indicative of a relatively high biosolids content. By contrast, sample F was predominately marginally composted green waste, which was evident visually as well as from the low N content (0.9%). Sample F was nearly N neutral, whereas sample E had apparent N availability of 13%, consistent with that expected of common animal manure-based composts.

A parallel laboratory study was conducted in which net N mineralization was estimated from aerobic incubation of biosolids-amended soil under constant temperature (77oF) and moisture (field capacity). At 2, 4, 8, 12, and 16 weeks samples were analyzed for mineral N content (NH4-N and NO3-N); the increase in mineral N over time in the biosolids-amended soil, minus the increase in unamended soil, represented net N mineralization from the biosolids samples. The incubation study gave similar results to the sudan grass microplot study (Fig. 1). The dewatered (samples C and D) and air-dried (samples A and B) biosolids showed 20-25% of original N content mineralized over the 16 weeks, with the composts (samples E and F) averaging just 5%. N mineralization was rapid in the first 8 weeks, with minimal mineralization over the remaining 8 weeks.

Development of an Educational Handbook on Fertigation for Grape Growers

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INTRODUCTION

In the past decade, the vineyard industry in California has adopted micro irrigation as the principle method of irrigation. Micro irrigation includes drip and low volume sprinklers. These systems allow water to be precisely and efficiently applied below the canopy of the vineyard, and directly to the soil above the root area of the vines. Consequently, fertilizer can be injected into the irrigation water and also be applied precisely in this zone. This process is known as "fertigation" or "chemigation."

Other technologies that have improved include affordable and accurate fertilizer injection pumps, soluble fertilizers, and equipment that can effectively suspend fertilizers and soil amendments into irrigation water.

PROJECT OBJECTIVES

This project is to develop an illustrated handbook for growers to assist them in developing environmentally safe and effective fertigation programs for their vineyards.

PROJECT DESCRIPTION

The primary focus of the book is how to utilize drip irrigation systems to deliver fertilizers to vines. The book is illustrated, and easy to read and understand. The following topics are covered:

- Nutritional needs of grape vines, and how to determine nutrient status in grape vines and soils
- Equipment needed for fertigation and how to design and install it (including backflow prevention
- Water quality issues and cautions to prevent system clogging
- Strategies for applying materials
- Fertilizer materials and their suitability for drip irrigation
- Charts and tables to assist growers in determining concentrations and application amounts to apply to known vineyard areas
- Environmental cautions on the storage and use of fertilizers, especially concentrated materials
- Monitoring to measure the effectiveness of the fertilizer applications and system performance

When finished, and published, this book will be a useful resource for vineyard managers that want to apply fertilizer materials through their drip systems in an effective and efficient manner.

Air Quality and Fertilization Practices: Establishing a Calendar of Nitrogen Fertilizer Application Timing Practices for Major Crops in the San Joaquin Valley

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INTRODUCTION

Volatilization of nitrogen from nitrogen fertilizer at or near the time of application is a possible source of nitrogen oxides and ammonia in the atmosphere. Nitrogen oxides can play a role in generating ozone. Nitrogen oxides and ammonia together can play a role in generating PM10.

OBJECTIVES

1. Establish, by means of interviewing farmers, a calendar of nitrogen fertilizer application timing practices for major crops in the San Joaquin Valley.
2. Report information on rate, source, and method of application of nitrogen fertilizer gathered in the course of interviewing farmers for the nitrogen fertilizer application calendar.
3. Identify crop production regions in the San Joaquin Valley.
4. Identify precise time indicators for the application of nitrogen fertilizer in the San Joaquin Valley.

PROJECT DESCRIPTION

Target crops for this survey were selected on the basis of acreage per county. (Table 1) The distribution of major crops selected as target crops by county is as follows:

Fresno	16
Tulare	14
San Joaquin	12
Kern	11
Merced	10
Stanislaus	8
Madera	7
Kings	5

The goal of this survey was to have at least two farm interviews conducted per target crop per county. For all of the crops reported here, this goal was achieved or surpassed.

Table 1. County X Crop X Acreage Distribution with a T indicating a target county/crop for interviews.

	KERN	TULARE	KINGS	FRESNO	MADERA	MERCED	STANISLAUS	SAN JOAQUIN
Lettuce	3,208	0	0	22,360 T	0	0	0	0
Potatoes, Sweet Potatoes	23,307 T	0	0	0	0	7,858	1,482	3070
Tomatoes	5,040	0	4,657	106,710 T	20,367 T	21,990 T	1,369	38230 T
Vegetables, Melons	71,163 T	11,432 T	9,611	111,300 T	0	16,479 T	19,389 T	48900 T
Barley	13,824 T	7,000 T	9,709	6,580	1,056	4,200	1,700	367
Corn	0	139,000 T	42,179 T	25,100 T	15,333	73,583 T	57,650 T	96200 T
Safflower	7,800	0	32,298 T	2,840	0	114	0	14300 T
Wheat	72,000 T	59,100 T	65,500 T	64,300 T	14,000 T	21,663 T	8,370	40600 T
Alfalfa	120,000 T	104,000 T	47,024 T	76,300 T	37,313 T	77,479 T	40,844 T	63800 T
Grain and Wild Hay	25,000 T	0	3,226	46,800 T	0	26,959 T	27,700 T	19000
Cotton	193,720 T	62,100 T	156,329 T	302,400 T	27,130 T	68,772 T	0	0
Dry Beans/Peas	6,331	7,600	8,074	15,300 T	2,100	6,102	18,900 T	22300 T
Sugar Beets	5,191	3,760	3,446	27,800 T	440	12,658 T	0	7600
Almonds	79,587 T	13,395 T	2,097	49,968 T	43,635 T	74,182 T	87,000 T	38500 T
Citrus	43,647 T	109,893 T	0	28,230 T	3,931	0	0	0
Cherries	0	476	0	0	0	0	1550	12500 T
Grapes	81,289 T	76,225 T	4,870	221,179 T	86,708 T	15,502	13,000	76800 T
Olives	1,154	16,621 T	0	1,456	1160	0	0	0
Peaches	2,091	13,169 T	4,024	20,019 T	876	6,101	9,220	2190
Pistachio	25,932 T	7,266	5,670	3,989	17,854 T	4,437	0	0
Plums	2,379	23,011 T	1,721	17,871 T	2,150	2,125	0	0
Walnuts	1,461	27,346 T	6,719	3,239	977	5,218	27,630 T	39300 T
Irrigated Pasture	8,000	86,200 T	10,000					
40,000 T	5,500	58,500 T	75,000 T	23900 T				

Based on: California Farmer, CALIFORNIA AT A GLANCE, A comprehensive analysis of acreage, head and dollar values for California's principal crop and livestock commodities by county and state totals. 1998 Crop Year. Published: August 1999. Crops not qualifying in any county as target crops were removed from this list.

