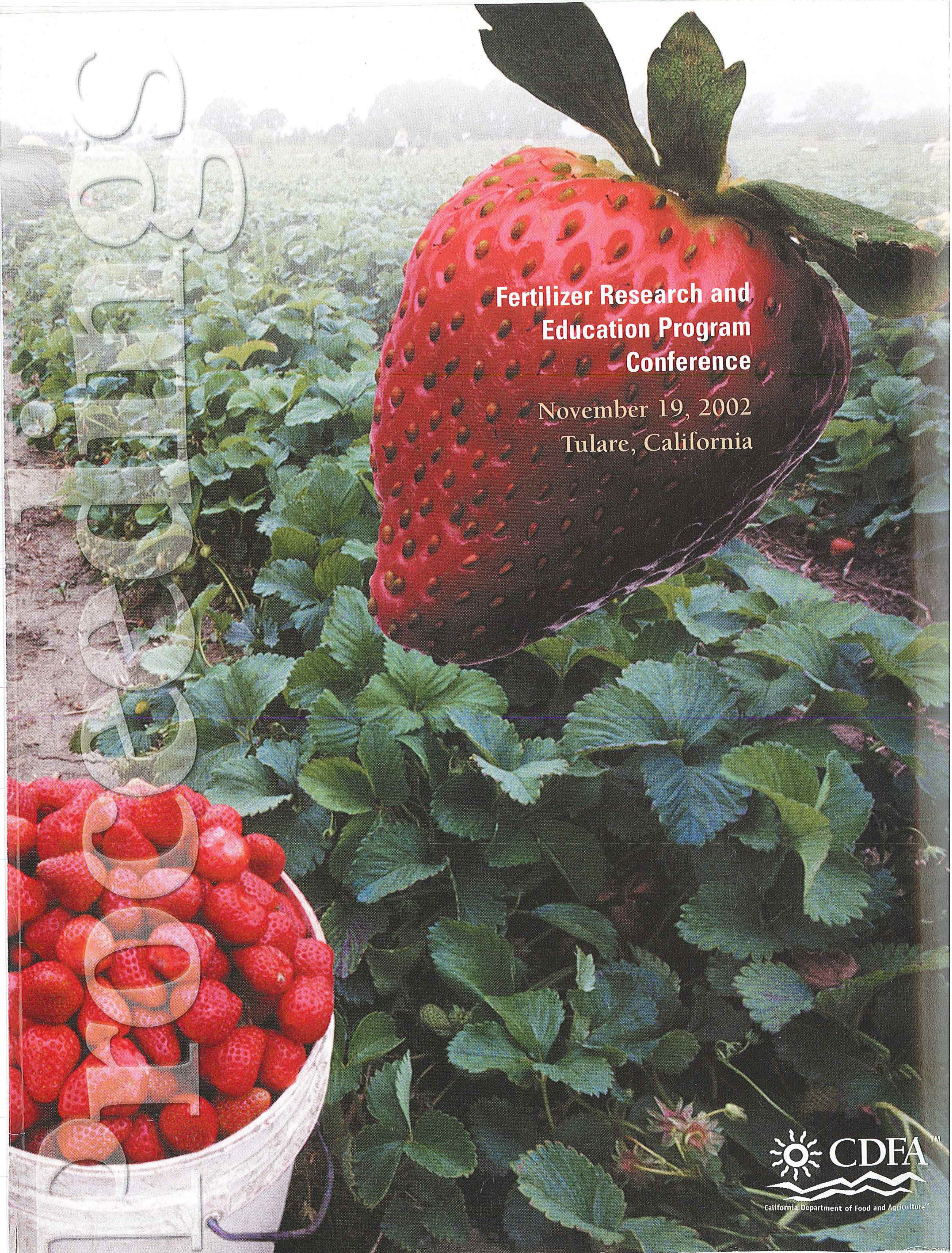

Fertilizer Research and Education Program Conference

November 19, 2002
Tulare, California

CDFA
California Department of Food and Agriculture

Proceedings of the
Tenth Annual

FERTILIZER RESEARCH AND EDUCATION PROGRAM CONFERENCE

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Since 1990, the California Department of Food and Agriculture's Fertilizer Research and Education Program (FREP) has advanced its mission to promote the environmentally sound and agronomic use and handling of commercial fertilizers. A primary objective is to improve the use efficiency of commercial fertilizing materials to benefit crop production and quality while minimizing nitrogen losses to the environment. FREP strives for excellence by supporting high quality research and education endeavors that have gone through a rigorous statewide competitive process, including independent peer review. From 1990-2002, FREP has supported over 100 research and education projects for a total of nearly $6 million in funding. FREP activities are funded entirely 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 support.

FREP's current funding priorities include:

- Research on crop nutrient uptake including the amounts, timing and partitioning of nutrients removed from the soil, and the role of balanced nutrition in improving crop production and reducing the amount of nutrients available for surface runoff or leaching from the root zone.
- Development of fertilization practices and application methodologies to improve crop production, fertilizer use efficiency or environmental sustainability.
- Irrigation management as related to fertilizer use efficiency and the reduction of nutrient losses to ground and surface water.
- Site-specific crop and fertilizer management technologies and best management practices related to precision agriculture.
- Development, testing, and demonstration of the use and benefits of practical field monitoring tools.
- Nutrient interactions with growth regulators, plant pests and disease.
- The integrated use of commercial fertilizers with cover crops or agricultural composts to improve crop yield or quality and to minimize nutrient losses in ground or surface water.
- Development and distribution of educational products and public information.

Project Funding Analysis

This publication includes summaries and results to date of all projects that are currently receiving funds. Section III lists completed projects. See Section IV of these proceedings for a list of articles published in peer-reviewed journals. Figures 1-2 below show where the cumulative program resources have been distributed in terms of geographic location, and discipline for FREP funded projects. Figure 1 shows that 59% 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 Monterey County and points south. A substantial number of projects have had statewide relevance, while smaller portions have been directed at the desert and south coast areas.

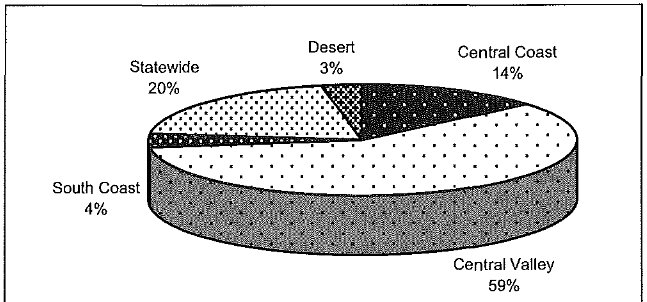

Figure 1. CDFA FREP Projects by Location: 1990-2002.

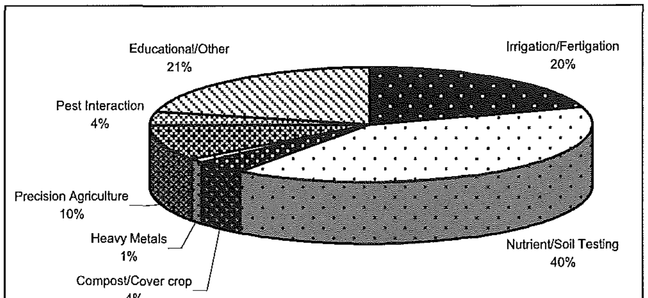

Figure 2. CDFA FREP Projects by Discipline: 1990-2002.

As detailed above, FREP has numerous funding priority areas, which have remained relatively consistent over the life of the program. Figure 2 shows the distribution of funded projects by discipline. Forty percent of FREP's projects have been related to developing, testing and demonstrating various nutrient tissue and/or soil testing procedures. 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. Work in improving irrigation management and fertigation practices to optimize both water and nutrient delivery remains an important focus of the program (20%). New precision agriculture technologies for nutrient management such as using GIS, GPS, remotes sensing, and yield monitors have also received funding attention. Other areas under consideration include the relationship between pests and diseases with fertility management, composts and cover crops, and air quality issues.

FREP continues to support the California Certified Crop Adviser Program. 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. This is reflected in significant FREP support (21%) of relevant education and outreach projects (Figure 2). 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:

- The California Plant Health Association
- 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 the program's success.

We would also like to recognize the members of the Fertilizer Inspection Advisory Board Technical Advisory Subcommittee who review and recommend projects for funding. Tom Beardsley, Bob Fry, Tom Gerecke, David McEuen, Eric McGee, Jerome Pier, Brock Taylor, Al Vargas, Jack Wackerman and Jack Williams have been invaluable in helping to ensure FREP's success. Their dedication to the program and professionalism is greatly appreciated. The members of the Fertilizer Inspection Advisory Board are also hereby acknowledged for their enthusiastic support and on-going commitment to the program.

We also 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 Stephen Mauch, Director of the Division of Inspection Services and Steve Wong, Branch Chief of the Agricultural Commodities and Regulatory Services Branch. Additional support from the Branch's clerical staff is also acknowledged.

The Effect of Nutrient Deficiencies on Stone Fruit Production and Quality

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INTRODUCTION

This project was developed to study nutrient deficiencies in mature peach, plum and nectarine trees. In 1999 sixty large tanks with individual drainage systems were installed in the plot and filled with sand. At the start of the 2000 season, one tree each of Zee Lady peach, Fortune plum and Grand Pearl nectarine (white flesh) was planted in each tank. Differential fertilization treatments were started in the summer of 2000 and continued through the 2001 and 2002 seasons. By 2001 nutrient deficiencies were apparent in some trees. A small amount of fruit was harvested from most of the trees in that year. By 2002 fruit production was substantial on the majority of the trees. Big differences among trees were measured in tree size, flower production, fruit set, fruit size, and fruit quality parameters. Many of these differences were correlated with leaf nutrient levels. In analyzing the relationships between these parameters and trees nutritional status, many interesting results have been obtained. In some cases, a single nutrient seems to explain the variability. In others, multiple nutrients appear to be involved, sometimes in rather complex ways. In addition, this research suggests the conventional mid summer timing of nutrient analyses may be too late for some nutrients. An early spring sampling may be more appropriate in a few cases. This research is also providing preliminary evidence that published critical levels may need to be revised for a few of the nutrients. Overall, this project is producing some very interesting and useful findings and should continue to do so as the trees grow larger and show even greater differences among treatments over time.

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.

PROJECT DESCRIPTION

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)

Besides the mixture of salts (based on Hoagland solutions) applied to each treatment, an additional fertilization program was followed in 2002 in order to achieve a wide range of nutrients among individual trees and to help depress the specific nutrient for a given treatment. For instance, extra nitrogen was applied to some treatments (5,7,9 and 12) to stimulate vigorous growth and thus help dilute the specific nutrient not supplied to that treatment. Also heavy applications of competing cations were made to treatments 6,7,8,9,11 and 12 in order to replace the given cation on the soil cation exchange sites. Finally, additional applications of P (treatments 6 and 11), B and Fe (treatments 1 and 3 to 12), and Zn (treatments 3,5,7,9 and 12) were made to specific treatments because these nutrients were generally low in all trees in 2001. Leaf samples were collected from all 180 trees in early May and early July 2002. These were sent to the DANR analytical lab for determination of all macro and micronutrients.

RESULTS AND CONCLUSIONS

Leaf Nutrient Levels. Table 1 shows the range of leaf nutrient levels from the July sampling period. There is a 2 to 3 fold difference between the low and high values for each of the nutrients measured. Some of the leaf samples tested below the published deficiency thresholds for N, B, Zn and Fe. The remaining nutrients also measured very low on some of the trees, often just above the deficiency threshold. Almost all the nutrients had both higher and lower values in 2002 compared to the year before. The one exception to this is potassium, which had some very high values but no minimum values as low as those measured in 2001. The other two major cations, calcium and magnesium, had minimum levels that were considerably lower than those achieved in 2001. Overall, the wide range of values and the low levels measured for each nutrient provide a very useful data set for examining nutrient effects on tree and fruit parameters.

Despite the low leaf nutrient levels measured in July, there were surprisingly few leaf deficiency symptoms observed on the trees (at least through late summer when this report was prepared). Nitrogen deficiency was obvious on many trees, starting right after bloom. Also early in the spring, some zinc deficiency symptoms were apparent, especially on some of the plum trees, but these disappeared as the weather warmed up. By mid summer, other than the yellow and red leaf symptoms of N deficiency, the trees looked very healthy and vigorous. However, there were many other subtle symptoms such as fruit size, fruit color and shoot vigor that were obviously caused by the nutrient treatments.

Zinc leaf levels measured in this experiment are particularly perplexing. Just about all the trees had leaf levels well below the published deficiency threshold of 15 ppm for peaches and nectarines and 18 ppm for plums (Table 1). Some trees were as low as 5 or 6 ppm, which suggests severe deficiency. However, none of these trees exhibited the typical "little leaf" symptoms associated with Zn deficiency. Perhaps the defi-

Table 1. Range of nutrients from July 2002 leaf samples taken from trees in sand tank experiment. Published deficiency thresholds are shown for comparison.

		Zee Lady Peach			*Grand Pearl Nectarine*			*Fortune Plum*	
Nutrient	*Deficient Below*	*Low*	*High*	*Deficient Below*	*Low*	*High*	*Deficient Below*	*Low*	*High*
N	2.3	1.64	3.27	2.3	1.62	3.60	-	1.08	2.39
P	-	.08	.19	-	.08	.19	-	.11	.25
K	1.0	1.43	3.21	1.0	1.17	2.97	1.0	1.52	3.42
S	-	720	1790	-	820	1820	-	850	2070
Ca	-	1.11	3.62	-	.75	3.12	-	1.55	4.72
Mg	.25	.29	.85	.25	.29	.75	.25	.55	1.14
B	18	14	37	18	19	36	25	22	48
Zn	15	5	19	15	6	19	18	6	26
Mn	20	38	121	20	37	121	20	24	90
Fe*	60	39	84	60	40	68	-	39	111
Cu	-	2.5	6.2	-	3.0	6.0	-	3.3	6.8

*Values for Fe are from May, 2002 leaf sample since deficiency threshold applies to this timing.

Table 2. Range of flowering, fruit set, fruit size and fruit quality parameters from sand tank experiment.

Parameter	Zee Lady Peach Low	Zee Lady Peach High	Grand Pearl Nectarine Low	Grand Pearl Nectarine High	Fortune Plum Low	Fortune Plum High
Flowering Density (#/cm)	.18	.50	.10	.32	.06	1.91
Initial Fruit Set (% of flowers)	44	100	26	93	-	-
Final Fruit Set (% of flowers)	4	71	0	58	-	-
Fruit Harvested (#/tree)	17	103	1	68	0	83
Fruit Weight (g/fruit)	123	248	80	163	60	123
Fruit Firmness (lb)	6.2	14.2	4.0	15.3	6.1	9.7
Fruit Red Color (%)	58	97	46	98	-	-
Fruit Soluble Solids Content (%)	10.0	17.8	13.1	25.4	11.9	16.8
Fruit Acidity	.63	1.05	.24	.38	.27	.74

ciency threshold for Zn will need to be revised in the future. In addition, perhaps the timing of sampling for Zn may need to be revised as well. Those treatments that were given extra Zn fertilizer had quite high levels in May (data not shown) but these dropped substantially by the July sampling period. Since zinc is often associated with actively growing tissues, it may be necessary to sample early in the spring when tissues are actively growing. This approach will be investigated in 2003.

Flowering and Fruit Set. Flower density varied about 3 fold for both peach and nectarine and much more for plum (Table 2). The treatments with no nitrogen (2 and 3) had distinctly lower flower densities than the other treatments, especially with plum. However, there was generally a very poor correlation between leaf nitrogen content and flower density for all the trees together. Instead, it appears other nutrients such as P, B and Fe may have contributed to flower development as well. There was also some moderate water stress in some of the trees during 2001 that may have affected flowering. Irrigation amounts and soil water status were monitored much more carefully in 2002 to make sure no stress occurred.

Fruit set was dramatically different from one tree to another (Table 2). A few nectarine trees had good flowering but ended up with virtually no fruit even though some flowers started to develop initially. The peach trees were not quite as extreme but still had some trees with fruit set as low as 4%. On the other hand, some peach and nectarine trees had 200-300 fruit per tree before thinning. Fruit set was not measured on the plum trees but total fruit load showed the same extremes as the peach and nectarine trees. For peach, the differences in fruit set correlated well with leaf B content in May (Figure 1). Since many of the tanks received an application of B in April, only those tanks that were not thus fertilized were used for this analysis. In 2003, samples will be taken at bloom since this timing should be more predictive of fruit set. For nectarine, fruit set also correlated with May leaf B but not as strongly as for peach. Again, sample timing is probably a key factor in this relationship (July leaf B showed no correlation) so an earlier sample should show a better correlation. Fruit set in the plum trees did not seem to be related to any nutrients. Often, fruit set in young plum trees is more a function of variable pollination.

Fruit Size. Average fruit weight varied about 2 fold among the various trees of peach, plum and nectarine (Table 2). Several of the trees had excellent fruit size even with fairly heavy fruit loads. The statistical analysis conducted to this point suggests that just about every nutrient measured had some effect on final fruit size. Our first approach was to use multiple regression. This analysis identified about 4 or 5 nutrients that appeared to explain nearly 75% of the total fruit weight variability. However, some of the relationships derived did not make physiological sense (larger fruit size at increasingly deficient nutrient levels). Therefore we tried a different approach based on the idea that maximum fruit size occurs at optimum nutrient levels and fruit size decreases linearly at nutrient levels both below and above this optimum. This ap-

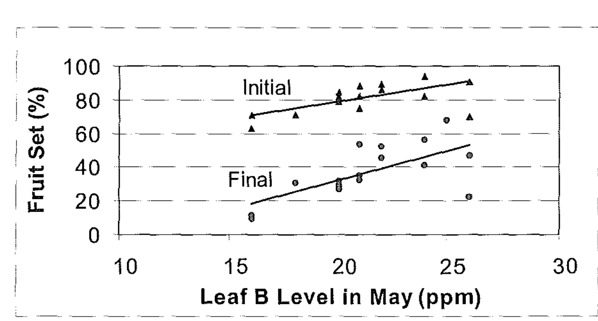

Figure 1. Fruit set of Zee Lady peach as related to leaf boron level in May 2002. Initial fruit set indicates all fruit that started to grow after petal fall. Final fruit set indicates just those fruit that were still growing at hand thinning time in mid April.

proach makes a lot more sense physiologically. We have just started analyzing the data with this approach but preliminary results suggest much of the fruit size variability can be explained. Once we have developed a model from the 2002 data, results from the 2003 season will provide a good opportunity to test these relationships.