Names of farmers growing target crops were obtained from the California Cotton Growers Association, the Nisei Farmers League, referrals from other farmers and farm bureaus in the following counties: Kern, Tulare, Fresno, Madera, Merced, Stanislaus, and San Joaquin.

The interviews covered the following questions: crop acreage, timing of nitrogen applications, nitrogen fertilizer used, and the amount of actual nitrogen applied.

RESULTS AND CONCLUSIONS

Spring and Summer Nitrogen Fertilizer Application Calendar

Alfalfa—Fifteen percent of alfalfa growers interviewed applied an average of 30 lbs./acre of nitrogen sometime during the months of April, May, June, and July. Quantities of nitrogen applied ranged from 22lbs/acre to 60 lbs./acre. Sixty percent of these farmers broadcast1 and then watered in 11-52-0. Twenty percent water ran CAN17 and twenty percent water ran ammonium sulfate.

Almonds—All almond growers interviewed applied nitrogen fertilizer to their almonds sometime during the time period of March through September. Amounts of nitrogen applied averaged 150 lbs./acre and ranged from 50 lbs./acre to 350 lbs./acre. Seventy-five percent of these farmers used UN32 as their source of nitrogen. Fifteen percent of these farmers used CAN17 as their source of nitrogen. The remaining fifteen-percent used various mixes of fertilizer or manure. Fifty-five percent of these farmers applied nitrogen to their almonds via a pressurized irrigation system. Thirty percent broadcast the nitrogen and then watered it in. Ten percent shanked the nitrogen in. Five percent ran the nitrogen with flood irrigation.

Table 2 Nitrogen fertilizer application calendar for selected target crops for spring and summer

CROP	MAR	APR	MAY	JUN	JUL	AUG	SEP
Alfalfa[1]		-----	-----	-----	-----		
Almonds	-----	-----	-----	-----	-----	-----	-----
Citrus	-----	-----	-----	-----			
Corn		-----	-----	-----	-----	-----	
Cotton	+++++[2]	++++++	-----	-----	-----		
Wheat	++++++						

[1]See narrative below for each crop.
[2]See narrative under Table 3 for + symbols.

Table 3 Nitrogen fertilizer application calendar for selected target crops for fall and winter

CROP	OCT	NOV	DEC	JAN	FEB
Alfalfa[1]			+++++	+++++	+++++
Almonds	+++++				
Citrus				+++++	+++++
Corn					
Cotton	+++++	++++++	+++++	+++++	+++++
Wheat		++++++	+++++	+++++	+++++

[1]Please see narrative below for each crop.

Corn—Ninety-five percent of corn growers interviewed applied nitrogen fertilizer to their corn sometime during the time period of April through August. The remaining five- percent used manure as a source of nitrogen. Amounts of nitrogen applied averaged 205 lbs./acre and ranged from 120 lbs./acre to 305 lbs./acre. Fifty-five percent of these farmers used UN32 as their source of nitrogen. Fifteen percent of these farmers used urea as their source of nitrogen. Anhydrous ammonia, ammonium sulfate and various blends each accounted for ten percent of the nitrogen fertilizer applied by corn growers. Fifty-five percent of these farmers applied nitrogen to their corn by means of shanking it in. Twenty percent broadcast the nitrogen and then watered it in. Fifteen percent watered the nitrogen in with furrow or flood irrigation.

Cotton—All of the cotton growers interviewed applied nitrogen fertilizer to their cotton sometime during the time period of May through July. Amounts of nitrogen applied averaged 120 lbs./acre and ranged from 70 lbs./acre to 200 lbs./acre. Eighty percent of these farmers used UN32 as their source of nitrogen. Fifteen percent of these farmers used anhydrous ammonia as their source of nitrogen. Ammonium sulfate accounted for five percent of the nitrogen fertilizer applied by cotton growers. Fifty-five percent of these farmers applied nitrogen to their cotton by means of shanking it in. Twenty percent broadcast the nitrogen and then watered it in. Fifteen percent watered the nitrogen in with furrow or flood irrigation.

Wheat—See narrative under Table 3.

Fall and Winter Nitrogen Fertilizer Application Calendar

Alfalfa—Eighteen percent of alfalfa growers interviewed applied an average of 25 lbs./acre of nitrogen sometime during the time period of December through February. Quantities of nitrogen applied ranged from 22 lbs./acre to 40 lbs./acre. All of these farmers broadcast and watered in 11-52-0.

Almonds—Thirty-three percent of almond growers interviewed applied nitrogen fertilizer to their almonds sometime during the month of October. Amounts of nitrogen applied averaged 70 lbs./acre and ranged from 35 lbs./acre to 100 lbs./acre. Eighty percent of these farmers used UN32 as their source of nitrogen. The remaining fifteen- percent used various mixes of fertilizer. Forty-five percent of these farmers broadcast the nitrogen and then watered it in. Thirty-five percent applied nitrogen to their almonds via a pressurized irrigation system. Twenty percent shanked the nitrogen in. Five percent ran the nitrogen with flood irrigation.

Corn—None

Cotton—Forty-five percent of cotton growers interviewed applied nitrogen fertilizer to their cotton sometime during the time period of October through April. Amounts of nitrogen applied averaged 85 lbs./acre and ranged from 17 lbs./acre to 150 lbs./acre. Forty-five percent of these farmers used various fertilizer blends as their source of nitrogen. Thirty-five percent used UN32 as their source of nitrogen. The remaining twenty- percent used anhydrous ammonia as their source of nitrogen. Eighty-five percent of these farmers shanked the nitrogen in. Fifteen percent broadcast the nitrogen and watered it in.

Wheat—Seventy percent of wheat growers interviewed applied nitrogen fertilizer to their wheat sometime during the time period of November through March. (The remaining fifteen- percent either used manure or depended on the residual nitrogen from a previous crop for nitrogen for their wheat crop.) Amounts of nitrogen applied averaged 80 lbs./acre and ranged from 0 lbs./acre to 200 lbs./acre. Twenty-five percent of these farmers used urea as their source of nitrogen. Twenty percent used UN32 as their source of nitrogen. Fifteen percent used anhydrous ammonia as their source of nitrogen and ten percent used ammonium sulfate. The remaining thirty- percent did not use chemical fertilizer as a source of nitrogen for their wheat crop. Fifty-five percent of these farmers broadcast the nitrogen and watered it in or disced it in. Twenty-five percent of these farmers watered the nitrogen in by means of sprinklers or flood irrigation. Fifteen percent shanked the nitrogen in.

Crop Production Regions in the San Joaquin Valley

Identifying target crops had the effect also of identifying some production regions in the San Joaquin Valley.

Only alfalfa qualified as a target crop in all eight counties of the San Joaquin Valley. Wheat qualified as a target crop in every county except one, Stanislaus, as did almonds, which qualified as a target crop in every county except Kings. Corn and cotton were also well distributed. Corn qualified as a target crop in all counties except Kern and Madera. Cotton qualified as a target crop in the six southern counties of the San Joaquin valley but not in the northern two.

There was also a series of one county crops. These crops qualified as target crops in only one county and are as follows: Olives/Tulare, Cherries/San Joaquin, Potatoes/Kern, Lettuce/Fresno and Safflower/Kings.

The citrus belt was clearly identified with citrus qualifying as a target crop in Kern, Tulare and Fresno counties. Also the center of stone fruit production in the San Joaquin Valley was identified with peaches and plums qualifying as target crops only in Fresno and Tulare counties.

Precise Time Indicators

Only one precise time indicator was identified and it was an obvious one. In the event of a wet winter and spring, a lot of nitrogen will be applied during the brief, dry interludes.

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[1]For the purposes of this survey, "broadcast" refers to any method of applying fertilizer to the surface of the soil whether by dribbling or spraying liquid or spreading dry fertilizer. Nitrogen fertilizer that has been broadcast is usually watered in with flood irrigation. Sometimes it is "rained" in or disced in.

Long-Term Nitrate Leaching Below the Rootzone in California Tree Fruit Orchards

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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. For regulatory purposes (implementation of basin water plans, TMDLs, drinking water protection), it is commonly assumed that nitrogen leaving the root zone is transferred directly to groundwater. Few studies have surveyed nitrogen levels or denitrification rates at depths below the root zone 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

APPROACH

Background: During 1997-98, we drilled and characterized approximately 3000 ft. of geologic material from 60 cores drilled to groundwater at 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: The annual fertilization rates had been less than 5 lbs/ac in the first subplot (0 lbs/ac treatment), 100 lbs/ac in the second subplot, and 325 lbs/ac in the third subplot. Drilling and field analysis during the initial months of the project provided a detailed characterization of the geologic architecture that makes up the vadose zone underneath the orchard.

Work Plan: The focus of the first project year 1998-99 was the distribution of water and nitrate in the vadose zone underneath the three subplots; and initiation of other hydraulic and chemical laboratory analysis. During the past two years (1999-2001; 1.5 funding years), we continued both chemical and hydraulic laboratory analysis. Chemical analysis focused on microbial carbon and total carbon distribution as indicator for denitrification; and on the development and initial implementation of the analytical protocol for nitrogen isotope analysis. Hydraulic analysis was implemented in two steps: first, completion of multistep outflow experiments that are designed to determine the transmissive and water storage properties of soil samples at various moisture levels; second, implementation of the inverse modeling analysis of the over one hundred multistep outflow experimental results. During the coming year (0.5 funding years) we will complete the geochemical characterization of the core samples, and implement a geostatistical analysis of the extensive field database that this project has provided. In particular, we will use scaling theory to interpret the spatial variability of soil properties, to integrate the small scale measurements across the entire orchard, and to provide the basis for vadose zone modeling. Our work will 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 obtained from the cores is the result of the geologic-hydraulic-geochemical architecture.

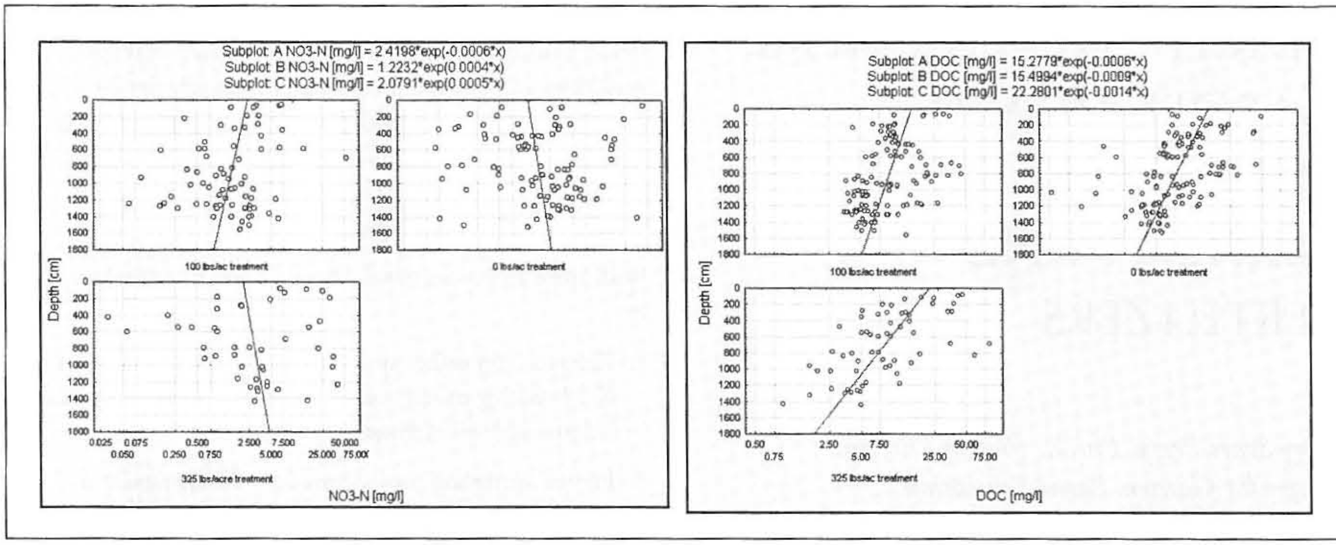

Figure 1. Nitrate-N (left) and dissolved organic carbon (right) as a function of depth and fertilizer treatment. The exponential regression models are given above the plots. Note that the independent variable in the regression model is depth (y-axis). The exponential model is equivalent to linear relationship between the log-transformed concentration and depth (hence, the linear-log plot above yields a straight line for the regression curve).

RESULTS

Work Progress, Geochemical Characterization: Analysis of soil extracts from all the core depths for microbial carbon, nitrate and ammonium is complete (Fig 1). As expected, microbial carbon generally declines with depth but also varies according to soil texture. Similar results have been seen for nitrate. Bromide was applied to selected plots of the orchard one year prior to drilling. No correlation was found between shallow bromide and nitrate concentrations or bromide and depth concentration suggesting large variability in the penetration depth of the bromide. We have completed development of the analytical protocol for N-15 analysis and begun analysis of soil samples, but the analytical instrumentation for our originally planned O-18 analysis is not available. Initial results of the N-15 analysis suggest that significant denitrification occurs in the soil profile.