The peach and nectarine trees tended to show similar results in their relationship of fruit size to leaf nutrients. However, fruit on the plum trees appeared to follow a somewhat different pattern. Most notably, calcium seemed to play a major role in fruit size with some of the "minus calcium" trees having noticeably larger fruit than many of the other treatments. These trees had leaf Ca levels around 2%, which is far from deficient and, in fact, is about the same level as that found in the peach and nectarine trees with the largest fruit. Therefore, it may just be a case of many of the plum trees having excessive Ca levels (some were as high as 4.72% - see Table 1), which could depress fruit size. Hopefully in 2003, leaf Ca levels will drop as low as 1% in some of the plum trees, which should be well below the optimum level. There is still some hope that a single fruit size model might apply to all 3 of the varieties being tested in this experiment.

Fruit Quality. At harvest several parameters of fruit quality were measured. These included firmness, % red color, % soluble solids content and acidity. As with the other parameters measured there tended to be at least a 2-fold difference from the lowest to the highest values (Table 2). Firmness and % red color correlated somewhat with leaf N but appeared to reflect maturity of the fruit more than nutritional status of the tree. Fruit % soluble solids content did not show a significant correlation with any nutrient. In 2003, a more extensive sampling technique will be used since there tends to be a lot of fruit-to-fruit variability in this parameter. Fruit acidity showed a high correlation with many different nutrients suggesting it might be affected by P, K, Ca, Mg and B. In 2003, there will be substantially more fruit on the trees, so multiple harvests will be employed to ensure more uniform maturity among treatments.

Tree Size. Final trunk growth will not be measured until the end of the year, so this analysis has not yet been completed. However, a preliminary evaluation based on the canopy size in July suggests the results will be quite similar to the conclusions from the fruit size analysis. It appears that most of the nutrients contribute in some way to the total vegetative growth of the tree. Eventually we will combine both the fruit size and the tree growth data so we can evaluate the total growth of the tree.

Nitrogen Management in Citrus under Low Volume Irrigation

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INTRODUCTION

Over the past several seasons, and particularly during 1993-1996, rind quality problems caused serious economic damage to the CA navel orange crop. Pioneering work by Embelton, Eaks, Coggins and others during the 1960s and 1970s largely solved rind stain problems by providing leaf analysis fertilization guidelines based in part on fruit quality considerations and also by improving the design of packing lines and post-harvest handling of fruit.

Over the past 2 decades orchard practices have changed. Most irrigation systems installed or renovated in the 1980s and 1990s are micro-irrigation systems with drippers or minisprinklers, rather than furrow, flood or high volume dragline sprinklers that dominated the industry previously. Nitrogen remains relatively inexpensive. Its ability to provide lush foliage growth and good looking groves has led in recent years to considerable over-use in the industry. Leaf analysis has provided the industry with a tool for monitoring fertilizer needs in citrus orchards, but too often growers are comfortable with nitrogen levels in the high end of the 'optimum' range, or even higher. The common thinking is that high nitrogen in the leaf analysis provides a good degree of safety and no tree in the orchard will suffer nitrogen deficiency. The effect of heavy nitrogen applications (in excess of 2 lb. N/tree), however, could be devastating to postharvest fruit quality.

Many growers have turned to foliar applications of low biuret urea to their trees in January and February to improve fruit set and ultimate yields. Additionally, the threat of nitrate groundwater contamination has changed the way some fertilizer recommendations are made, with several small applications of nitrogen over the season considered less likely to pollute than a single application. It is hoped that this project will assist in developing recommendations that can be made that minimizes nitrate movement into the groundwater while maintaining fruit quality and productivity.

OBJECTIVES

1. To determine the effect of nitrogen applications on navel orange fruit quality and leaching losses of nitrogen;
2. To compare the effects of foliar versus soil applied nitrogen on fruit quality and leaching losses of nitrogen;
3. To evaluate the impact of nitrogen application timing on fruit quality and leaching losses of nitrogen; and
4. To determine the effectiveness of various nitrogen application levels and methods on maintaining optimal nitrogen levels in navel orange trees.

PROJECT DESCRIPTION

Main Project Site

A site for the study in the Exeter-Woodlake area of Tulare County was identified in March 1996. 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. Each experimental plot consists of 12 trees, with the central 2 trees serving as the data trees. The experimental treatments for this site are listed in Table 1. The differential nitrogen treatments were imposed commencing January 1997.

Leaf samples are collected in September for leaf analysis. Trunk circumference, tree height, and canopy volume of the data trees are measured in October. Trees are also monitored for the average timing of color break and attainment of minimum maturity. In spring the data trees are harvested. All fruit are taken to UC Lindcove REC, where the fruit are run over the packing line at the Fruit Evaluation Center. We collect both size and grade information from the packing line. A subsample of fruit (from the average peak size) are taken from each data set, waxed and treated with fungicide and subsequently held under simulated storage and transit conditions.

Monitoring of the water and nitrogen status in selected experimental plots within the study site continues throughout

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

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

Foliar Only

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

Soil Only

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

Combination Treatments

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

[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.

the year. Soil water content is determined using a neutron probe in access tubes. Soil solution samples are collected from suction lysimeters. Collection of data on irrigation, water application, evaporation, precipitation and temperature contribute to the development of water balances for the study site. Weather data is collected from the local CIMIS

Table 2. Schedule of experimental treatments for nitrogen management project for satellite experimental sites in Tulare County (Orange Cove, Woodlake/Exeter).

Treatment	*Soil Applied (times/yr)*	*Timing (lb/tree/yr)*[z]	*Foliar (# applications)*[y]	*Total N (lb/tree/yr)*
1	1.00	1	-	1.00
2	1.50	1	-	1.50
3	2.00	1	-	2.00
4	1.50	C	-	1.50
5	1.25	1	1	1.50
6	1.00	1	2	1.50

[z]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.

[y]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.

station located at the UC Lindcove REC (approximately 6 miles east of the site). Data on nitrogen application amounts will be combined with data on nitrogen levels in trees, amounts of nitrogen leaving the rootzone and nitrogen removed in fruit to develop nitrogen balances for the various treatments.

Satellite Sites

The two remaining sites are located in commercial groves in Orange Cove and Exeter/Woodlake. The treatments at each site are listed in Table 2. The procedures for site monitoring are the same as outlined for the main site. All sites are harvested upon consultation with the owner and the cooperating packinghouse. All fruit from each site are commercially harvested and treated with standard packinghouse procedures. Yield, fruit size and packout are determined. Three cartons of each of two sizes (determined at the time of harvest) for each treatment are separated at the time of packing and held under simulated storage and transit conditions at the Mitchell Postharvest Lab at the UC-KAC. When sufficient export fruit are available, at least one pallet of fruit from each treatment will be included in a Japan export shipment and inspected on arrival for incidence of rind disorders and decay.

RESULTS

Figure 1 reports the average leaf N content of each treatment in the first 3 years of the project. Note that it took multiple years to establish the treatment differentials as reflected by leaf N. Figure 2 reports the same data but for the second 3 years of the project (1999 – 2001). In these three years there is a clear treatment (amount of N) effect on leaf N; however, the effect of the method of application and timing of application is less clear with the possible exception of the foliar only applications. We still need to conduct a more detailed

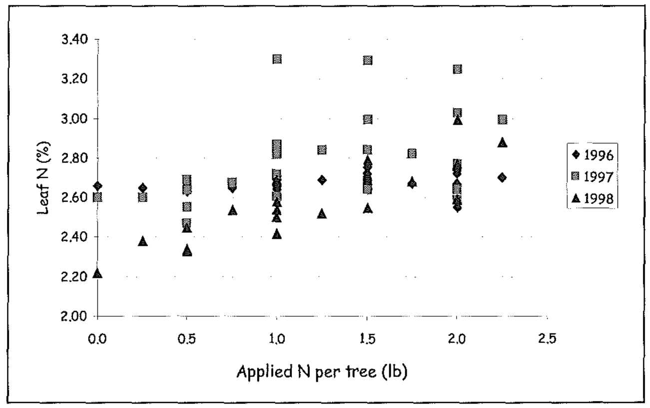

Figure 1. Average leaf nitrogen content for Woodlake experimental site for 1996 - 1998. Leaves collected in September of each year.

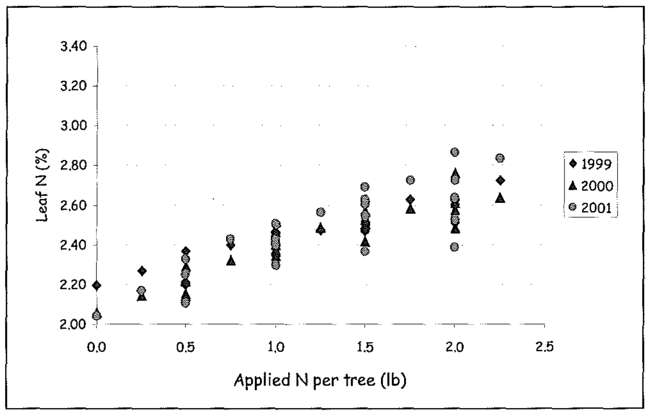

Figure 2. Average leaf nitrogen content for Woodlake experimental site for 1999 – 2001. Leaves collected in September of each year.

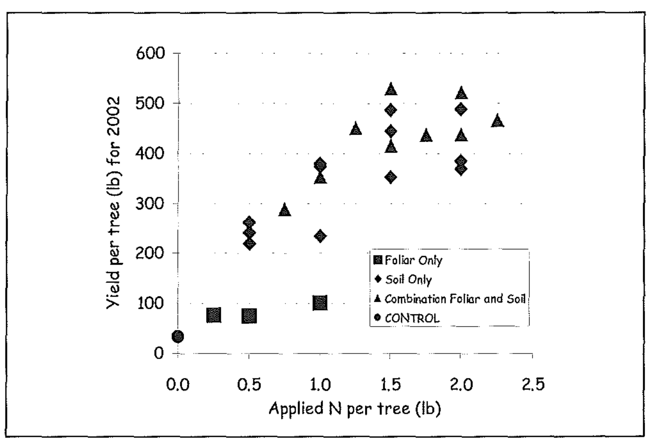

Figure 3. Average yields (lbs of fruit per tree) from Woodlake, experimental site. Fruit harvested in March 2002.

statistical analysis of this data before definitive conclusions can be made.

Figure 3 reports the yield data collected in March 2002. The 2002 yield was greatly reduced as compared to previous years (Figure 4). This was in line with overall yield throughout the citrus industry in the San Joaquin Valley due to intense heat during the early stages of fruit set in May 2001, which caused extensive fruit drop. In spite of the reduced yield, we observed similar trends in yield data collected in 2000 and 2001 with yield increasing up to 1.0 to 1.5 lb N per tree regardless of application methodology. The cumulative yield for 2000 – 2002 is reported in Figure 5. The data shows the same trend of maximum production, under our experimental conditions, being achieved between 1.0 to 1.5 lb N/tree.

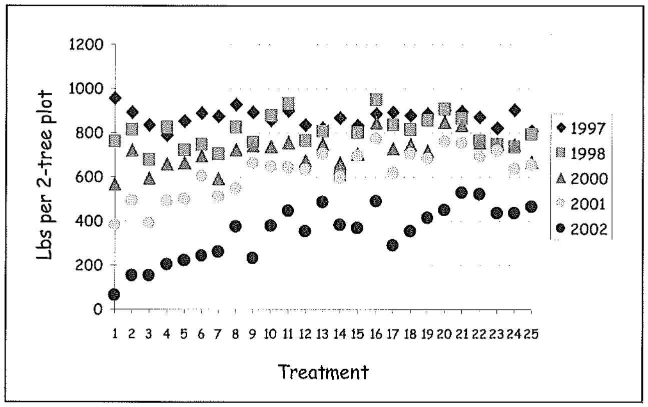

Figure 4. Average yields (lbs of fruit per 2-tree plot) for each year of the study. 1997, 1998 are prior to establishment of differential results in leaf N per tree. 2000 – 2002 are yields from years where there were differential trends in leaf N related to treatment. No yield data was collected in 1999 due to the December 1998 freeze. Fruit harvested in March of each year.

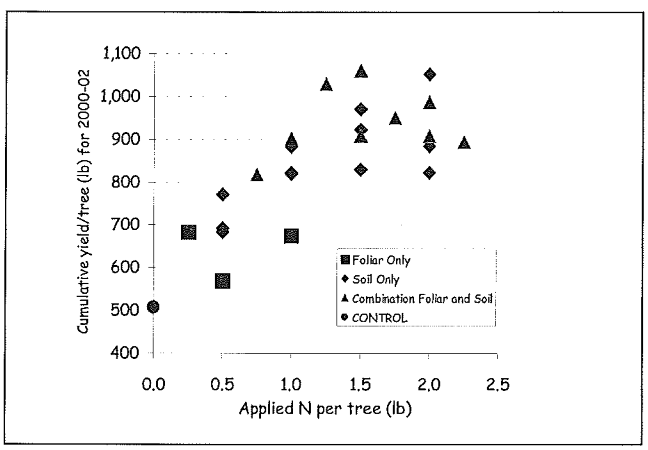

Figure 5. Average cumulative yield (lbs of fruit per tree) from Woodlake experimental site for 2000 - 2002. Fruit harvested in March of each year.

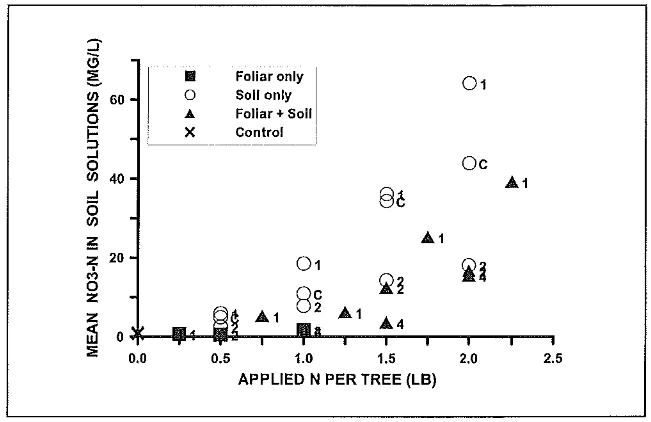

Figure 6. Mean nitrate N in soil solution extracts collected from 1997 – 2002 from Woodlake experimental site. In case of soil only, 1 = single application, 2 = split application, C = continuous application. For foliar treatments numbers indicate number of foliar applications.

Soil solutions were extracted from the plots almost monthly from 1997 through early 2002. These extracts were analyzed for nitrate-nitrogen (NO_3-N) to determine the levels of nitrogen in soil solutions leaching from the root zones and for chloride (Cl) which can be used to account for different fractions of applied water leaving the root zones under the different plots. The cumulative soil nitrate data over the course of the study show an increase in the NO_3-N concentrations in the soil leachate with increasing nitrogen application, i.e. higher nitrogen application, higher NO_3-N concentrations in leachates leaving the rootzones (Figure 6). While yields did not appear to be affected by method of application, it clearly impacted the NO_3-N concentrations in leachates. The highest NO_3-N concentrations were found in leachates collected from the plots receiving the soil-only treatments. The foliar-only applications resulted in the lowest concentrations, ones that were not different from the control treatment. The concentrations leaving the combination treatments were intermediate. Within the soil-only treatments, the single application always resulted in higher concentrations of NO_3-N in the leachates than the split or continuous applications.

The Cl concentrations in extracts were not related to the amounts of nitrogen applied (Figure 7). This is to be expected, as the source of the Cl was the irrigation water and the irrigation system was designed to apply water uniformly across the experimental field. The different Cl concentrations are an indication of different fractions of applied water leaching from the plots, i.e. the higher the concentrations, the lower the proportion of applied water leaching below the rootzone. The different leaching fractions are likely caused by different soil properties (permeability, layering, cementation) in the various plots.

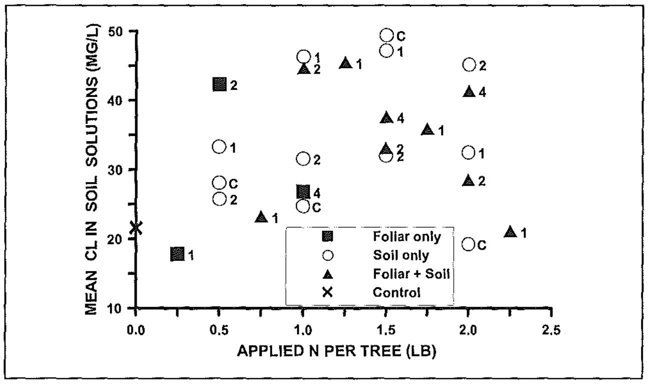

Figure 7. Mean chloride levels in soil solution extracts collected from 1997 – 2002 from Woodlake experimental site. In case of soil only, 1 = single application, 2 = split application, C = continuous application. For foliar treatments numbers indicate number of foliar applications.