Work Progress, Hydraulic Characterization: The multistep outflow experiments were implemented on over 100 undisturbed cores representing 9 major textural classes identified in the field cores: sand, loamy sand, sandy loam and silty loam to sandy loam, Hanford fine sandy loam (surface soil), loam, clay loam, clay, hardpan, deep paleosol. The undisturbed soil cores were taken during the original drilling in 1997. They are approximately 2 inches long and 1.5 inches in diameter. After developing the experimental protocol for the multistep outflow experiments in 1998/99, the experiments were implemented in sets of ten cores at a time. Each set takes approximately two to three weeks for setup and implementation. In principle, the experiment is a step-wise, controlled drying experiment: After saturating the core with water, air pressure is applied to one end of the core, thereby "driving out" water at the other end. The core is forced to dry out in multiple steps by stepwise increasing the pressure. We monitor how quickly the soil moisture inside the core changes in response to each pressure step; and we monitor how much water leaks out of the core as a result. Soil moisture and outflow are recorded automatically with sensoring equipment connected to a computer. After completion of each experiment, the measurement data are cleaned up and converted into meaningful units utilizing laboratory-derived calibration curves.

Water drainage from the soil core is a unique function of the hydraulic properties of the soil material. To compute the hydraulic properties of the soil core, the experiment is repeated in computer simulations. The hydraulic parameters of the computer model are adjusted until results from the computer simulation match the measurements from the outflow experiment. This process is referred to as "inverse modeling" or "parameter estimation". We completed the parameter estimation of each of the over 100 experiments and are implementing (geo)statistical analysis of the results. The large set of hydraulic parameters will be critical in assessing and understanding the transport pattern of nitrogen through thick unsaturated material of alluvial origin. These types of unsaturated zones are the most common buffer between California's intensively cropped agricultural regions and their groundwater resources.

TEACH THE TEACHERS: GARDEN-BASED EDUCATION ABOUT FERTILITY AND FERTILIZERS

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INTRODUCTION

Currently, there is a great deal of interest in integrating garden-based learning into K-12 classrooms, stimulated by State Superintendent of Instruction Delaine Eastin's call for *A Garden in Every School.* The emphasis is on addressing the various curricular standards such as science, literature, social studies, nutrition, mathematics, and art through garden-based themes. To that end, Cal Poly Pomona has been designated and provided funding since 1999 as one of three Regional Support Centers by the California Department of Education. Our charge is to reach out to schools, and teachers in our region (eastern Los Angeles County, western San Bernardino County, and part of Riverside County) to provide support and training in garden-based learning.

This program will soon be housed at AGRIscapes, a 40-acre demonstration and education center for food, agriculture, and the urban environment on the Cal Poly Pomona campus. AGRIscapes is slated to open in mid-September 2001, and will include a visitor center with interactive exhibits, a farm store, nursery, classroom building, offices, and 30 acres of demonstration plots and gardens. We have a unique opportunity to reach out to an urban public that is very much disconnected from the source of its food, and the systems which provide it.

PROJECT OBJECTIVES

The project objectives have been integrated into the ongoing programs already established by the RSC such as our annual school gardening conference and resource fair, our hands-on workshop series, and our communication vehicles such as a newsletter and website (which is still undergoing development). In addition, the opening of AGRIscapes, which we anticipate in Fall 2001, will provide a site for additional teacher and student education.

With these aspects in mind, the objectives of this project are to:

1. Research and gather appropriate curricular materials for K-12 relating to soil science, plant nutrition, soil/water relations, and soil management.
2. Present workshop component on soils, fertility, and soil/water relations.
3. Include presentations on these topics at the annual conference.
4. Involve appropriate organizations in Teacher's Resource Faire at annual conference.
5. Include resources and information on website, in resource guide, and in newsletter.
6. Research, design, and implement field experiment stations for appropriate grade level(s) for hands-on demonstrations of the principals of soil science, plant nutrition, soil management, and soil/water relations to be installed at AGRIscapes.

PROJECT DESCRIPTION

In addition to the specific tasks listed above under objectives (which are ongoing), a primary focus of the project has become a workshop series for middle school science teachers on topics such as insect taxonomy and adaptation, soil chemistry and physics, plant biotechnology, and plant propagation. This series will tie these topics and how they relate to agriculture directly to science standards in life science, physical science, and earth science which are taught by 6-8 grade teachers. This four-day workshop will be held in Fall 2001.

RESULTS AND CONCLUSIONS

While much of the work of this project is ongoing, we have found so far that there is a great deal of information including classroom materials, tools, and lab equipment that can be adapted to lessons on soil science and plant fertility. While some of this material is developed for the study of earth science and geology, it can be adapted for more applied situations. However, teachers need to be educated on how to use these materials in the classroom.

It has become further evident that there is a great deal of emphasis in garden-based education on K-6 curriculum and activities. Through our workshops, we have learned from middle-school science teachers who have attended that they struggle to find good applications for their garden-based activities to science standards, particularly in physical science. We saw a ready application for soil, water, and fertility lessons. Thus, the development of a specific professional development opportunity for middle school science teachers was undertaken.

We are planning to offer the workshop during October of 2001, but already there is interest among teachers, and from those who work with teachers on garden-based themes. This appears to be a unique offering and we are anticipating an excellent learning experience for the teachers who participate, and for ourselves, so that we can continue to improve these workshops in the future.

On-Farm Monitoring and Management Practice Tracking for Central Coast Watershed Working Groups

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INTRODUCTION

The Coalition of Central Coast County Farm Bureaus (CCCCFB) represents six County Farm Bureaus in the development and implementation of voluntary, cost-effective, producer-directed programs to protect water quality in the greater Monterey Bay watershed. CCCCFB is utilizing existing industry networks to establish local watershed working groups made up of farmers, ranchers, and timber landowners. The role of the working group is to identify problem sites, and develop and carry out local agricultural watershed protection plans to assess and control nonpoint pollution on a voluntary basis. The watershed working groups inventory existing water quality protection measures, identify water quality improvement projects, and track management practice improvements. Technical assistance agencies have identified useful self-monitoring techniques, necessary equipment, and data collection methods that producers can utilize to respond proactively to concerns over non point source pollution. As part of this Fertilizer and Research Education Program (FREP) project, the CCCCFB has compiled those methods into a guide that will be used to train agricultural producers. Each of the six County Farm Bureau Agricultural Water Quality Programs is using the guide to purchase monitoring and tracking equipment that will be made available to watershed working group participants to guide their management practices. UC Cooperative Extension Office in San Luis Obispo is finalizing the curriculum for Farm Water Quality Planning (FWQP) short courses, and will also use the guide in the monitoring component of the courses. By participating in the on-farm monitoring and management practice tracking, producers are taking advantage of the opportunity to respond to water quality problems voluntarily. This FREP project is not conducting actual water quality research. It is helping to identify areas where new research can be developed that would be the most helpful to Central Coast producers.

PROJECT OBJECTIVES

1. Gather existing information on tool kits, self-monitoring/tracking methods, and necessary equipment available to producers related to water quality. Provide needs assessment and a feedback loop from producers to research/technical assistance organizations.
2. Purchase self-monitoring equipment to be housed at County Farm Bureau Offices. Train County Farm Bureau Agricultural Water Quality Program Coordinators on methods of tracking management measures and monitoring equipment.
3. Coordinate watershed working group on-farm field sessions and short course sessions to train watershed working group participants in use of monitoring tools and tracking methods.
4. Utilize industry networks to promote educational activities surrounding nutrient management developed by local technical assistance agencies and consultants.

PROJECT DESCRIPTION

A Monitoring/Tracking guide has been developed that includes on-farm monitoring, and tracking tools and methods related to water quality pollutants of concern. It also identifies contacts for on-site technical assistance and related research. County Farm Bureau Water Quality Program Coordinators and watershed working group participants will review the Monitoring/Tracking section, and their feedback will be communicated to research and technical assistance agencies. Equipment will be purchased for each County Farm Bureau Agricultural Water Quality Program. County Farm Bureau Program Coordinators will be trained by technical experts on monitoring and tracking techniques included in the guide. The County Coordinators will conduct at least twelve watershed working group field demonstrations or FWQP monitoring sessions. The watershed working group participants are also being encouraged to participate in mobile lab irrigation assessments, the FWQP short course, and in workshops and trainings that address nonpoint source pollution control.

RESULTS AND CONCLUSIONS

There is more information available for low-cost methods of tracking nitrates and sediment movement on and off of farms and ranches than for other pollutants of concern (phosphates, pesticides, pathogens, etc.). Producers would like more detailed information on specific crop needs for inputs like fertilizers to help them reduce the risk of inputs being lost to the environment. Local information on the effectiveness and the quantitative water quality benefits of various practices needs to be further researched. A continuous feedback loop between technical assistance representatives, agricultural producers, water quality experts, and regulators is imperative in the next few years because water quality protection practices, and appropriate monitoring and tracking techniques are part of a developing science.

From The Ground Up: A Step-by-step Guide To Growing A School Garden: Video and Booklet

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INTRODUCTION

Californians are increasingly unaware of agriculture in the Golden State. Of the more than 30 million individuals living in California, only one out of 10 are employed directly by agriculture. Clearly, as more and more acres are taken out of agricultural production annually throughout the state, the connection between agriculture and the general public continues to diminish. With increased urbanization into traditional agricultural areas, the need for increased awareness and understanding is imperative.

While the diminishing connection between agriculture and Californians is clearly complex, the benefits of programs targeted at youth are fairly clear. The California Fertilizer Foundation (CFF) School Garden Program's overall goal is to increase awareness and understanding of agriculture through the hands-on learning experience of school gardens. By providing funding to California elementary, middle, and high schools for implementation and/or continuation of school gardens, the program helps improve a child's agricultural literacy.

Incorporating school garden programs in California schools provides a unique opportunity for raising agricultural awareness and literacy. Students, teachers, faculty, and parents have an opportunity to not only learn more about food production, but to learn about their connection to agriculture through a hands-on experience. Understanding where food comes from is a critical connection for students for a variety of reasons. School gardens provide a real-life model of where food comes from, how it is grown, how it gets from the field to the table, as well as the consumer's (i.e., the child's) role in it.

California teachers and students in kindergarten through 12th grade are the primary recipient of the information provided through this project. Teachers and students who either have, or are implementing, a school garden project on their campus will receive the information through a variety of methods: California Department of Education "Garden In Every School Program" mailers, training seminars, and conferences; California Foundation for Agriculture In The Classroom conferences, mailers, and Ambassador Program; California Fertilizer Foundation and other web sites; and others. Teachers and students will, through the video, observe an actual teacher and students doing a variety of preplanting and planting steps, including soil sampling, best management/safe handling procedures for fertilizer use, watering techniques, etc.

OBJECTIVES

The purpose of the "From The Ground Up" video and booklet is to provide a visual, step-by-step, how-to guide of planning and implementing a school garden. Teachers and students will be able to identify with the model used in the video: an actual teacher and students at a school campus. Teachers and students will increase their knowledge and ability to manage a garden, as well as understand the relationships between soil, fertilizers, best management practices, food production, and the environment. CFF has ensured that the video will achieve this goal through the following objectives:

1. Develop a step-by-step, how-to video, and guidebook that show proper soil, planting, fertilization, and watering techniques for a school garden.
2. Distribute the video to K-12 California teachers through a variety of methods (existing organizations, Internet, conventions, etc.) free of charge for the initial 1,000 printed (additional copies would be made at a nominal, at-cost fee).
3. Conduct a follow-up survey with teachers and students to measure how the target audience's understanding of the relationships between soil, planting, fertilization, watering, and general best management practices has changed/improved.

CURRENT PROGRESS

The California Fertilizer Foundation is pleased that the FREP-funded project, "From The Ground Up," a "how-to" school garden video and booklet for kindergarten through 12th grade teachers in California, is nearing completion. Major portions of the project, including the video, booklet, and evaluation form, were completed in July 2001 and are scheduled for distribution in early fall. More than 1,000 California teachers will receive the video and booklet free of charge through either direct mail, or at conferences. Both the coordinators of the project, and several teachers who have had an opportunity to preview the video, and booklet have been incredibly complementary. Thanks to advance marketing of the project at school garden conferences, workshops, and newsletters, requests for the video/booklet continue to come into the Foundation on a weekly basis.

Ammonia Emission Related to Nitrogen Fertilizer Application Practices

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INTRODUCTION

This project involves adapting techniques developed to measure trace gasses in the atmosphere of urban areas for monitoring ammonia from agricultural operations. Ammonia has significance to air quality both as a buffer against atmospheric acidity and as a precursor of $PM_{2.5}$ particles. The study began in the fall of 1999 as a California Air Resources Board (CARB) project to develop and validate a method for monitoring NH_3 volatile losses from fertilizer applications. This project is continuing the use of the methodology from the ARB project to extend the monitoring of atmospheric ammonia to the whole crop season of some of the crop/fertilizer/soil combinations. While the fertilizer application process is likely to be the point at which the highest ammonia losses occur in a field, the literature suggests, and project results confirm, those levels exist for only a short time. In order to accurately model the ammonia losses from cultivated crops, monitoring of the atmospheric levels during the rest of the crop season is also necessary

OBJECTIVES

The project has one primary, and two secondary objectives to further refine the models and conclusions to a level beyond the scope of the initial study.