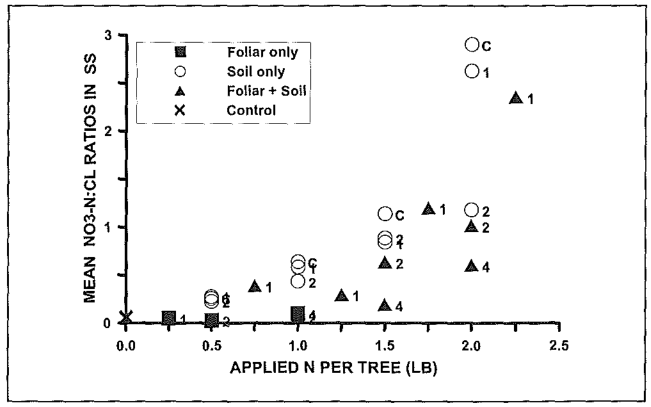

Figure 8. Mean nitrate-N:Chloride levels in soil solution extracts collected from 1997 – 2002 for Woodlake experimental site. In case of soil only, 1 = single application, 2 = split application, C = continuous application. For foliar treatments numbers indicate number of foliar applications.

In examining the NO_3-N:Cl ratios, the same general trends in nitrogen levels in soil solutions extracted from the plots hold (Figure 8). As applied nitrogen increases, the NO_3-N levels relative to Cl increase. These increases are greater for the soil-only treatment, least for the foliar-only treatments and intermediate for the combination treatments. The difference seen in Figure 8 compared to Figure 6 is that the continuous soil application resulted in higher NO_3-N to Cl ratios than either the single or split nitrogen application. The relationship between nitrogen applied and NO_3-N:Cl ratios for soil applications is reasonably linear with three "outliers" (Tmt 14, 2# single; Tmt 16, 2# continuous; Tmt 25, 2# continuous soil + 0.25# foliar). Maximum yields were found with the 1.0 to 1.5 pound nitrogen treatments (Figure 5). These "outliers" include three of the four treatments with >1.5 pound soil-applied nitrogen. This would suggest that the "excess" nitrogen that did not increase the yield above that obtained with 1.5 pounds applied nitrogen was leached from the rootzones.

Soil samples were collected during summer 2002 in order to evaluate nitrate leaching below the treated plots by a second method. These samples are presently being analyzed. More complete data analyses and the development of project conclusions will be possible when these additional data are available.

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

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PROJECT 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.

PROJECT DESCRIPTION

To protect the groundwater from potential nitrate pollution, 'Hass' avocado growers in California divide the total annual amount of nitrogen (56-168 $kg \cdot ha^{-1}$) 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, my laboratory 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 $kg \cdot ha^{-1}$ (168 trees/ha) in six small doses of N at 28 $kg \cdot ha^{-1}$ 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 $kg \cdot ha^{-1}$ was applied at each time for total annual N of 196 $kg \cdot ha^{-1}$. Two phenological stages were identified for which N application at 56 $kg \cdot ha^{-1}$ 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: 1) when shoot apical buds have four or more secondary axis inflorescence meristems present (mid-November); and 2) 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 total 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 $kg \cdot ha^{-1}$), time of application was the more important factor.

The danger is that we don't know whether using double or triple doses of soil-applied N to increase yield will increase the potential for nitrate groundwater pollution. It is hypothesized that supplying an avocado tree with more N at times when demand is greater should not increase leached nitrate. Since yield increased, the interpretation is that the tree utilized the extra N. Our CDFA-FREP project is coordinated with a project funded by the California Avocado Commission to determine whether the results obtained in the above study, which was conducted in Temecula, could also be obtained with a different soil type and location. In the current study being conducted in a 'Hass' avocado orchard in Somis, all trees receive an equal amount of N as NH_4NO_3 at 140 kg(ha^{-1} in five small doses of N at 28 kg(ha^{-1} in August, November, January, April, and July. Note that the control treatment in the current study includes the two phenological stages identified in the previous study as benefiting from extra N, a July application to increase fruit size, and an August application based on the discovery by my lab. that avocado trees transition from vegetative to reproductive growth at this time. Treated trees received high doses N as NH_4NO_3 at 44.8 kg·ha^{-1} or 67.2 kg·ha^{-1} in August or November or April or April and November. The remaining N was split into equal aliquots and applied in the other months included in the control. There was one treatment in which trees received only a single application of N as NH_4NO_3 at 44.8 kg·ha^{-1} N to the soil in August. This new study also integrated the results of a previous 2-year long study we undertook with funding from the CDFA FREP program. The results of that CDFA project provided evidence that foliar N fertilization was successful in increasing yield of the 'Hass' avocado when urea was applied at the time the leaves of the new flush were 66% to 100% fully expanded but not hardened. Thus, both foliar and irrigation applied N treatments were included. In addition to yield, the amount of nitrate and ammonia leaching past the root zone of 'Hass' avocado trees under the various N fertilization strategies was quantified. Our goal is to identify the Best Management Practice for N for the 'Hass' avocado in California.

Table 1. Effect of eight nitrogen fertilization strategies initiated in January 1999[y] on the average yield of 'Hass' avocado harvested in 2001 and 2002. A freeze occurred in December 1998 that reduced yield in 1998, bloom in spring of 1999 and yield in 2000.

Treatment[y]	*2000-2001 kg fruit/tree*	*2001-2002 kg fruit/tree*
Control	76 bc	63 a
2x N in August	81 abc	32 c
Grower fertilization practice	82 abc	53 abc
2x N in November	92 ab	35 bc
2x N in April and November	81 abc	38 abc
3x N in April	90 ab	50 abc
2x N in April	98 a	31 c
3x N in April applied foliarly	68 c	59 ab
P-value	0.05	0.05

[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 N as NH_4NO_3 at 44.8 kg·ha^{-1} applied to the soil in August split as two applications in July and in August for all years of the experiment. Since January 1999 control trees received N as NH_4NO_3 at 140 kg·ha^{-1}, divided into five applications of N at 28 kg·ha^{-1} in August, November, January, April, and July. Trees in all other treatments received 140 kg·ha^{-1} applied as 2N= N at 44.8 kg·ha^{-1} or 3N=N at 67.2 kg·ha^{-1} in the months indicated. The total N applied in any treatment is 140 kg·ha^{-1}; 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.

PROJECT RESULTS AND CONCLUSIONS

Time of N application had a significant effect on yield for the harvest of 2000-01 (Table 1). Trees that received 44.8 kg·ha^{-1} N applied to the soil in April for all years of the study had a significantly higher yield than control trees receiving five applications of N at 28 kg·ha^{-1} despite the fact that these single doses of N were applied at key stages in 'Hass' phenology. This result is consistent with the result of our earlier research conducted in Temecula. The treatment supplying N at 44.8 kg·ha^{-1} to the soil in April was also significantly better than the foliar application of low-biuret urea in April supplying N at 67.2 kg·ha^{-1}. Trees receiving a double dose of N to the soil in April had yields that were not significantly different from trees receiving a double dose of N to the soil in August or November, a triple dose of N to the soil in April, or only 44.8 kg·ha^{-1} N to the soil in August. Thus far, there is no added benefit from the extra N when a triple dose of N is applied to the soil in April, and 44.8 kg·ha^{-1} N applied to the soil in August was sufficient to maintain yield equal to that of trees receiving significantly more N in year 1. The harvest for 2002 was an off-year crop. Treatments producing the higher yields in 2001 resulted in the lowest yields in 2002. Thus, control trees which had a low yield in 2001 had the highest yield in 2002. Control trees and trees that received N at 67.2 kg·ha^{-1} in April to the soil had the highest 2-year-cumulative yields. N treatments significantly ($P \leq 0.05$) affected tree N status as indicated by standard leaf tissue analyses. However, there was no significant correlation between tree N status and yield. Due to alternate bearing, additional years of harvest data are required to confirm these observations.

The amounts of nitrate leaching past the root zone were not significantly affected by the treatments on any sampling date or in any year (Table 2). However, it is clear that dividing the total annual N into five small doses results in a numerically, but not statistically significant reduction in the amount of N leaching past the root zone, reducing the potential for nitrate pollution of the groundwater. Trees receiving N at 67.2 kg·ha^{-1} in April had numerically but not statistically more nitrate leaching past the root zone than trees receiving N at 44.8 kg·ha^{-1} in April. The amounts of ammonium leaching past the root zone were low and significantly affected by the N treatments only in November of 2001 (Table 3). The high amount of ammonium leaching past the root zone in April for control trees is due to an abberant datum point. The data have not yet been tested for outliers, corrected for N contributed by organic matter or analyzed in relation to irrigation volume. It is likely that trees receiving N at 44.8 kg·ha^{-1} in both April and November would leach higher amounts of N.

The results thus far suggest that the strategy (control treatment) of applying N as NH_4NO_3 in five small doses at 28 kg·ha^{-1} in August, November, January, April and July contributes to reducing the potential for nitrate pollution of groundwater. Timing the N applications in the control to key events in the phenology of the 'Hass' avocado identified from our previous research resulted in this treatment having a high 2-year-cumulative yield and the lowest degree of alternate bearing. However, due to alternate bearing, a minimum of two additional years of yield data are required before an N fertilization recommendation can be made for the 'Hass' avocado in California.

Table 2. Effect of application time for the double dose of N vs. control on nitrate leaching past the root zone from April through November in 2000 and 2001[z].

	2000				2001				2-year
Treatment[y]	*Apr.*	*Aug.*	*Nov.*	*Cumulative total*	*Apr.*	*Aug.*	*Nov.*	*Cumulative total*	*cumulative total*
					μg NO_3^-/5 g resin				
2x N in August	1185	n/a	3833	5018	7339	776	544	8655	13673
2x N in November	4808	n/a	1043	5850	2051	10148	2449	14648	20498
Control	1064	n/a	1465	2530	1050	1250	2405	4701	72321
3x N in April	1789	n/a	7868	9656	2693	2899	1688	7277	16933
2x N in April	7920	n/a	619	8539	1009	1485	551	3047	11586
P-value	NS	n/a	NS	NS	NS	NS	NS	NS	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 N as NH_4NO_3 at 44.8 kg·ha^{-1} applied to the soil in August split as two applications in July and in August for all years of the experiment. Since January 1999 control trees received N as NH_4NO_3 at 140 kg·ha^{-1}, divided into five applications of N at 28 kg·ha^{-1} in August, November, January, April, and July. Trees in all other treatments received 140 kg·ha^{-1} applied as 2N= N at 44.8 kg·ha^{-1} or 3N=N at 67.2 kg·ha^{-1} other months is reduced to compensate for the extra N applied in the month(s) specified for the treatment.

Table 3. Effect of application time for the double dose of N vs. control on ammonia leaching past the root zone from April through November in 2000 and 2001[z].

	2000				2001				2-year
Treatment[y]	*Apr.*	*Aug.*	*Nov.*	*Cumulative total*	*Apr.*	*Aug.*	*Nov.*	*Cumulative total*	*cumulative total*
					μg NH_4^+/5 g resin				
2x N in August	633	n/a	84	717	236	330	102 ab	669	1386
2x N in November	412	n/a	71	483	331	95	119 a	544	1027
Control	1226	n/a	65	1290	235	67	101 ab	402	1690
3x N April	401	n/a	99	500	201	162	75 b	438	939
2x N in April	416	n/a	118	533	257	95	119 a	471	1004
P-value	NS	n/a	NS	NS	NS	NS	0.08	NS	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 N as NH_4NO_3 at 44.8 kg·ha^{-1} applied to the soil in August split as two applications in July and in August for all years of the experiment. Since January 1999 control trees received N as NH_4NO_3 at 140 kg·ha^{-1}, divided into five applications of N at 28 kg·ha^{-1} in August, November, January, April, and July. Trees in all other treatments received 140 kg·ha^{-1} applied as 2N= N at 44.8 kg·ha^{-1} or 3N=N at 67.2 kg·ha^{-1} in the months indicated. The total N applied in any treatment is 140 kg·ha^{-1}; 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.

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 (Persea americana L.) 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 of uptake to thus protect the groundwater and increase profitability for California's 6,000 avocado growers.

PROJECT OBJECTIVES

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

PROJECT DESCRIPTION

The research is being conducted in a commercially bearing avocado orchard in Moorpark, 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 (off-crop trees) and heavy fruiting on-crop trees. The experiment is a randomized complete block design with factors: (1) cropping status (heavily cropping—on-crop

Table 1. Biomass (dry weight) of components of mature off-crop (A) and on-crop (B) 'Hass' avocado trees sampled between January and June 2002.

A.			*Tree Biomass (kg dry wt/tree)*			
Tree Component	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*
New Shoots	0	0	0	0.36	1.80	1.38
Reproductive structures	0	0	1.52	1.88	1.44	0.49
Leaves	12.59	9.75	10.61	3.92	2.30	7.86
Green twigs <1/2"	10.64	13.73	10.89	7.89	5.34	7.52
Fruit	5.26	0.10	0.32	0.18	0.17	0.33
Small Branches >1/2-2"	17.12	23.82	13.05	14.36	6.54	7.99
Canopy Branches*	86.18	83.95	80.58	71.41	61.93	58.13
Trunk	15.88	8.29	7.09	14.21	10.14	10.78
Rootstock		28.56				12.79
Large Roots		21.89				9.83
Small roots		11.68				4.03
Total	147.66	201.79	124.06	113.94	89.67	120.86

B.			*Tree Biomass (kg dry wt/tree)*			
Tree Component	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*
New Shoots	0	0	0	0.22	1.97	1.47
Reproductive structures	0	0	0.05	0.08	0.09	0.11
Leaves	11.29	6.28	13.76	3.12	2.26	8.72
Green twigs <1/2"	10.68	8.32	14.10	7.18	6.68	10.04
Fruit	25.98	2.08	0.88	4.78	7.58	2.68
Small Branches >1/2-2"	16.72	10.62	20.04	8.64	6.70	12.32
Canopy Branches*	88.04	66.43	79.24	59.11	56.65	73.84
Trunk	13.04	12.26	9.71	17.76	11.05	10.49
Rootstock		19.56				20.69
Large Roots		7.55				11.64
Small roots		7.36				9.23
Total	165.76	140.46	138.28	100.88	92.90	160.85

*Two components comprising canopy branches were combined.

trees and lightly cropping—off-crop trees) and (2) time of excavation. Two trees (one on-crop and one-off-crop tree) are dissected at each sampling date; there are a total of 13 sampling dates. For each sampling date, the entire tree is dissected into the following components, and the total fresh and dry weight of each component determined: leaves, new shoots, inflorescences or fruit (separated into seed, flesh and peel), small branches (≤ 2.5 cm), mid-size branches (2.5-5.0 cm), scaffolding branches, scion trunk, rootstock trunk, scaffolding roots, small roots, and new actively growing roots. Sub-samples are 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 tissues.

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 sampling dates. 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. Nitrogen uptake will also be determined from ^{15}N applications to both on- and off-crop trees over the season.

RESULTS AND CONCLUSIONS

Effect of alternate bearing on 'Hass' avocado tree biomass, nutrient content and nutrient distribution within the tree

Table 2. Nutrient concentrations (g/100 g dry wt. tissue) in tree components of mature, heavily cropping 'on' and lightly cropping 'off' 'Hass' avocado trees, measured in August (A) and November (B) 2001.

A.

Tree Component	*Heavily Cropping* N	P	K	*Lightly Cropping* N	P	K
Scaffold Branches	0.40	0.06	0.38	0.40	0.06	0.31
Branches 2-4"	0.50	0.19	0.67	0.30	0.19	0.48
Small Branches	0.50	0.17	0.33	0.70	0.54	1.41
New shoots	0.80	0.39	1.21	0.80	0.57	1.55
Leaves	2.00	0.21	0.89	2.10	0.26	1.15
Fruit – Seed	1.50	0.24	1.12	1.30	0.27	1.27
Fruit – Flesh	2.60	0.35	2.39	1.54	0.32	1.92
Fruit – Peel	1.10	0.18	1.33	2.44	0.12	1.07
Fine Roots	1.00	0.22	0.24	0.80	0.23	0.39
Small Roots	0.40	0.09	0.21	0.70	0.11	0.21
Scaffold Roots	0.40	0.09	0.20	0.40	0.08	0.27
Rootstock	0.20	0.08	0.10	0.20	0.04	0.12
Trunk	0.30	0.04	0.27	0.20	0.04	0.12

B.[1]

Tree Component	*Heavily Cropping* N	P	K	*Lightly Cropping* N	P	K
Trunk	0.30	0.05	0.31	0.30	0.05	0.31
Scaffold Branches	0.20	0.03	0.19	0.20	0.03	0.19
Branches 2-4"	0.20	0.03	0.18	0.30	0.04	0.27
Small Branches	0.30	0.12	0.44	0.70	0.18	0.57
New shoots	0.60	0.32	0.74	0.80	0.42	1.06
Leaves	1.70	0.15	0.61	2.10	0.15	0.66
Fruit – Seed	0.75	0.16	0.89	0.80	0.20	1.03
Fruit – Flesh	1.42	0.19	1.46	1.58	0.23	1.66
Fruit – Peel	0.98	0.17	1.13	1.18	0.23	1.48

[1]Roots were not excavated in the November sampling.

The results thus far provide evidence of the effect of crop load (i.e., on-year crop vs. off-year crop) on production of reproductive structures in spring and through early fruit set (Table 1). Trees (A) carrying an off crop (the spring 2001 fruit were removed in July 2001) produced significantly greater biomass of reproductive structures from March through June 2002 compared to trees (B) that were not defruited in July 2001. The surprising result was that even the presence of a few fruit (2 kg) was sufficient to reduce return bloom. The spring 2001 fruit were harvested in July 2002.

Nutrient concentrations varied among the tree parts as a result of alternate bearing (Table 2). Concentrations of the macronutrients N, P and K were greater in the leaves, new shoots, and small branches of off-crop trees than in the analogous structures of on-crop trees. Similarly, K levels in fine actively growing roots were greater in off-crop compared with on-crop trees. These differences likely result from a higher demand for nutrient redistribution out of these tissues and into the large number of fruit of on-crop trees.