1. Determine the ammonia levels in the atmosphere related to several crop/soil combinations in the San Joaquin Valley over the entire crop season by monitoring on a 15-30 day frequency from initial soil preparation through post harvest cultural practices. This data will be used in atmospheric models to add the seasonal emissions to the flux rates monitored for fertilizer applications.
2. Investigate the affect of soil texture and other factors on ammonia emissions with the goal of using precision agriculture techniques to adjust N fertilizer applications in fields where factors change significantly.
3. Document and disseminate the sampling method developed in the ARB project to the agriculture and fertilizer industry.

PROJECT DESCRIPTION

The goal of the initial CARB-funded project was to measure the magnitude of volatile NH_3 loss and its duration as a result of various N fertilizer applications. The volatile loss percentage for a specific N application is influenced by several factors that could be identified in the statewide database developed by the NASA-Ames cooperators. The first step in the project was to list those factors in a matrix and then select representative combinations from the matrix cells to monitor in the field. The first factor identified was crop type. The database utilized county-based crop maps from the California Department of Water Resources. The second factor was soil. Initially, the soil texture was considered to be the most likely soil characteristic to affect NH_3 volatilization. Four general soil texture classes were selected based on % clay. The most significant chemical soil characteristic was assumed to be pH. The intention was to select sites with different textures and pH values on which the specific crop types were common. The most subjective selections for the sampling matrix were the fertilizer forms and application methods. Six combinations of a material and application method were selected as common to many of the crops and soils for the completion of the sampling matrix. Prior to the sampling, ten crops, four soil textures, and six fertilizers resulted in a matrix of 240 cells. Changes in the matrix during the sampling period produced a final matrix of 936 (nine crops × thirteen fertilizer/application methods × two pH categories × four soil texture) categories. Three sites were located on the CSUF farm/laboratory, the rest were in commercial

Table 1. Field Sampling Sites for the Ammonia Emissions From Fertilizer Applications Project

Site	*CROP*	*Fertilizer*	*N lb/A*	*Application Method*	*LOCATION*
A	Almond	UAN-32	100	surface band, watered in	15 m West of Madera
B	Almond	$(NH_4)_2SO_4$	100	surface band, watered in	16 m West of Madera
C	Almond	Urea liquid	15	foliar with bloom spray	CSUF Farm
D	Citrus	NH_4NO_3	50	Broadcast - rained in	5 m North of Sanger
E	Almond	UAN-32	100	Water Run-buried drip	7 m North of Sanger
F	Onions	UAN-32	40	Water Run-sprinkler	3 m South of Five Points
G	Tomato	UAN-32	100	Side dressed	3 m SW of Five Points
H	Garlic	UAN-32	50	Water Run-furrow	4 m SW of Five Points
I	Cotton	NH_3	100	Injected, 15cm shank	2 m SW of Five Points
J	Cotton	NH_3	100	Injected, 15cm shank	4 m West of Five Points
K	Almond	21-21-21	9	Water Run-microspray	CSUF Farm
L	Pasture	effluent	100	Flood	CSUF Farm
M	Broccoli	NH_4NO_3	60	Surface spray for weed control	8 m SW of Mendota
N	Cotton	defoliant	0	Aerial Spray	5 m South of Lemoore NAS
O	Lagoon	effluent	100	Ponded	CSUF Farm
P	Broccoli	UAN-32	75	Water Run-buried drip	8 m SW of Mendota
Q	Lettuce	UAN-32	60	Water Run-furrow	3 m SW of Five Points
R	Cotton	NH_3	80	Injected, 15cm shank	4 m SW of Five Points
S	Tomato	NH_3	100	Injected, 10cm shank	2 m South of Five Points

fields. The sampling period for the ARB funded project was the calendar year, 2000. 19 individual applications were sampled, and usable data was obtained from 14 of those. The five sites for which data is incomplete were two early winter locations (A and C) where the weather data collection system failed, and three sites in the fall. Site N was a cotton defoliant experiment where no fertilizer was applied, site O was a repeat of site L, the dairy lagoon disposal pasture, and site P was a second fertilization of the broccoli at site M with sampling at 1 and 2 meters only. Data from these other sites is still being analyzed, and may be included in a later report. Table 1 is a list of the sites sampled in 2000.

Selecting appropriate sampling sites was one step in the study; the second problem was to develop a field sampling procedure that would characterize the emission factor for each site in a manner suitable for the needs of the statewide database. The magnitude and duration of the volatile losses were the values needed to establish an emission factor. Duration could be characterized easily as long as a continuous sampling method was used. Sampling began two days prior to an application to determine background level, continued through the fertilization and for five days afterward to monitor the expected spike of atmospheric NH_3 from the application.

Selecting a sampling procedure to measure the magnitude of the NH_3 emission was a more difficult task. Closed chambers in the lab or greenhouse were not considered suitable for this project in which field monitoring was mandated. Field measurement of NH_3 has been done in air quality studies, primarily in urban settings. Two basic methods have been employed: denuders and open-path spectroscopy. The denuder is a medium through which an air stream is passed in the same manner as a filter for particulates. In the case of NH_3, it is a fibrous material treated with a substance that will react with NH_3 to form a compound that will be trapped by the denuder media. The denuder is generally an active sampler utilizing a pump to pull a known flow of air through a disk of the treated material in a filter holder located at the point of measurement. This requires a pump, power system and air flow measurement for each sampling point. Denuders can also be passive, depending on wind to move the air through the denuder medium. An active denuder was selected for the initial sampling season of this project because it represents an established method in air quality studies, and it satisfied the requirement for continuous sampling. A 47mm disk of glass fiber filter paper was treated with citric acid (5% in 95% ethanol), and dried. A commercially available, 12 volt air sampling pump was used to pull air through the denuder disk at a rate of about four liters per minute. Previous work suggested differences in day and night levels of NH_3 in the air so the sampling was diurnal with the denuders changed at dawn and dusk. Samples were refrigerated, and taken to the Graduate Laboratory of the CSUF College of Agricultural Science and Technology, to be analyzed by project personnel. The NH_4-Citrate was extracted from the denuder with distilled water, and analyzed with Nessler's Reagent in a spectrophotometer. The amount of ammonia on the denuder disk was reported in mg NH_3. The concentration of NH_3 in the air at the sampling point could be determined by dividing the amount of ammonia on the

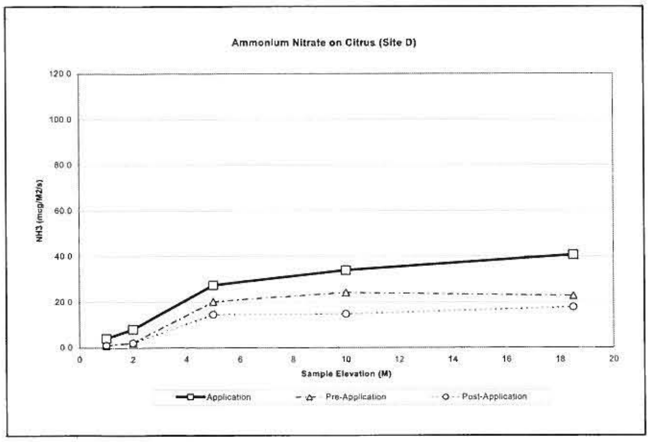

Figure 1. NH3 emissions before, during and after NH_4NO_3 application to citrus.

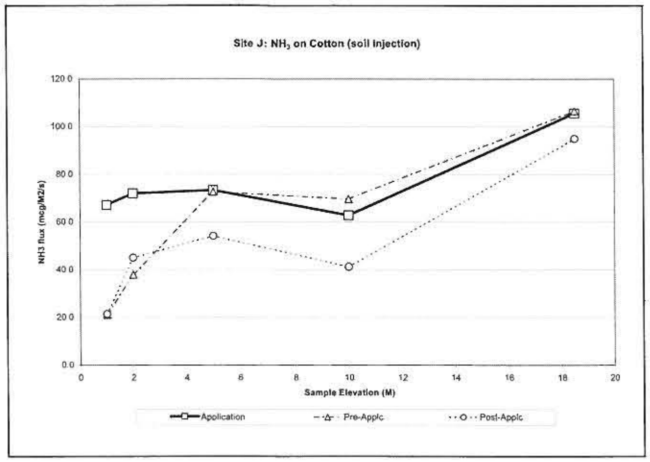

Figure 2. NH_3 emissions before, during, and after NH_3 (anhydrous) injection on cotton.

disk by the volume (meter3) of air through the denuder in the sampling period to get mgNH_3/meter^3 of air.

The measurement of NH_3 concentration at a particular sampling point is not sufficient to determine the emission factor for a particular field site. The amount of NH_3 in the atmosphere depends not only on the concentration but also the flow of the air mass (wind velocity) at the sampling point. The value necessary to characterize the sampling point was the flux in mgNH_3/meter^2/second. This ammonia flux is the amount of NH^3 passing through a 1meter^2 cross section per second at the sampling point. The measurement of the flux of a single sample is not enough to determine an emission factor. The plan was to monitor ammonia flux at several elevations above the field surface to characterize the gradient between the soil surface and the ambient atmosphere. Denuders and anemometers were located at 1, 2, 5, 10 and 20 meters above the soil surface. Initially, it was assumed that a positive NH_3 flux gradient from the soil surface, decreasing as the elevation increased could be used to indicate the magnitude of the emission factor for the sampling period. Prior to the application, it was suspected that negative gradients, with higher flux rates in the atmosphere, decreasing at elevations closer to the soil surface might be found due to ammonia absorption by foliage and/or a moist soil surface.

RESULTS AND CONCLUSIONS

Conclusions can be drawn based on the sites sampled in 2000. The most significant is the fact that field sampling can detect volatile NH_3 from an application of N fertilizer. In each of the 14 applications for which complete data is available, an increase in atmospheric NH_3 was measured compared to the levels sampled both before and after the application. The two graphs, Fig. 1 (site D) and Fig. 2 (site J) are typical of the results. The line labeled "Application" is the average of 2 to 5 sampling periods during which the N application was actually occurring. The lines labeled "Pre-application" and "Post-application" were the averages of up to 10 samples taken prior to and after the application. The "Application" values were greater than those before and after for each of the sites analyzed so far. This is the basis for the conclusion that the methodology can detect volatile NH_3 resulting from a fertilizer application.

This field data was analyzed further by the cooperating atmospheric scientists at NASA-Ames. They subtracted the background NH_3 from that present during the application, fit a curve to the resulting differences and integrated under the curve to determine the quantity of NH_3 in the atmosphere as a result of the fertilizer. That value divided into the fertilizer rate produced the percentage of NH_3 lost through volatilization. This percentage is termed the emission factor by the atmospheric scientists and the ARB. Table 2 shows the emission factors for each of the sampled sites. Comparison of the emission factors with the crop/soil/fertilizer combinations used to develop the original sampling matrix shows correlation with some characteristics but not others. The primary correlations appear to be with the application method and soil pH. All of the sites with emission factors higher than 1.3% involved fertilizers applied at the surface; banded, broadcast or in irrigation water. Most of the high % loss sites also had a soil pH near or above 8. Subsurface applications to both high and neutral pH soils had relatively low emission factors so it appears that placing the material well below the surface is efficient even at an unfavorable soil pH. There did not appear to be any correlation with crop type, fertilizer type or soil texture in the data from 2000.

Table 2. Summary of Field Sampling Site Emission Estimates

Site	*CROP*	*N #/Ac*	*N g/m²*	*Soil pH*	*Irrigation*	*NH3 Emission g N m-2*	*NH_3 Emission Factor*
B	Almonds	100	10.9	8.1	Surface	0.72	6.6%
D	Citrus	50	5.5	6.1	Surface	0.24	4.3%
E	Almonds	100	10.9	6.4	Buried Drip	0.05	0.5%
F	Onion	40	4.4	8.5	Sprinkler	0.28	6.5%
G	Tomato	100	10.9	7.9	Furrow	0.10	0.9%
H	Garlic	50	5.5	7.9	Furrow	0.32	5.8%
I	Cotton	100	10.9	8.5	Furrow	0.62	5.6%
J	Cotton	100	10.9	7.8	Furrow	0.43	3.9%
K	Almonds	10	1.0	6.4	Microspray	0.00	0.0%
L	Pasture	100	10.9	6.6	Surface	0.32	2.9%
M	Broccoli	60	6.5	7.9	Buried Drip	0.10	1.6%
Q	Lettuce	40	4.4	7.8	Furrow	0.02	0.5%
R	Tomato	80	8.7	7.9	Fallow	0.01	0.1%
S	Cotton	100	10.9	8.5	Fallow	0.14	1.3%