Whole tree nutrient contents were calculated as the product of dry weight of the tree structure and the nutrient concentration of that structure (Table 3). Total tree nutrient contents were similar for both on-crop and off-crop trees, although tissues in close proximity to fruit (leaves, current wood) tended to have lower nutrient contents in on-crop vs. off-crop trees. In both tree sampling dates, heavily cropping trees accumulated nutrients primarily in their fruit, while lightly cropping trees stored nutrients in their leaves.

It will be very interesting to see how the nutrients in the tree tissues change over the season and as a result of alternate bearing. This information is critical in determining the seasonal pattern of nutrient uptake and for matching fertilizer application with periods of high nutrient demand.

Woody tissues comprised most of the tree dry weight, but contained few nutrients, whereas current season's growth made up a small fraction of the tree's dry weight, yet contained most of the tree's nutrients (Table 4). New shoot, leaves and fruit, structures that would be added to the tree each year, made up only 16% of the total biomass on a dry

Table 3. Tree dry weights (kg/tree) and nutrient content (g/tree) of mature, heavily cropping 'on' and lightly cropping 'off' 'Hass' avocado trees, excavated in August (A) and November (B) 2001.

A.

Tree Component	*Heavily Cropping* Dry Wt kg/tree	N	P	K	*Lightly Cropping* Dry Wt kg/tree	N	P	K
	kg/tree		*g/tree*		*kg/tree*	*g/tree*		
Trunk	34	103	14	93	23	46	9	27
Scaffold Branches	98	390	59	371	85	339	51	263
Branches 2-4"	25	123	47	165	49	146	93	234
Small Branches	7	37	12	24	25	178	137	359
New shoots	11	85	41	129	13	107	76	208
Leaves	22	431	45	192	29	615	76	337
Immature Fruit	5	107	15	102	9	138	25	137
Mature Fruit	11	355	55	534				
Fine Roots	13	128	28	31	17	133	38	65
Small Roots	11	44	10	23	14	97	15	29
Scaffold Roots	29	117	26	59	19	76	15	51
Rootstock	37	74	30	37	34	68	14	41
Total	302	1994	382	1758	317	1944	550	1751

B.[1]

Tree Component	*Heavily Cropping* Dry Wt kg/tree	N	P	K	*Lightly Cropping* Dry Wt kg/tree	N	P	K
	kg/tree		*g/tree*		*kg/tree*	*g/tree*		
Trunk	38	114	19	118	53	158	26	163
Scaffold Branches	94	188	28	178	79	159	24	151
Branches 2-4"	39	77	12	70	39	118	16	106
Small Branches	18	54	22	79	38	266	68	216
New shoots	26	158	84	194	29	232	122	307
Leaves	22	376	33	135	37	767	55	241
Immature Fruit	40	462	71	501	18	233	39	267
Total	277	1429	269	1276	292	1933	350	1452

[1]Roots were not excavated in the November sampling.

weight basis of the tree but contained 47% of the total N in the tree, 36% of all the P and 44% the total K (Table 4). Scaffolding branches accounted for twice as much biomass as that of new shoots, leaves and fruit combined but contained less than half as much N, P and K. The rootstock (trunk, scaffolding roots, small roots and actively growing roots) represented 28% of the total tree biomass but only 20% of the total tree N and P and only 9% of the tree's total K. It is clear that actively growing scion tissues are the major sinks for N, P and K during the year. Quantifying the monthly demand of each of these sinks for each nutrient will contribute to our goals of developing best management fertilizer practices for the 'Hass' avocado in California and reducing the potential for groundwater pollution.

Table 4. Percent contributions of the various tree components to the total tree dry weight and N, P, and K contents from the August tree sampling. Data are averaged over both the heavily and lightly fruiting (on-crop and off-crop) trees.

Tree Component	*Dry Wt % Total*	*N*	*P % Total*	*K*
Trunk	9	4	3	3
Scaffold Branches	30	18	12	18
Branches 2-4"	12	7	15	11
Small Branches	5	6	14	11
New shoots	4	5	12	10
Leaves	8	27	13	15
Fruit	4	15	11	22
Fine Roots	5	7	7	3
Small Roots	4	4	3	1
Scaffold Roots	8	5	5	3
Rootstock	11	4	5	2
Total	100	100	100	100

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.

There is a tendency for vegetable growers to apply generous amounts of water to produce because of anxiety about crop quality and the lack of sufficient information to do otherwise. Additionally, concerns about salt accumulation having an adverse affect on land sustainability often prompts growers to employ a generous leaching requirement. A perceived lack of practical technologies on irrigation scheduling is another major obstacle to progress in implementing efficient irrigation practices. It is the opinion of the authors 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, it is of the utmost importance to show growers that this can be achieved without compromising crop yield and quality and long-term land sustainability.

The first phase of this project experimentally evaluated irrigation scheduling technologies and management practices. The second phase of this project included demonstration of the use of these technologies.

OBJECTIVES

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 and N leaching.
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 studies focused on the development of efficient furrow irrigation practices. However, because some of 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 conducted during 1999, 2000, 2001, and 2002 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

Studies were established in 2000, 2001, and 2002 to evaluate and validate irrigation scheduling for lettuce. The first and third 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 (1998-2000), (2) model calibration and validation (2000-2002), (3) simulation experiments and development of management tools [i.e., performance charts and lookup tables (2001-2002)], and (4) development of management guidelines that facilitate effective use of the management tools (2001-2002). 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 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

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). Data for melons suggest a MAD of 40% depletion of available water to a 0.6 m soil depth. Data for crop coefficients for melons are currently being analyzed.

Lettuce yields were generally not affected by irrigation regime in 2001 indicating that irrigation scheduling would not compromise yield compared to grower standard practices. In fact, grower practices resulted in reduced yield compared to irrigation scheduling in 2002. During both years, crop yield and crop N uptake responses to N rate were minimal indicating that residual N was high on this sites used in these experiments. Residual N as measured by soil analysis and N leaching as measured by resins increased with N rate.

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. The suitability of these performance charts was further validated in demonstrations performed during 2002.

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 performance of slow release fertilizers on cool season vegetable production in the Salinas Valley. Controlled laboratory studies were conducted in the first year of the project (2000-01) and field studies were conducted the first and second year of the project. The evaluations include the effect of two slow release materials at three rates on broccoli grown over the winter during the rainiest time of the year. Broccoli was selected as the test crop because it is a key cool-season vegetable that is extensively planted in the Salinas Valley (54,899 acres in 2001). In addition, significant acreage is grown in the winter when the potential for losses of nitrogen due to leaching and the risk of being rained out of the field to make sidedress applications is high.

OBJECTIVE

Evaluate nitrogen release, yield and the economics of a select number of coated urea, slow release fertilizer materials in a field trial conducted on winter broccoli.

DESCRIPTION

A slow release fertilizer trial was conducted in a commercial broccoli field in the Salinas Valley during the winter of 2001-02. 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 a low rainfall year as a total of only 4.70 inches of rain fell during the trial with no one rainfall event exceeding 0.95 inches in a 24 hour period. The slow release fertilizer was shanked into listed beds on November 30 and the broccoli was direct seeded on December 3. 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 (Table 2). The slow release treatments were compared with an untreated control and a standard treatment that received a total of 200 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 two dates (April 18 to 24) and the number and weight of broccoli heads per plot was collected.

RESULTS AND CONCLUSIONS

There were high levels of residual nitrate-N in the soil at the beginning of the trial and the levels of soil nitrate-N in the untreated plots did not separate from the standard fertilizer treatment until after the February 5th sampling date (Figure 1). The slow release and standard fertilizer treatments had higher nitrate-N in the soil than the untreated on the February 19 and March 5 sampling dates. These differences were not reflected in differences in the total-N in broccoli tissue at the two later sampling dates (Table 1). The soil nitrate-N in the 200 lb N/A slow release treatments declined steadily over the course of the season, while the standard and combination

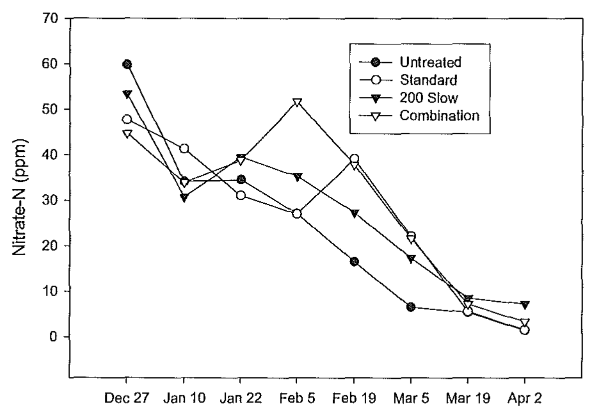

Figure 1. Nitrate-N in the soil over the course of the season in selected slow release fertilizer treatments (combination = 100 lbs slow release + 100 lbs standard fertilizer)

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

Treatments (N/A)	*Feb 26*	*Mar 19*	*Apr 4*
Polyon 200	6.11	4.94	5.22
Polyon 150+50	6.23	4.87	5.74
Polyon 100+50+50	6.24	4.81	5.59
Duration 200	6.09	5.23	5.82
Duration 150+50	6.12	4.67	5.33
Duration 100+50+50	6.07	5.13	5.59
Standard	6.31	4.94	5.64
Untreated	5.64	4.82	5.53
LSD (0.05)	0.17	n.s.	n.s.
Contrast (0.05)			
Slow release vs Standard	n.s.	n.s.	n.s.

Table 3. Cost comparison summary for standard and slow release fertilizer applied to winter grown broccoli (230 lbs N/A applied)

		Cost per Application and Total Costs/A			
		Standard Fertilizer	Slow Release Fertilizers[4]		
Application	*Material*		*100%*	*75%*	*50%*
Preplant	15-15-15[1]	43	179	138	97
Sidedress #1	AN 20[2]	48	0	0	34
Sidedress #2	AN 20	48	0	34	34
Water run	CAN 17[3]	26	26	26	26
Total		156	207	198	191

[1]$0.47/lb N assigned to the nitrogen cost; [2]$0.47/lb N; [3]$0.59/lb N; [4]$0.82/lb N.

slow release fertilizer treatments spiked higher soil nitrate-N values following fertilizer applications.

There was significantly greater broccoli head biomass in all slow release fertilizer and standard fertilizer treatments than the untreated control on the first harvest date (data not shown). The total number and weight of broccoli heads harvested from the standard and slow release fertilizer treatments were comparable (Table 2). There was no increase in the mean head weight of broccoli in the 2001-02 season as was observed in the first year of the study. The cost of fertilizer programs that utilize 100, 75 and 50% slow release fertilizers in a typical broccoli fertilizer program (i.e. 230 lbs N/A) cost 33, 27 and 22% more than the standard fertilizer program (Table 3). Slow release fertilizers did not increase the yield of broccoli in these trials and they have additional costs. Growers may still be motivated to utilize slow release fertilizers to

Table 2. Fertilizer application schedule and total yield of broccoli

Treatment	*11/30/01 lbs N/A*	*Sidedress #1 1/15/02*	*Sidedress #2 1/29/02*	*Sidedress #3 2/22/02*	*Sidedress #4 3/18/02*	*Total No. Heads*	*Total Wt. (lbs)*	*Mean Head Wt.*
Polyon	200	0	0	0	0	149.4	84.1	0.56
Polyon	150	0	0	0	50	152.7	87.9	0.57
Polyon	100	0	50	0	50	148.8	84.6	0.57
Duration	200	0	0	0	0	140.1	83.7	0.59
Duration	150	0	0	0	50	146.5	85.1	0.58
Duration	100	0	50	0	50	142.2	79.4	0.55
Standard	0	50	50	50	50	141.5	83.5	0.59
Untreated	0	0	0	0	0	148.5	77.4	0.52
LSD (0.05)						n.s.	7.0	0.05
Contrasts (0.05)								
Polyon vs Duration	n.s.	n.s.	n.s.					
Slow release vs Standard	n.s.	n.s.	n.s.					
200 slow release vs standard	n.s.	n.s.	n.s.					
200 slow release vs 100 slow release	n.s.	n.s.	n.s.					

reduce the risk of being rained out of the field to make side-dress applications during high rainfall growing seasons. Under these conditions, slow release fertilizers can give comparable yields to a standard fertilizer program.

The 2000-01 growing season was a low rain fall year. Further tests with heavier rainfall events during the growing season 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 DROP IRRIGATED BEAUREGARD SWEETPOTATOES

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INTRODUCTION

The use of drip irrigation for sweetpotatoes in California has increased every year since its inception back in the late 80s, and is now used on an estimated 65-75% of the production acreage. Some of the reasons for this continued growth include irrigation convenience, uniformity of application, the ability to irrigate rolling land, and the ability to spoon feed nutrients with the system through the growing season.

Drip irrigation is just one of many agronomic changes that have contributed to substantial average yield increases in the past 20 years. Since 1982, average county yields have increased > 35% (from 9.5 to 13 tons per acre). Despite the widespread adoption of drip irrigation, however, no fertilizer trials have been performed with this system to determine optimal rates of N and K for maximum economic production. Based on old fertilizer trials performed in furrow irrigated fields, current N and K recommendations are 80 – 120 lbs N/A and 0 – 100 lbs K_2O/A. Increased yields certainly imply that increased nutrients are required, but because nitrogen is metered into the system during the growing season, nitrogen use efficiency may be improved to the extent that increased fertilizer rates (especially for nitrogen) are not necessary.

The judicial use of nitrogen fertilizer has more than just economic implications for sweetpotato production in Merced county as well: almost the entire industry is situated in an area with deep, well drained loamy sands where water and nutrients can easily leach out of the root zone.

OBJECTIVES

In 2001, we initiated a study to evaluate the nitrogen and potassium requirements for Beauregard sweetpotatoes. The objectives of this trial were:

- Determine the optimal rates of N and K fertilizer for best yield and quality in drip irrigated Beauregard sweetpotatoes.
- Determine the effect of different rates of potash and nitrogen on moisture loss in storage.
- Re-evaluate current fertilizer application tissue analysis guidelines.
- Determine if applications of N with the drip system results in substantial leaching of nitrate beyond the root zone.

PROJECT DESCRIPTION

A trial was initiated with a commercial sweetpotato grower beginning in the spring of 2001 and again in 2002. Nitrogen rates were 0, 50, 100, and 200 lbs N per acre, and potash rates were 0, 75, 150, and 300 lbs K_2O per acre. 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 were 2 rows wide by 45 feet long and replicated four times.

Granular potassium sulfate and phosphorous were applied to the beds under the drop lines at transplanting. Phosphorous rates were 60 lbs P_2O_5 uniformly applied to all plots. Nitrogen treatments began in late June or early July. CAN17 was injected on a 5 to 7 day schedule for a total of 7 - 8 applications. All nitrogen was applied through the drip tubes using a small battery operated piston pump. The nitrogen rate injection schedule is shown in Table 1.

Sampling: Soil samples were taken in April and late August. The August soil sampling occurred after all nitrogen treatments had been applied. Samples were taken in each plot to three feet and divided into one-foot increments, then analyzed for N (as NO_3-N) and K. Leaf and petiole samples were taken three times during the growing season. A sub sample of harvested roots were also analyzed for N and K to determine nutrient removal rates. Moisture loss in storage

Table 1. N fertilizer injection schedule for 2001 and 2002.

App.	2001 Date	2002 Date[1]	Rate	50	100	200
				Lbs N per week*		
1	7/5	6/26	1/2 x	3.5	7.0	14.0
2	7/13	7/5	1 x	7.0	14.0	28.0
3	7/18	7/10	1 x	7.0	14.0	28.0
4	7/23	7/16	1.5 x	10.5	21.0	42.0
5	7/30	7/23	1.5 x	10.5	21.0	42.0
6	8/3	7/29	1 x	7.0	14.0	28.0
7	8/8	8/2	1/2 x	3.5	7.0	14.0
8	8/13		1/2 x	3.5	7.0	14.0

* Due to rounding, actual total N applied was 5% greater than target rate.
[1]The 8th application was not made in 2002; instead rates were increased on the 7th application.

Table 2. Spring initial soil samples, 2001 and 2002.

Year	Sample depth	pH	EC	CEC	NO_3-N ppm	P ppm	Sol K ppm
2001	0 – 12"	5.8	0.79	6.8	13.7	58.1	51.0
	12–24"	5.2	0.64	9.0	8.6	23.8	23.1
	24–36"	5.5	0.53	8.4	6.2	15.8	11.9
2002	0 – 12"	4.7	0.89		21.5	68.6	86
	12 – 24"	5.0	0.44		6.2	27.9	50
	24 – 36"	5.5	0.62		9.4	19.2	52

EC = electrical conductivity in mmhos/cm.
CEC = cation exchange capacity in meq/100 g (not determined in 2002)

measured each month from November to May on 40 lb samples from each plot. Plots were harvested using a commercial harvester on October 31 and November 1, 2001.

RESULTS

Since not all data for 2002 has been collected, results presented here are for 2001 to early 2002. Spring soil test results are shown in Table 2. Nitrate levels in the top foot were moderate, averaging 13.7 ppm (~ 54 lbs NO_3-N), and fairly low at the lower depths. Potassium was below 100 ppm at all depths, indicating that a response to potash fertilizer would be expected.

Leaf and petiole sample results for July and September, 2001, are shown in Tables 3 and 4. In July, the plants in the 150 and 300 lbs K_2O treatments had significant greater potassium in the petioles than the lower rates. Late season (September) results showed significantly higher nitrate levels as the N rate increased. Tissue results from August after all fertilizer treatments were finished are shown in Figures 1 and 2.

Table 3. Leaf and petiole samples taken July 6, 2001.

K rate, lbs/A	N rate, lbs/A*	K %	NO_3-N, ppm
0	0	5.19	2537
75	0	5.52	3297
150	0	6.11	5627
300	0	5.95	3602
	LSD 0.10	0.53	NS

* At time of sampling nitrogen treatments had not started.
LSD 0.10 = Least Significant Difference at the 90% confidence level. Means separated by less than this amount are not significantly different.

Table 4. Leaf and petiole analyses from samples taken September 17, 2001.