Evolution of the study from data collection and a database of NH_3 emission factors for the CARB to an investigation of seasonal, volatile losses is the primary characteristic of the current CDFA-FREP project. The existing sampling system proved to be effective in monitoring NH_3 emissions during fertilizer applications but the large, trailer-mounted tower was difficult to place properly in the field and difficult to relocate. It was also found, during the analysis of the data, that the measurement at 20 meters was not necessary. Consequently a smaller system on a tripod-mounted mast was developed that would sample up to a 10-meter elevation. This system is much more portable, which makes it easier to place properly in a field. One of the smaller systems was built and used at several sites beginning in March 2001. After several modifications, the design was adopted and two more units were built in August, 2001. The set of three tripod-supported masts can be used separately at three different sampling sites or together to monitor horizontal as well as vertical NH_3 gradients when monitoring point sources. The lowest sampling height during the CARB study was 1 meter. Some experimentation in the spring of 2001 indicated the need to sample closer to the surface, particularly when the crop was absent or very short. The sampling elevations on the tripod/mast units can be easily changed to allow samples at any height from the soil surface to 10 meters. A second CARB project has been funded to study seasonal NH_3 emissions from various natural soil/vegetation communities. The procedures will be very similar to those developed for the CDFA-FREP project and will also use portable tripod/mast sampling systems. At least three additional units will be built for the new ARB study. The systems will be sufficiently similar to allow all six to be set up together when intensive sampling is required for either project.

The CDFA-FREP sponsored project, at this point, has completed the development of the field sampling systems and is beginning the process of sampling at several sites on a regular basis that will continue through the next crop season. Some crop/soil sites have yet to be selected but each will be in place for at least one complete season prior to the end of the project in 2003. It is anticipated that data collection in 2001-2 will indicate the need for some additional sites in the final season. That data and the proposed additions will be discussed in the report next year.

Completed Projects

The following is a list of FREP projects completed prior to October 2001. Summaries of many of these projects appear in the 2000 FREP Conference Proceedings; final reports are available by calling FREP or on the Program web site: (www.cdfa.ca.gov/is/frep).

FRUIT/NUT AND VINE CROPS

Fertilizer Use Efficiency and Influence of Rootstocks on Uptake and Nutrient Accumulation in Winegrapes
Larry Williams

Development of Nitrogen Fertilizer Recommendation Model for California Almond Orchards
Patrick Brown and Steven A. Weinbaum

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
R. Scott Johnson

Using High Rates of Foliar Urea to Replace Soil-Applied Fertilizers in Early Maturing Peaches
R. Scott Johnson and Richard Rosecrance

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

Soil Testing to Optimize Nitrogen Management for Processing Tomatoes
Jeffrey Mitchell and Don May

Water and Fertilizer Management for Garlic: Productivity, Nutrient and Water Use Efficiency and Postharvest Quality
Marita Cantwell, Ron Voss and Blaine Hansen

Soil Testing to Optimize Nitrogen Management for Processing Tomatoes
Jeffrey Mitchell, Don May and Henry Krusekopf

Determining Nitrogen Best Management Practices for Broccoli Production in the San Joaquain Valley
Michelle LeStrange, Jeffrey Mitchell and Louise Jackson

Effects of Irrigation Non-Uniformity on Nitrogen and Water Use Efficiencies in Shallow-Rooted Vegetable Cropping Systems
Blake Sanden, Jeffrey Mitchell and Laosheng Wu

Demonstration of Pre-sidedress Soil Nitrate Testing as an Nitrogen Management Tool
Timothy K. Hartz

Drip Irrigation and Fertigation Scheduling for Celery Production
Timothy K. Hartz

Diagnostic Tools for Efficient Nitrogen management of Vegetables Produced in the Low Desert
Charles Sanchez

Evaluation of Controlled Release Fertilizers and fertigation in Strawberries and Vegetables
Warren Bendixen

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

Developing Site-Specific Farming Information for Cropping Systems in California
G. Stuart Pettygrove, et.al.

Development and Testing of Application Systems for Precision Variable Rate Fertilization
Ken Giles

Management of Nitrogen Fertilization in Sudangrass for Optimum Production, Forage Quality and Environmental Protection
Dan Putnam

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

IRRIGATION AND FERTIGATION

Uniformity of Chemigation in Micro-Irrigated Permanent Crops
Larry Schwankl and Terry Prichard

EDUCATIONAL/MISCELLANEOUS

Improving the Fertilization Practices of Southeast Asians in Fresno and Tulare Counties
Richard Molinar and Manuel Jimenez

Western States Agricultural Laboratory Proficiency Testing Program
Janice Kotuby-Amacher and Robert O. Miller

Agriculture and Fertilizer Education for K-12
Pamela Emery and Richard Engel

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 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

Peer Reviewed Publications of CDFA FREP-Sponsored Projects

Brown, Patrick, UC Davis, Department of Pomology

Rosecrance, R.C., S.A. Weinbaum, and P.H. Brown. 1996. Assessment of nitrogen, phosphorus, and potassium uptake capacity and root growth in mature alternate-bearing pistachio (*Pistacia vera*) trees. Tree Physiology 16:949-956.

Youssefi, Farbod, Patrick H. Brown, and Steven A. Weinbaum. 1999. Regulation of nitrogen uptake at the whole plant level: A study in almond trees. HortTechnology 9:598-600

Youssefi, Farbod, Steven A. Weinbaum, and Patrick H. Brown. 2000. Regulation of nitrogen partitioning in field-grown almond trees: effects of fruit load and foliar nitrogen applications. Plant and Soil 227:273-281.

Youssefi, Farbod, Patrick H. Brown, and Steven A. Weinbaum. 2000. Relationship between nitrogen status, xylem and phloem sap amino acid concentrations and apparent soil nitrogen uptake by almond trees (*Prunus dulcis*). Journal of Horticultural Science and Biotechnology 75(1):62-68.

Youssefi, Farbod, Patrick H. Brown, and Steven A. Weinbaum. 2000. Regulation of nitrogen uptake by almond trees (Prunus dulcis). Plant and Soil. (In Press)

Marita Cantwell, UC Davis, Department of Vegetable Crops

Marita Cantwell, Gyunghoon Hong, Ron Voss, Don May and Blaine Hanson. 2000. Nitrogen Fertilization and Irrigation Regimes Modify the Composition and Quality of Garlic. In: Proc. Alliums 2000 Conference (3rd International Symposium on Edible Alliaceae, Univ. Georgia, Athens, 29 Oct to 3 Nov, 2000), in press. 3 pp.

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