K rate, lbs/A1	K %	N rate, lbs/A	NO_3-N, ppm
0	2.56	0	1375
150	2.72	50	4210
		100	2858
		200	7433
LSD 0.10	NS		1935

1. Only 0 and 150 lb rates were sampled at this time.
LSD = Least Significant Difference at the 90% confidence level. Means separated by less than this amount are not significantly different.

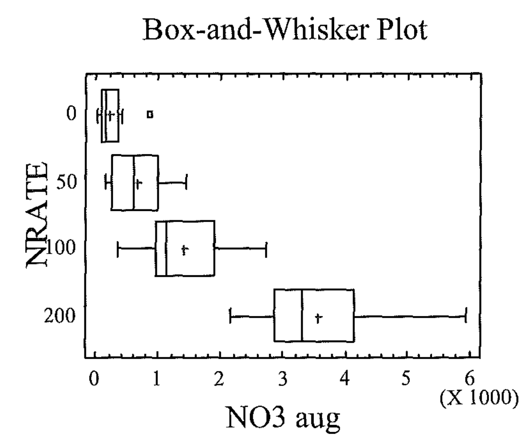

Figure 1. August leaf and petiole tissue N (as NO_3) as affected by N fertilizer rate. LSD 0.90 = 502 ppm.

Tissue NO_3-N and K were significantly increased as fertilizer rate increased. There was no significant nitrogen by potassium interaction.

Yield results are shown in Table 5. At the 90% confidence level, nitrogen significantly increased #1's, jumbos, and total

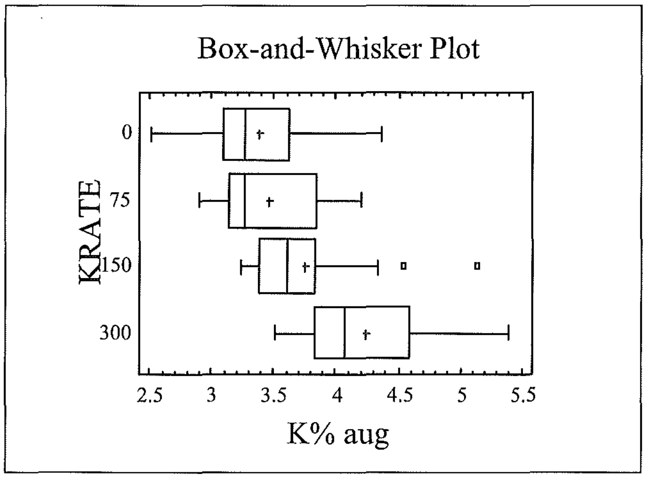

Figure 2. August leaf and petiole tissue K as affect by potash rate. LSD 0.90 = 0.29%.

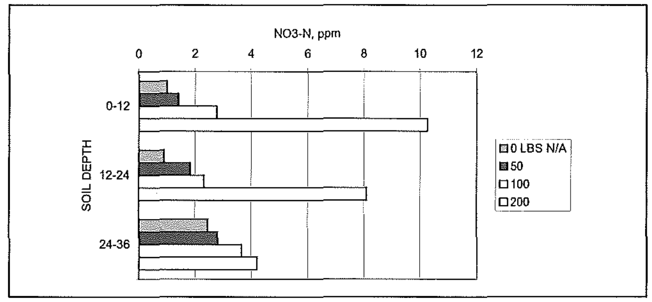

Figure 3. Average soil nitrate-nitrogen (NO_3-N in ppm) at the end of the summer for different depths and nitrogen fertilizer treatments. LSD (0.90) for 12, 24, and 36" depths are 2.41, 2.28, and 1.15 ppm respectively.

marketable yield as compared to the treatments that did not receive any N. However, there was no significant difference between the rate of N applied. Potash did not have any significant effect on yield, and the N x K interaction was not significant for any size. The lack of potassium response in this trial probably occurred because the whole test site was accidentally top dressed with 150 lbs K_2O per acre mid-way through the growing season.

Soil samples taken in August after the last irrigation with fertilizer application showed increased amounts of NO_3-N and K as fertilizer rates increased for all depths (Figures 3 & 4). The 200 lb N rate significantly increased soil NO_3 in the first and second foot as compared to the other treatments. Greatest K was found at the 12-24" depth, while most of the N was at the surface. The amount of NO_3-N in the profile, however, was very low for the amount applied. Even at 200 lbs of N per acre, less than 4 ppm N as NO_3-N was found at a depth of 3 feet. This suggests that most of the N applied was not being leached past the root zone during the growing season. However, spring 2002 soil samples from the 200 lbs N/A plots showed levels of 9.6 ppm NO_3-N at 3 feet, suggesting that some movement of N had occurred over the winter.

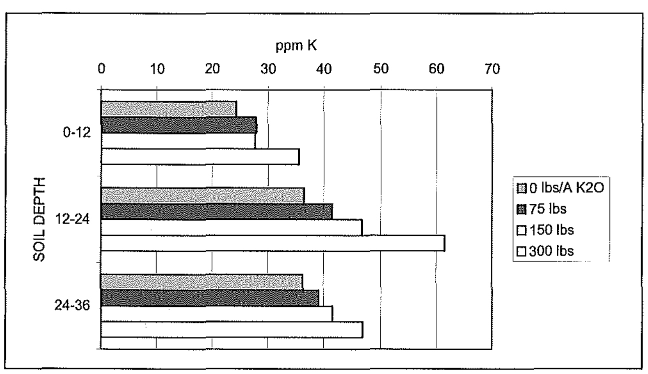

Figure 4. Average soil potassium (as ppm K) from 0 to 3 feet as affected by potash fertilizer rate. LSD (0.90) for 12, 24, and 36" depths are 4.16, 7.05, and 4.33 ppm respectively.

Because of the lack of a yield response to potassium fertilizer, correlation and calibration curves comparing fertilizer K to soil K and yield show no clear association. Regression analysis comparing potash fertilizer rate to cumulative soil test K showed a significant positive linear response ($p = 0.001$, $r^2 = 39.1\%$) in soil test K as fertilizer K increased (Figure 5). However, there was no correlation between fall soil test K and total marketable yield (Figure 6). There may be two reasons as to why this occurred. One, there was simply more potassium in the soil, either as indigenous soil K or from applied fertilizer, than was needed by the crop. On the other hand, the lack of a response may be because there was not enough difference between low and high soil test values to cause a significant yield response. Average soil K values

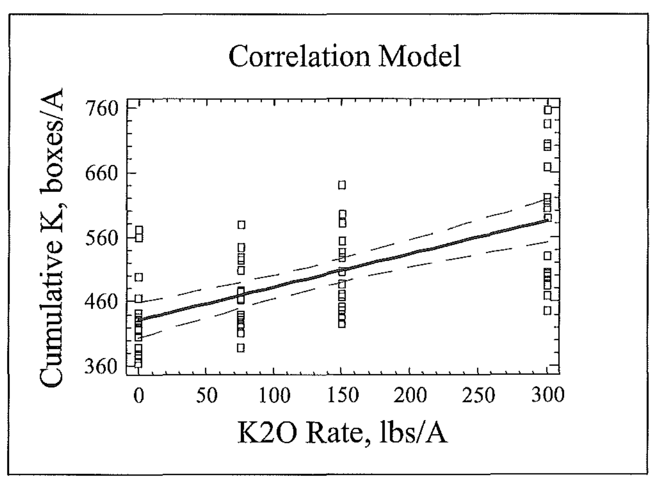

Figure 5. Correlation between applied potash and total K in the 3 ft profile. Best fit line is linear, with the equation $K_{soil} = 432 + 0.51(K_2O\ rate)$.

Table 5. Main effect of nitrogen and potash rate on yield and grade of Beauregard sweetpotatoes in 2001.

Treatment	*#1's*	*Jumbos*	*Mediums*	*Market Yield*	*#1's %*	*Culls Boxes/A*
N Rate			*40 lb Boxes/A*			
0	328	206	158	685	48.1	107
50	420	208	156	784	54.0	95
100	463	209	159	830	56.0	126
200	459	279	177	915	50.1	121
LSD 0.10	122	59	NS	159	6.8	NS
K Rate						
0	437	219	171	828	53.2	105
75	409	212	168	788	51.9	116
150	431	251	158	833	51.4	102
300	393	219	152	764	51.7	126
LSD 0.10	NS	NS	NS	NS	NS	NS
N x K LSD	NS	NS	NS	NS	NS	NS

US #1's: Roots 2 – 3.5" in diameter, 3 – 9" in length, must be well shaped and free of defects.
Mediums: Roots 1 – 2" diameter, 3 – 7" in length.
Jumbos: Roots that exceed the diameter and length requirements of the above two grades, but are of marketable quality.
% US #1's: Wt. of US #1's divided by the total marketable wt (culls not included).
Culls: Roots >1" in diameter and so misshapen or unattractive as to be unmarketable.
LSD 0.10: Least significant difference at the 90% probability level. NS = not significant.
CV Coefficient of variation, a measure of variability in the experiment.

Table 6. Partial soil N balance based on vine weight, root yields, and soil NO_3-N in the upper three feet of the profile.

N rate	*Vine wt1 Lbs/A*	*Vine N ppm NO_3*	*Vine N Lbs/A2*	*Root wt Lbs/A*	*Root N %*	*Root N3 Lbs/A*	*Soil N4 Lbs/A*	*TOTAL N Lbs/A*
1. 0 lbs/A	868	1375	30.6	27,400	0.85	48.0	18.5	97.1
2. 50 lbs/A	1309	4210	63.9	31,360	1.15	74.3	27.0	165.2
3. 100 lbs/A	1437	2858	59.9	33,200	1.01	69.1	37.3	166.3
4. 200 lbs/A	1589	7433	103.0	36,600	1.52	114.6	93.2	310.8
Average	1301	3969	64.3	32,200	1.13	---	44.0	---
LSD 0.05	426	2388	25.2	6360	0.25	---	26.8	---

[1]Vine weight is the total dry weight (6% D.M.) of the vine plus leaves by the end of the season (September sampling).
[2]Vine N estimated by converting NO_3-N values to total N% and multiplying by dry weight.
[3]Root nitrogen is total dry weight of roots using total marketable yield (D.M. = 20.6%) multiplied by N% in roots.
[4]Soil N is the sum of NO_3-N in the upper 3 feet of soil based on soil bulk density of 1.7, 1.6, and 1.5 g cm^{-3} for the 1st, 2nd, and 3rd foot in the profile, respectively (soil BD values based on USDA NRCS soil survey data).

ranged from 25 to 62 ppm, which basically classifies the soil as low K for all treatments (below 100 ppm K).

Very little relationship was found between the leaf and petiole analyses in August and yield. There was a slight positive relationship with plant NO_3-N and total marketable yield (r^2 = 12%), with highest yields occurring when nitrate levels in the tissue were around 3000 ppm (Figure 7). For tissue K, a slightly *negative* (r^2 = 10%) relationship was found (yield decreased as K% increased). The data suggest that there is no clear association between tissue test levels taken during root bulking and yield, but that tissue NO_3-N concentrations greater than 3000 ppm are clearly sufficient.

Weight loss in storage was measured at 6, 12, and 18 weeks. There was no significant effect from either N or K fertilizer rate on moisture loss until 18 weeks. On average, the roots lost 8.2% of their weight over 4 months, with 3.5% of that occurring in the first 6 weeks (initial losses are higher because of curing).

To help explain the lack of yield response to additional N fertilizer, a simple nitrogen balance was calculated using soil,

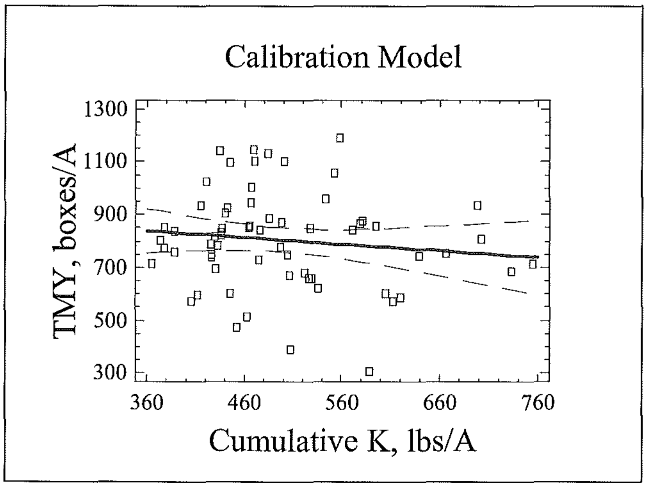

Figure 6. Regression model showing the lack of any significant correlation between cumulative soil K (to 3 ft) and total marketable yield.

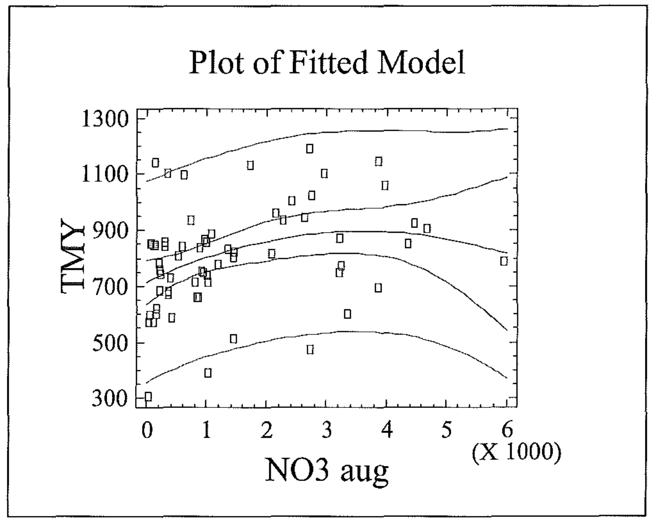

Figure 7. Relationship between leaf and petiole tissue sampled in August and total marketable yield (TMY). Best fit equation: $TMY = 715 + 0.1x - 0.000014x^2$*, where* $x = NO_3\text{-}N$ *in ppm.*

crop, and tissue N analyses (Table 6). About 165 lbs N/A was found in the treatments receiving 50 and 100 lbs of N, and 310 lbs N/A at the 200 lb N rate. While the high rate of N only marginally increased yield as compared to the other two rates, it also resulted in increased vine weight, leaf N, root N, and the amount of NO_3-N in the soil. Based on this data, optimal rates of N appear to be at least 100 lbs per acre, but less than 200.

In summary, we saw a significant yield response to N, but there was no significant difference between 50 to 200 lbs of N. However, as N rates increased, more N accumulated in the leaves and roots, and vine weight also increased as N rates increased. Thus, one of the effects of the 200 lb rate of N was thick, green vine growth. There was no significant yield response to potassium fertilizer, but all treatments received at least 150 lbs K_2O per acre, and thus no conclusions can be made. Varying N and K fertilizer rates had little effect on weight loss in storage. Regression analysis on leaf and petiole results showed a plant response to increased rates of N and K, however, this response was not correlated to yield. Mid-season nitrate levels in excess of 3000 ppm are more than sufficient; no conclusions can be drawn from the K tissue analyses. On a positive note, our research suggests that using drip irrigation in sweetpotatoes results in little build up of soil N or leaching beyond the root zone, even at high fertilizer rates.

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 100 to over 400 lbs/Ac. The rates of nitrogen application on potatoes are high for several reasons: (1) Potatoes are a high value crop (approx. $4,000/Ac gross farm gate), thus the goal is maximum yield; (2) Potatoes are relatively shallow rooted and have low root density, thus are inefficient in nitrogen uptake; (3) Much of the production is on sandy soils under solid-set sprinkler irrigation, 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 this last deficiency, growers have increased the amount and duration of nitrogen fertilization in an effort to keep the vines healthier and alive longer. 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.

Several new clonal selections have been made of Russet Norkotah that have stronger vines and later maturity. Research in other states and grower observations indicate 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. CalWhite, CalRed, Silverton Russet, and Klamath Russet) may also have lower nitrogen requirements. Numerous advanced selections and clones are evaluated annually. For economic and environmental reasons, these clones should produce well under conditions of relatively low input.

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.

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. The 2001 and 2002 experiments, the second and third years of the study, were supported by the CDFA-FREP program, in cooperation with the California Potato Research Advisory Board and the USDA Potato Variety Development Progam.

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

1. *Nitrogen x Variety Trials:* Nine trials have been conducted in the three years of the study, three in each year. A trial has been conducted in Kern County and in the Tulelake Basin each of the three years. Trials have been conducted in the Stocton Delta in 2001 and 2002, and one trial was conducted at UC Davis in 2000. The number of varieties in each trial has varied from six to nine entries. In Kern County and at Davis, red, long white and russet varieties were studied. At Tulelake (UC-IREC) the emphasis has been on russets. In the Stockton Delta, the emphasis has been on red skinned varieties. A total of 8 russet, 1 long white, and 8 red varieties were studied. Five nitrogen rates were utilized in each trial. An effort to have a zero (0) rate was made, but some trials were grown in grower's fields with unavoidable sprinkler applied and/or pre-plant applied nitrogen. The maximum rate varied based on the experience in the respective locations, from 300 to 400 pounds N per acre. Applications were split into two equal components at most locations, with half at planting and half as a side-dress 45-60 days after planting.

   Petiole samples were accomplished at most locations at 15-day intervals. Soil samples were collected at the beginning and end of growing seasons. Whole plant samples, followed by partitioning into vines, roots and tubers, were collected at two sites at the same time as petiole samples were collected. Total nitrogen and nitrate-nitrogen, as well as P and K on some samples, were determined on all samples. Total root mass samples were also collected at maturity from two sites. All of these petiole and nutrient analyses, as well as fresh and dry weights, are still being conducted and/or analyzed.

2. *Field Days, Grower Meetings, & Other Dissemination of Information:* Field days were conducted at harvest in Kern County and UC-IREC locations in 2000 and 2001, at midseason at UC-IREC in 2002, and at harvest at Kern County in 2002. 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 journal.

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

Although all nine trials of this project have been harvested, yield data are available from seven. Petiole and whole plant analyses are not yet complete. The survey has been partially completed. Thus, conclusions are pre-mature, and all results must be considered preliminary. Numerous interesting findings have been recorded, however.

Nitrogen rate and spacing experiments were conducted with sixteen varieties (7 reds, 1 long white and 6 russets) in Kern County—CalRed, Cherry Red, Red LaSoda, Mazama, Winema, Durango, Cherry Red, CalWhite, Russet Burbank Russet Norkotah, CORN #3, TXNS 112, TXNS 223, and Silverton Russet. The nine varieties (8 russets and 1 red) 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 nine varieties (3 reds, 1 long white and 5 russets) included were CalRed, Cherry Red, Red LaSoda, CalWhite, Russet Norkotah, CORN #3, TXNS 112, TXNS 223, and Russet Burbank. In the Stockton Delta, the eight varieties (6 reds and two whites) were Cheiftain, CalRed, Modoc, NDO4323-2R, Red Ruby, Mazama, CalWhite and A91556-2W. Thus, a total of 19 varieties (8 russets, 9 reds and 2 long whites) were included in one or more locations.

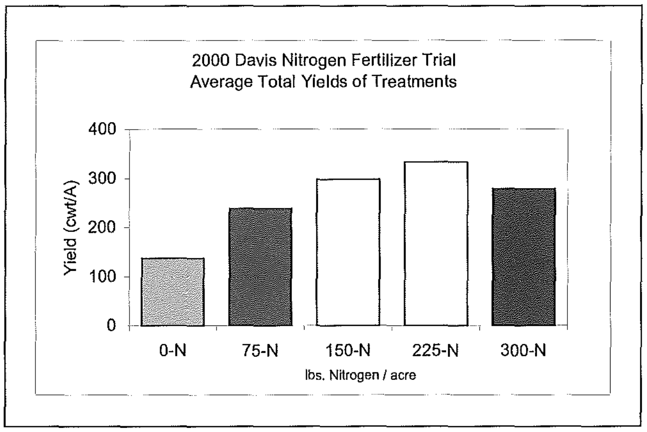


Figure 1.

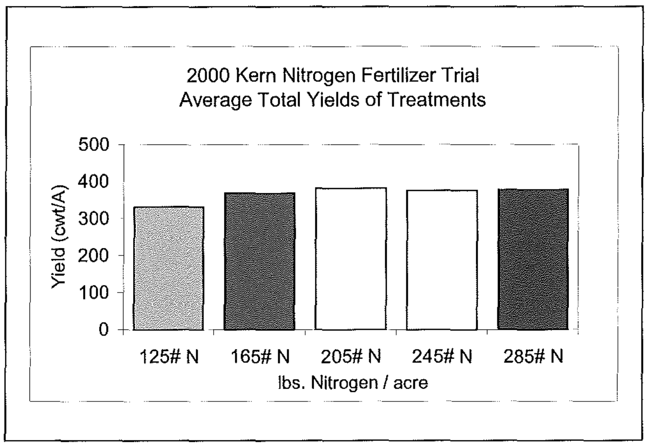
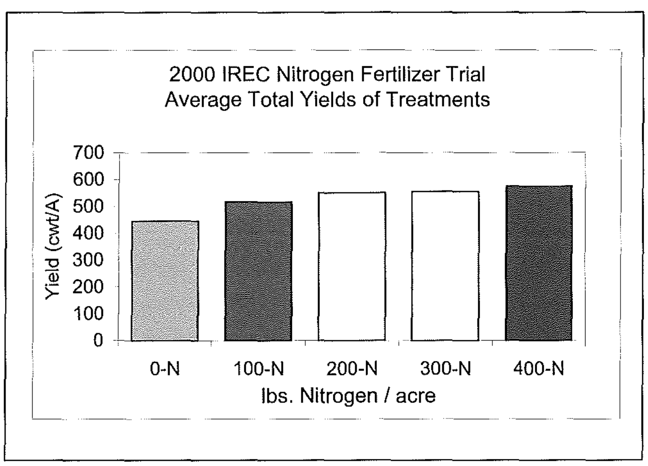


Figure 2.



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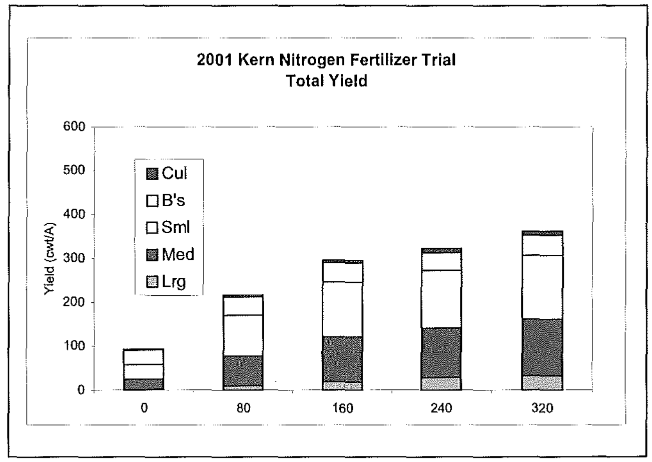

Figure 4.

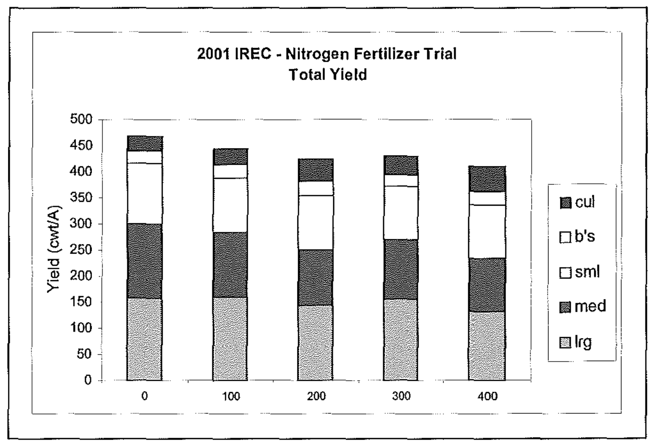

Figure 5.

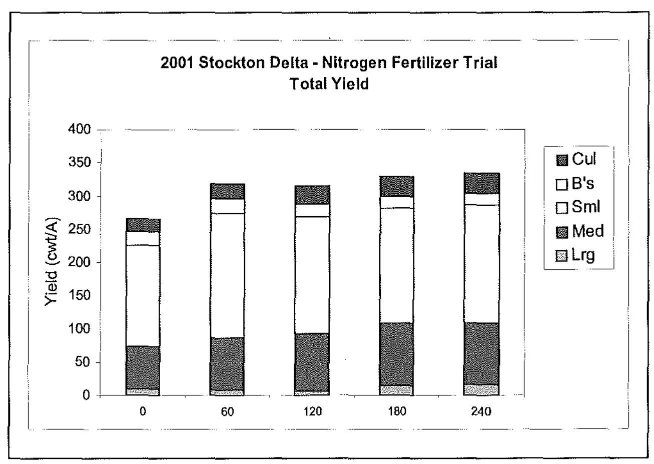

Figure 6.

Figures 1 – 6 illustrate the average response of all varieties included at each location-year. The response to nitrogen varied widely among the different locations. The classic parabolic response was observed at some locations, i.e. increasing yield up to the 4th rate and then a decrease in yield at excessive nitrogen rates. In some locations yields were increasing still at the highest rate, while in other locations no response or negative response to increasing nitrogen rates was measured. Thus, a preliminary conclusion is that optimum nitrogen fertilization rate varies from location to location. The organic soils in the Delta, and the high clay and organic soils of Tule-

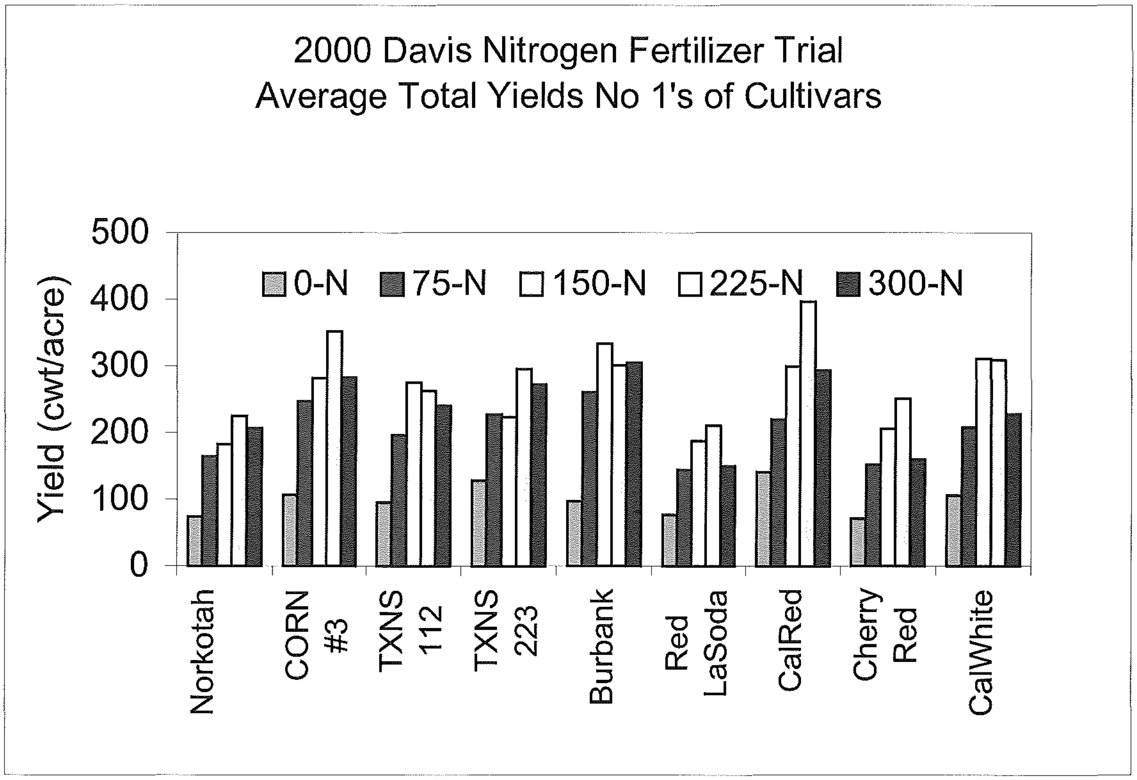

Figure 7.

lake were less responsive to nitrogen than the very sandy soils of Kern County. However, even among the sandy sites in Kern County, the response varied significantly. Thus, other factors must be considered. Soil type, past cropping history, residual nitrogen and the nitrogen content in the irrigation water are all important components in determining nitrogen fertilizer rates.

Figures 7 through 12 illustrate the variability among varieties in their responses to nitrogen fertilization. In some locations, the new Russet Norkotah strains did respond to lower nitrogen rates than the standard Russet Norkotah. In other locations, however, no differences among responses were measured. Some varieties, such as CalWhite, respond to high rates of nitrogen, while others, such as CalRed, do not respond to high rates. The level of responsiveness, understandably, correlates well with the total yield potential. In some locations all or nearly all varieties responded similarly (e.g. Davis 2000), while in other locations varieties responded quite differently (e.g. Kern County 2000).

Since the petiole and soil analyses have not been completed, correlations among plant analyses, soil nitrogen residual, fertilizer rate and yield response have not been determined. Similarly, the growth rate measurements have not been completed, thus the correlations with that parameter have not been determined.

It will be difficult, if not impossible, to make generalized nitrogen fertilizer recommendations based on potato variety or soil type in California. Several other factors must be included in determining the fertilizer needs. It does appear that potato varieties do respond differently to nitrogen. Thus, growers should consider the variety in making fertilizer applications. Furthermore, breeders should consider the fertility level of the soil when making selections; more efficient varieties can be selected if lower nitrogen rates are used.

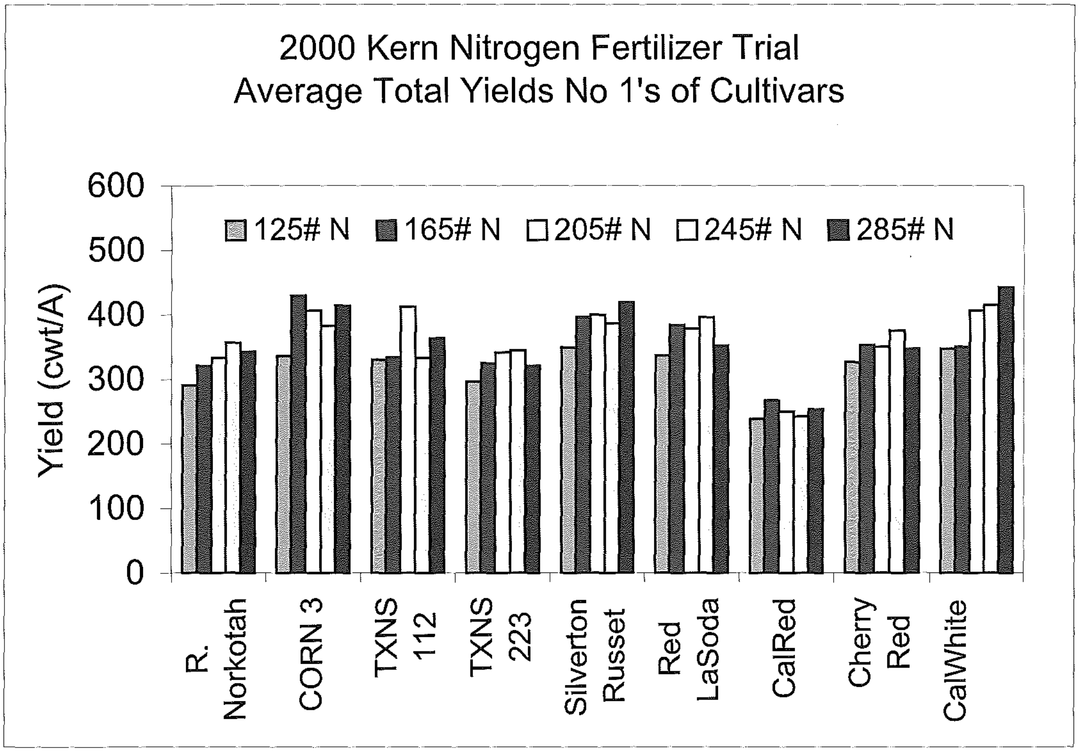

Figure 8.

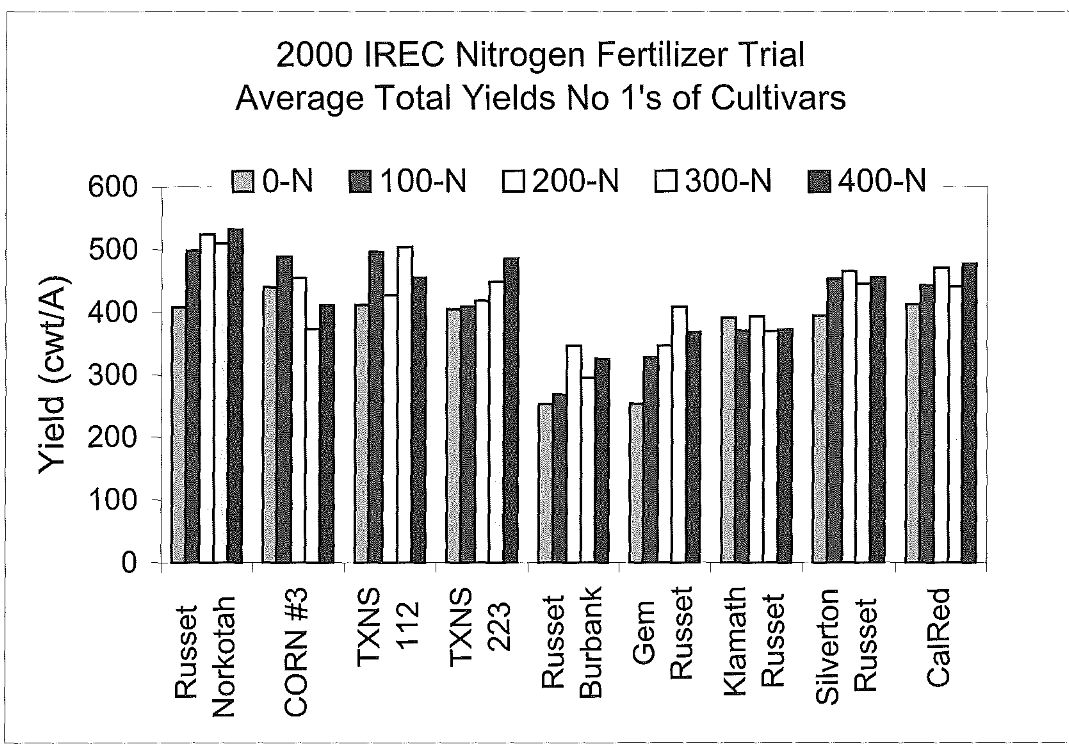

Figure 9.

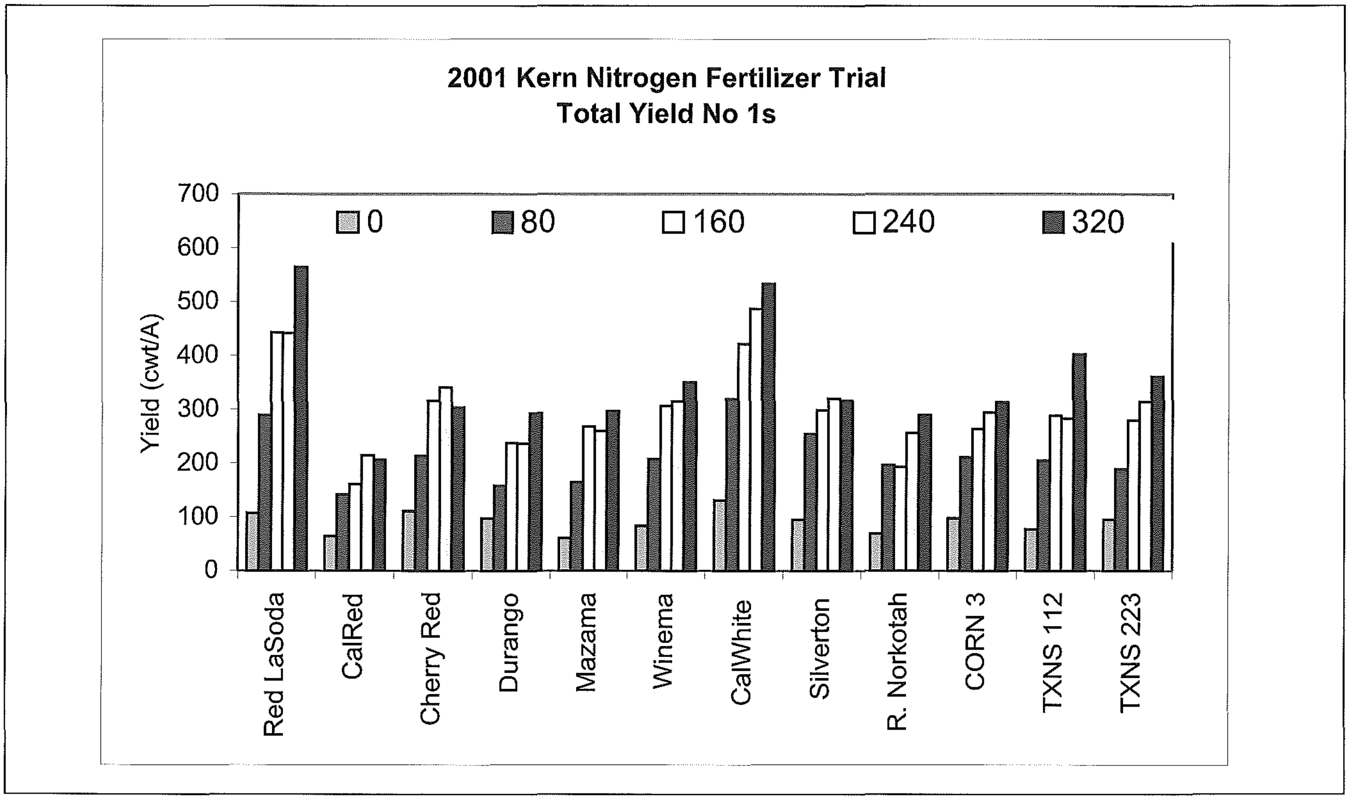

Figure 10.

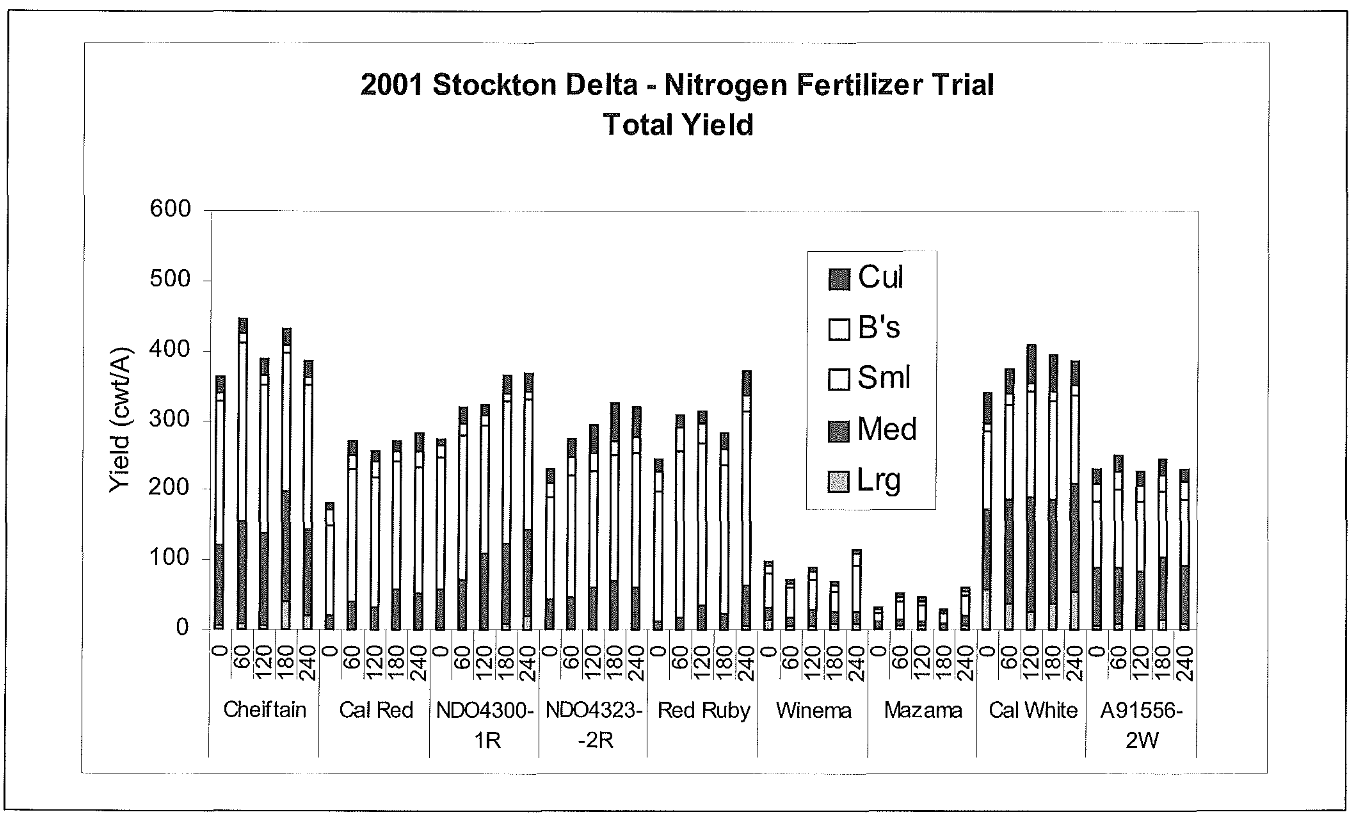

Figure 11.

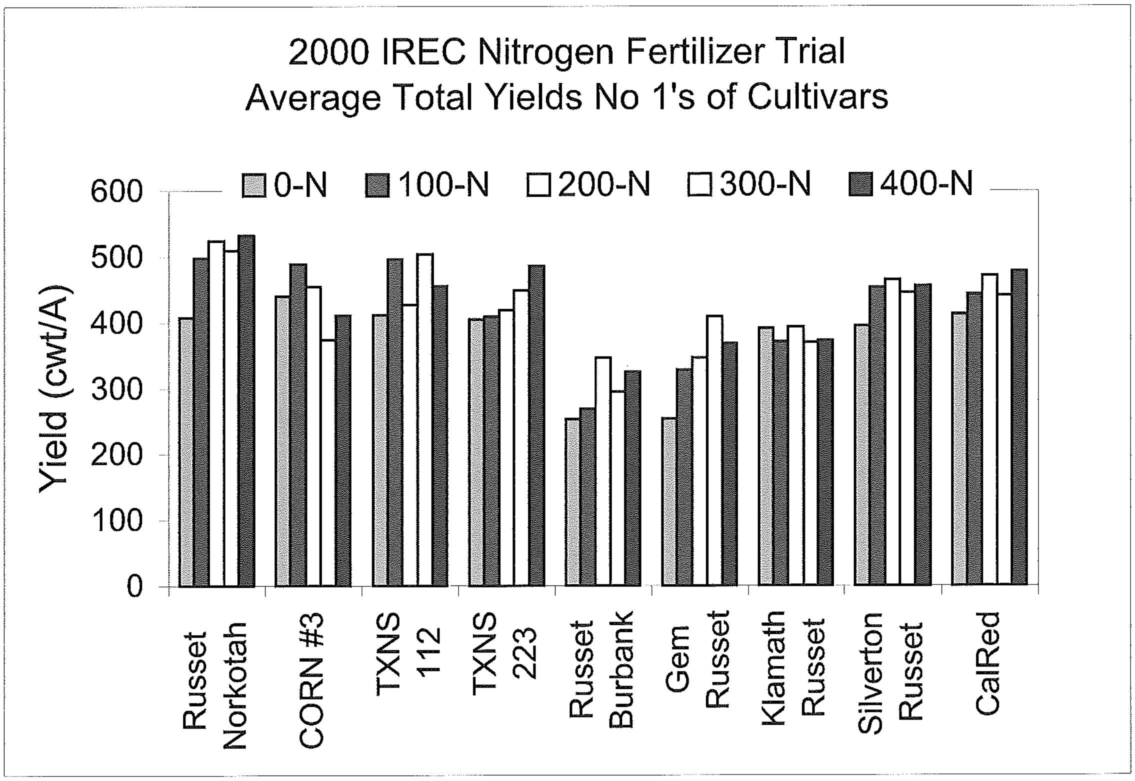
2000 IREC Nitrogen Fertilizer Trial
Average Total Yields No 1's of Cultivars
0-N
100-N
200-N
300-N
400-N
Yield (cwt/A)
600
500
400
300
200
100
0
Russet Norkotah
CORN #3
TXNS 112
TXNS 223
Russet Burbank
Gem Russet
Klamath Russet
Silverton Russet
CalRed

Figure 12.

EFFICIENT PHOSPHORUS MANAGEMENT IN COASTAL VEGETABLE PRODUCTION

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INTRODUCTION

Decades of heavy phosphorus fertilizer application to vegetable fields in the Salinas and Pajaro Valleys have resulted in substantially increased soil P concentration. Soil test P levels frequently exceed the threshold for expected crop response to continued P fertilization; however, many growers continue to apply P to such fields. While this generally does not cause agronomic problems, it may be a significant contributor to the undesirably high P concentration found in the Salinas and Pajaro River systems. Parts of both watersheds have been listed by the California EPA as 'impaired' for soluble nutrients, based on the prevailing Federal water quality standards. This project was undertaken to reevaluate the current P management recommendations for lettuce production in light of this potentially serious environmental problem.

OBJECTIVES

1. Develop efficient P fertilizer guidelines for coastal lettuce production
2. Document the relationship between soil characteristics, soil test P levels, and potential loss of P through runoff.

METHODS

To determine the current P status of agricultural land in the Salinas and Pajaro Valleys, soil from 30 fields, most in long-term vegetable rotations, was collected in spring, 2002 (Table 1). The fields, located in Monterey, San Benito, Santa Clara and Santa Cruz Counties, represented both conventionally farmed and organically managed land. These soils will be used in a study designed to correlate the soluble and total P concentration of runoff water (from rain or irrigation) with the soil test P value and soil hydraulic properties. The intent is to provide a simple system by which growers can rank their fields for P runoff potential, so that remedial actions can be targeted where they would do the most good.

Six trials were conducted in commercial lettuce fields in the Salinas Valley in 2002 evaluating whether P fertilization in fields with moderate or high soil test P levels actually affected crop productivity. The fields chosen varied from 54 – 171

Table 1. Soil test bicarbonate P content (PPM) of survey fields.

Field	*Location*	*Management type*	*Bicarbonate P (PPM)*[z]
1	King City	conventional	14
2	King City	conventional	18
3	King City	conventional	30
4	Hollister	organic	33
5	Santa Cruz	organic	34
6	Salinas	conventional	36
7	Morgan Hill	conventional	40
8	San Juan Bautista	organic	41
9	Gilroy	conventional	42
10	San Martin	conventional	42
11	Gonzales	conventional	47
12	King City	conventional	54
13	King City	conventional	58
14	Salinas/Buena Vista	conventional	65
15	Gilroy	conventional	65
16	Greenfield	conventional	77
17	Salinas	conventional	78
18	Chualar	conventional	79
19	Greenfield	conventional	80
20	Salinas/Buena Vista	conventional	85
21	Morgan Hill	conventional	87
22	Hollister	organic	92
23	Gilroy	conventional	93
24	Soledad	conventional	95
25	Watsonville	conventional	124
26	Castroville	conventional	126
27	Chualar	conventional	149
28	Salinas	conventional	185
29	Santa Cruz	organic	188
30	Santa Cruz	organic	196

[z] top six inches

Table 2. Characteristics of the 2002 field trial sites.

Field	Location	Bicarbonate extractable soil P (PPM)[x]	Lettuce type	P application rate (lb P_2O_5 / acre)	Planting date[y]
1	Salinas	54	Head	59	April 3
2	Salinas	124	Head	60	April 11
3	Soledad	55	Romaine	130	May 11
4	Chualar	72	Head	42	June 12
5	Chualar	171	Romaine	130	July 15
6	Chualar	78	Head	47	July 26

[x]top six inches of soil
[y]date of first water

PPM bicarbonate P (top 6 inches of soil, Table 2). Existing recommendations rank these field as moderate (fields 1 and 3) or high P availability (fields 2,4,5 and 6); a strong crop response to pre-plant P fertilization would not be expected, based on prior research with cool-season vegetables. In fields 3 and 5 the grower did not apply P fertilizer; we established 4 plots within each of these fields which received a pre-plant fertilization with 130 lb P_2O_5 / acre. In all other fields the growers applied pre-plant P, and we established 4 plots per field in which this P application was skipped. The experimental design was randomized complete block, with each plot being 4 beds wide and 200 feet long. All data were collected in the middle 100 feet of each plot, from the middle two beds.

Plant P status was monitored by biweekly sampling through the crop season, including at harvest. Plots with and without P fertilization were photographed on a biweekly basis with a digital infrared camera; these images allowed calculation of the percent of ground covered by the plant canopy, an objective, non-destructive measure of plant vigor. Prior to commercial harvest 32 whole plants per plot were selected at random and weighed to compare total plant biomass between treatments. Where practical, data on marketable yield and head size distribution was collected by working with the commercial harvest crew. Where that was not possible, randomly selected plants were trimmed to simulate commercial harvest, and the marketable yield of the treatments was compared.

RESULTS

The soils collected in the survey ranged from 14 – 196 PPM bicarbonate extractable phosphorus, averaging 78 PPM (Table 1). To put these numbers into context, soils from California's Central Valley that have been farmed for an equivalent period of time typically range from 10-25 PPM bicarbonate P. The difference reflects the higher application rates, and more frequent application, of P fertilizers in the coastal valleys. Despite these high soil test P values, many coastal vegetable growers continue to apply P before each crop, and a substantial number also apply P in side-dressings.

Four of the trials have been harvested to date (Table 3). In the first trial, planted in early April, significant response to pre-plant P was observed. This was somewhat surprising, since the soil bicarbonate P level was 54 PPM, above the response threshold cited in most references. Early planting (cold soil temperature) was undoubtedly a factor, since P bioavailability is reduced at lower soil temperature. Field 2 had high soil bicarbonate P (124 PPM). As expected, production in plots in which pre-plant P was skipped was equivalent to the grower's standard P application. Fields 3 and 4 had moderate soil test P levels, and neither showed significant crop response to P fertilization; they differed from field 1 in that they were planted in early summer, and therefore had warmer soil temperatures and recently incorporated crop residues (a source of available P). It is interesting to note that in the first 3 trials there was a trend toward slightly smaller plants in the infrared camera images. These differences were apparent at thinning, and were maintained through most of the growing season. The implication is that pre-plant P functioned mostly to maximize early seedling growth; once a substantial root system was established, the field soils had sufficient P availability to maximize crop growth. This implies that a low rate, at-planting P fertilizer application (a phosphoric acid over-spray, for example) might provide equivalent crop response to a heavier pre-plant application. This would be environmentally desirable, since it would minimize further P loading in these soils.

Table 3. Lettuce response to P fertilization.

Field	P treatment (lb P_2O_5 / acre)	% of plants marketable	Marketable wt (lb / plant)	Boxes 24s / acre
1	0	81[z]	1.46[z]	847[z]
	59	87	1.56	751
2	0	93	1.58	1020
	60	95	1.57	1018
3	0		2.35	
	130		2.38	
4	0	84	1.66	
	42	83	1.70	

[z]significantly different from the applied P treatment

P application had minimal impact on tissue concentration at any time in the cropping cycle (Table 4). This reinforces the concept that heavy pre-plant P application is not an efficient practice in soils with moderate to high soil test P levels. Early

Table 4. Effect of P fertilization on lettuce tissue P concentration.

Field	*P treatment* (lb P_2O_5 / acre)	*At thinning* % leaf P	*At heading* % leaf P	*At heading* PPM midrib PO_4-P	*At harvest* % leaf P
1	0	0.42	0.43	1370	0.64
	59	0.42	0.43	1250	0.66
2	0	0.35	0.48	1620	0.68
	60	0.35	0.51	1600	0.71
3	0	0.39	0.37	840	
	130	0.41	0.40	830	
4	0	0.50		3480	
	42	0.50		3440	

season midrib PO_4-P concentration in plots both with and without P was below commonly cited sufficiency levels (usually considered to be 2,000 – 3,000 PPM), suggesting that these standards need to be reevaluated.

In summary, soil P levels in the coastal vegetable production areas are high enough to potentially contribute to surface water quality problems. Continued P fertilization of high P soil is an inefficient practice, particularly for fields planted when soils are warm. Even for spring planted fields there may be a more environmentally benign, and more cost effective, approach than the conventional pre-plant application at listing.

Fertilization Technologies for Conservation Tillage Production Systems in California

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Introduction

Conservation tillage production row crop systems have a number of potential advantages that may be desirable to California producers including reduced production costs, maintenance of soil organic matter, and water conservation. Evaluation of this potential has been an increasingly important focus of the University of California Division of Agriculture and Natural Resources Conservation Tillage Workgroup in recent years. To date, however, no systematic studies have been conducted in California to evaluate and understand the basis for optimal fertilization management strategies for reduced tillage systems. The selection of fertilizer rates, materials and application methods will likely require management decisions in conservation tillage systems that differ from those used in conventionally tilled systems. This project address two of FREP's key research and education priorities by developing new information on the fertilizer use efficiency of conservation tillage systems with and without cover crops compared to standard tillage systems with and without winter cover crops, and by providing this information in educational functions such as field demonstrations that are readily accessible to producers, consultants and resource managers.

Despite a 300% increase in conservation tillage (CT) production systems in the Midwest 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 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 at the same time improve the soil resource through greater carbon sequestration.

Recent pioneering studies by Reicosky and Lindstrom 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.

In this project, we are adapting fertilization equipment that is currently used in CT systems in the midwest and southeast US and determining the fertilizer use efficiency using CT practices that we develop for San Joaquin and Sacramento Valley row crop systems. The hypothesis that we will test 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

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

PROJECT DESCRIPTION

This project is being conducted in a 5 acre field at the Vegetable Crops and Weed Science Field Headquarters on the UC Davis campus and in an 8 acre field study at the UC West Side Research and Extension Center in Five Points, CA. A corn/tomato/corn/tomato rotation is being pursued at the UC Davis site, and a tomato/cotton/tomato/cotton rotation is used in Five Points. We report here on progress during 2001 and 2002 in the UC Davis study.

Four experimental treatments (standard tillage no cover crop, STNO, standard tillage with incorporated cover crop, STCC, conservation tillage no cover crop, CTNO, and conservation tillage with cover crop, CTCC) were established in the fall of 2000 in nine-bed (60" each) field plots that are replicated 4 times in a randomized complete block design. In 2001, a uniform field corn crop was produced across the entire field. Following corn harvest in September 2001, common vetch cover crops were seeded in each of the CC plots. Forty ^{15}N microplots (4.57m wide band 3m long) were then established during the 2001 – 2002 winter as indicated below.

STNO	**STCC**	**CTNO**	**CTCC**
Zero N	Zero N	Zero N	Zero N
Labeled fertilizer	Labeled fertilizer + vetch	Labeled fertilizer	Labeled fertilizer + vetch
	Labeled vetch + fertilizer		Labeled vetch + fertilizer

These microplots are being used to track the amount of ^{15}N-labeled fertilizer and vetch cover crop that is taken up by each of the main summer crops during the course of the study.

RESULTS AND CONCLUSIONS

Corn crop growth, percent post-harvest residue biomass and groundcover were quantified in October 2001 after soil tillage operations in the ST treatments were done. An average of about 2800 kg/ha of vetch dry matter was produced from November 2001 – April 2, 2002 in the CC plots.

Soil water content at the time of cover crop management in April 2002 was lower in each of the cover cropped (STCC and CTCC) systems at 0 – 15, 15 – 30, and 30 – 60 cm depths. The 2002 tomato crop was successfully transplanted into both the previous year's corn residues and the corn residue/cover crop mulch. Fertilization was done using a rig fitted with 20" coulters ahead of standard fertilizer shanks. Yield data were collected in each plot using a machine harvester and weighing gondolas in August 2002. These data are currently being analyzed as are the ^{15}N uptake samples now being processed. It is premature to draw conclusions from this work at this time.

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 300 kg N/ha. This project seeks to identify and demonstrate N best management practices (BMPs) for sweet corn. In 2001-2002, we initiated N studies aimed at evaluating several diagnostic tools for efficient N management of sweet corn (*Zea mays*). Diagnostic tools evaluated included 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 2001-2002 were designed to evaluate the response of sweet corn to side dress 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 planted in the spring is following lettuce, broccoli or cauliflower. Sweet corn planted in the fall generally follows leaching of the fields with large amounts of irrigation water.

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 2001-2002 to evaluate, and demonstrate to growers several diagnostic tools. The experiments in order were designated as 47H, 47I, 47J, 47K and were conducted in grower fields. We selected sites in the Thermal and Indio areas of the Coachella Valley.

Table 1. Visual quality of sweet corn in relation to 4 nitrogen fertilization treatments (2001, Exp. 47H). Corn was stored 8 days at 0°C (32°F) before evaluation of maturity, tip and earfill, and 20 days at 0°C for other evaluations. Data based on 3 reps of 4 ears each.

Nitrogen Fertilization Treatment	*Maturity*[1]	*Tip Fill*[2]	*Ear Fill*[2]	*Visual*[3] *Quality Husk*	*Visual*[3] *Quality Ear*	*Visual*[3] *Quality Silk*	*Decay*[4] *Silk*
1. No sidedress	2.0	2.1	3.0	6.9	7.2	4.0	3.9
2. First sidedress	2.0	2.2	3.0	7.1	7.2	3.2	3.7
3. Second sidedress	2.0	2.1	2.9	7.0	7.4	2.8	3.9
4. First & Second sidedress	2.0	2.5	3.0	6.8	6.8	2.8	3.8
Average	2.0	2.2	3.0	7.0	7.2	3.2	3.8
LSD.05	ns	0.3	ns	0.2	0.5	ns	ns

[1]Maturity: 1=immature, kernels small, 2=optimum maturity, 3=overmature, kernel sap milky; evaluation of 8 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 8 ears rep, 3 reps.
[3]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.
[4]Decay on silks was scored on a 1 to 5 scale, 1=none, 2=slight, 3=moderate, 4=moderately severe, 5=severe.

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

Experiment	**Crop**	**Planting Date**	**Harvest Date**	**Location**
47H	Sweet corn	02-16-01	05-22-01	Thermal
47I	Sweet corn	02-19-01	05-23-01	Indio
47J	Sweet corn	08-18-01	Lost	Thermal
47K	Sweet corn	02-18-02	05-20-02	Indio

In all experiments sweet corn was seeded to a stand in single row beds. Individual plots in all sites were approximately $65 m^2$ (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.

Field experiments 47H-47K consisted of 4 treatments (two N fertilizer applications after planting) in a 2^2 factorial design. Rates of N used in each side dress application were those actually used by cooperating growers and ranged from 30 gallons per acre (gpa) to 50 gpa of UN32 (approximately 70 to 118 kg N/ha).

Table 2. Color values of sweet corn in relation to 4 nitrogen fertilization treatments (2001, Exp. 47H). Corn was stored 8 and 20 days at 0°C (32°F) before evaluation.

Nitrogen Fertilization Treatment	*Days at 0°C (32°F)*	*Husk*				*Kernel*		
		Color1 Score	*L*2*	*Chroma*[2]	*Hue*[2]	*L*2*	*Chroma*[2]	*Hue*[2]
1. No sidedress	8	3.5	69.0	33.6	111.3	71.4	13.9	98.9
2. First sidedress	8	4.1	67.1	33.0	113.1	71.7	14.5	98.7
3. Second sidedress	8	3.8	67.4	33.0	111.9	70.6	13.7	99.0
4. First & Second sidedress	8	4.4	64.4	32.1	114.0	72.4	15.5	98.3
Average		4.0	67.0	32.9	112.6	71.5	14.4	98.7
1. No sidedress	20	--	68.8	32.4	109.6	--	--	--
2. First sidedress	20	--	62.4	30.0	113.7	--	--	--
3. Second sidedress	20	--	67.9	33.2	109.5	--	--	--
4. First & Second sidedress	20	--	61.5	30.3	114.9	--	--	--
Average			65.1	31.5	111.9			
LSD.05		0.4	2.0	1.2	1.2	ns	0.9	0.6

[1]Husk color evaluated on a 5 to 1 scale, where 1=light green, 3=bright green, 5=dark green.
[2]L* represents lightness or darkness (0=black, 100=white) and chroma represents the intensity of the green or yellow color, the higher the value the brighter the color appears; hue represents true color. Chroma and hue values are calculated as $(a^{*2} + b^{*2})^{1/2}$ and $\tan^{-1}(b^*/a^*)$.

Table 3. Composition and color values of sweet corn in relation to 4 nitrogen fertilization treatments (2001, Exp. 47H). Corn was stored 8 days at 0°C (32°F) before evaluation.

Nitrogen Fertilization Treatment	*Days at 0°C (32°F)*	*Soluble[1] Solids, %*	*% Dry weight*	*Sugars[2] mg/g DW*	*Toughness, Newton*	*Pericarp[3] Pericarp, % of Dry Weight*
1. No sidedress	8	18.0	27.0	416	5.27	2.9
2. First sidedress	8	16.8	26.0	384	5.32	2.8
3. Second sidedress	8	17.9	26.5	423	4.99	2.7
4. First & Second sidedress	8	15.5	24.8	382	5.18	2.8
Average		17.1	26.1	401	5.22	2.8
1. No sidedress	20	16.2	25.5	380	5.24	--
2. First sidedress	20	14.4	24.0	358	5.27	--
3. Second sidedress	20	16.3	25.9	414	5.40	--
4. First & Second sidedress	20	13.7	24.2	316	5.34	--
Average		15.1	24.9	367	5.28	
LSD.05		0.5	0.8	20	0.14	ns

[1]Soluble solids determined by refractometer.
[2]Sugars were determined on ethanol extracts by colorimetry.
[3]Pericarp toughness determined on 30 kernels per rep x 3 reps by measuring the resistance to penetration of a 2 mm flat cylinder probe on TA-XT texture analyzer, 2 mm deep.

RESULTS

Studies conducted in 2001-2002 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. 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. Those results are still being analyzed and will be reported in the near future. This report will cover the results of the post harvest studies.

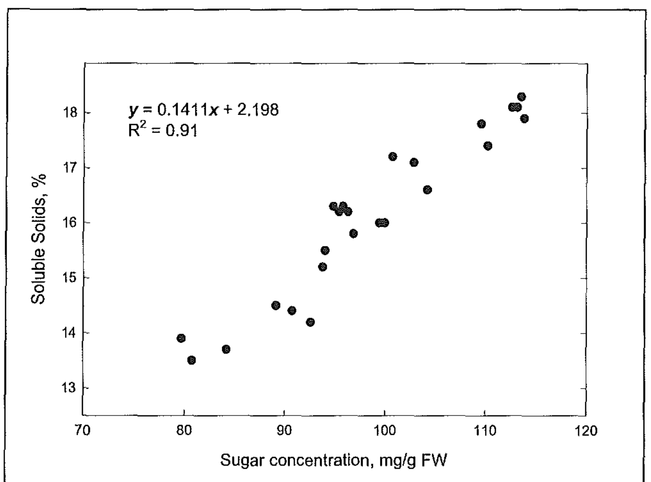

Figure 1. Relationships between soluble solids and sugar concentrations (colorimetric) in kernels of sweet corn stored 8 and 20 days at 0°C (32°F) from Exp. 47H, May 2001.

Experiment 47H

The sweet corn from experiment 47H was harvested at near optimum maturity (Table 1). Tip fill did vary among treatments, but ear fill did not. After a total of 20 days at 0°C, overall visual quality of corn in husks was similar among treatments, although ear quality of treatment 4 was significantly less. Visual quality of silks and decay on silks were not different among ears from different N fertilization treatments (Table 1). Husk color was perceived as brighter green in treatments #2 and #4 (Table 2), and this corresponded to

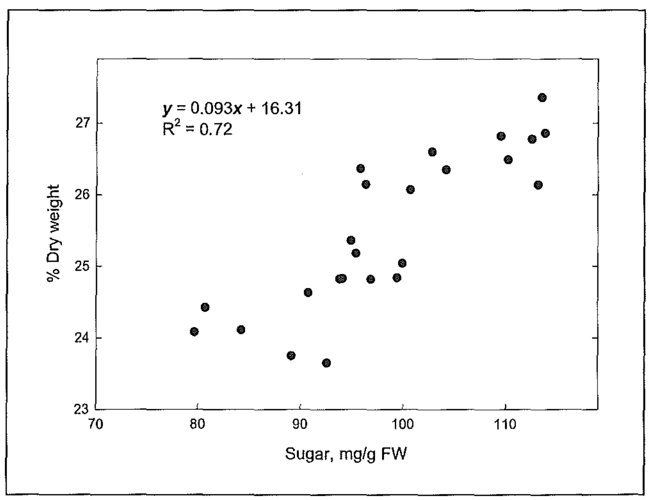

Figure 2. Relationships between % dry weight and sugar concentrations (colorimetric) in kernels of sweet corn stored 8 and 20 days at 0°C (32°F) from Exp. 47H, May 2001.

Table 4. HPLC analysis of sugars in sweet corn in relation to 4 nitrogen fertilization treatments (2001, Exp. 47H). Corn was stored 8 days at 0°C (32°F) before analysis.

Nitrogen Fertilization Treatment	*Sucrose, mg/g DW*	*%*	*Glucose, mg/g DW*	*%*	*Fructose, mg/g DW*	*%*	*Total Sugars mg/g DW*
1. No sidedress	391	93	15	4	15	4	421
2. First sidedress	365	95	8	2	9	2	383
3. Second sidedress	390	92	22	5	13	3	426
4. First & Second sidedress	308	90	20	6	14	4	342
Average	364	92	16	4	13	3	393
LSD.05	24		6		3		25

Table 5. Visual quality of sweet corn in relation to 4 nitrogen fertilization treatments (2001, Exp. 47I). Corn was stored 8 days at 0°C (32°F) before evaluation. Evaluations were based on 3 replications of 4 ears each from a composite field sample.

Nitrogen Fertilization Treatment	*Maturity[1]*	*Tip Fill[2]*	*Ear Fill[2]*	*Husk[3] Color*	*Dry[4] Kernels*
1. No sidedress	2.5	2.7	3.0	4.5	1.9
2. First sidedress only	2.5	2.8	3.0	4.6	1.9
3. Second sidedress only	2.5	2.8	3.0	4.7	1.8
4. First & Second sidedress	2.5	3.0	3.0	4.4	1.9
Average	2.5	2.8	3.0	4.6	1.9
LSD.05	ns	ns	ns	ns	ns

1 Maturity: 1=immature, kernels small, 2=optimum maturity, 3=overmature, kernel sap milky; evaluation of 8 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 8 ears rep, 3 reps.
3 Husk color evaluated on a 5 to 1 scale, where 1=light green, 3=bright green, 5=dark green.
4 Dry kernels 1=none, 2=moderate, a few kernels affected, 3=severe, numerous kernels affected

Table 6. Composition and color values of sweet corn in relation to 4 nitrogen fertilization treatments (2001, Exp. 47I). Corn was stored 8 days at 0°C (32°F) before evaluation.

Nitrogen Fertilization Treatment	*Soluble[1] Solids, %*	*% Dry weight*	*Pericarp[2] Toughness, Newtons*	*Husk[3] Color, Chroma*	*Husk[3] Color, Hue*	*Kernel[3] Color, Chroma*	*Kernel[3] Color, Hue*
1. No sidedress	14.5	24.8	5.19	27.7	118.9	16.0	98.1
2. First sidedress	14.8	25.2	5.21	28.1	119.4	16.2	97.8
3. Second sidedress	13.2	24.6	5.34	26.3	119.8	16.2	97.7
4. First & Second sidedress	12.5	24.1	5.12	28.0	118.7	16.1	97.8
Average	13.8	24.7	5.22	27.5	119.2	16.1	97.9
LSD.05	0.7	ns	0.14	ns	ns	ns	ns

[1]Soluble solids determined by refractometer.
[2]Pericarp toughness determined on 30 kernels per rep x 3 reps by measuring the resistance to penetration of a 2 mm flat cylinder probe on TA-XT texture analyzer, 2 mm deep.
[3]Chroma represents the intensity of the green or yellow color, the higher the value the brighter the color appears; hue represents true color; values are calculated from a* and b* objective color values.

higher hue color values after 8 and 20 days at 0°C (32°F). Chroma and hue values decreased between 8 and 20 days of storage. There were small differences in kernel color at 8 days (Table 2).

Sweet corn kernel composition was significantly affected by N fertilization treatment. Higher soluble solids concentrations were obtained with no sidedress N (Trt #1) or 2nd sidedress N (Trt #3) (Table 3). Kernels from these same field

Table 7. Visual quality of sweet corn in relation to 4 nitrogen fertilization treatments (2002, Exp. 47K). Corn was stored for 0 or 6 days at 5°C (41°F) before evaluation (2 and 8 days from harvest date). Data based on 3 reps of 6 ears each.

Nitrogen Fertilization Treatment	Days stored	Maturity[1]	Tip Fill[2]	Ear Fill[2]	Visual[3] Quality Ear	Decay[4] Silk
1. No sidedress	0	2.03	2.7	3	--	--
2. First sidedress	0	2.03	2.8	3	--	--
3. First & Second sidedress	0	2.08	2.7	3	--	--
4. Second sidedress	0	2.19	2.7	3	--	--
Average		2.08	2.7	3		
1. No sidedress	6	2.14	2.6	3	7.1	1.5
2. First sidedress	6	2.17	2.6	3	7.2	1.3
3. First & Second sidedress	6	2.17	2.9	3	7.4	1.5
4. Second sidedress	6	2.17	2.7	3	7.6	1.4
Average		2.16	2.7	3	7.3	1.4
LSD.05		0.14	ns	ns	ns	ns

[1]Maturity: 1=immature, kernels small, 2=optimum maturity, 3=overmature, kernel sap milky.
[2]Tip fill and ear fill (kernel fill): 1=kernels not fill end or length of ear, 2=moderately well filled, 3=well filled;
[3]Visual quality of intact ear in husk, 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.
[4]Decay on silks was scored on a 1 to 5 scale, 1=none, 2=slight, 3=moderate, 4=moderately severe, 5=severe.

Table 8. Color values and color score of sweet corn in relation to 4 nitrogen fertilization treatments (2002, Exp. 47K). Corn was stored 0 and 6 days at 5°C (41°F) before evaluation (corn was 2 and 8 days from harvest). Data are averages of 3 replicates of 6 ears each.

Nitrogen Fertilization Treatment	Days at 5°C (41°F)	Husk				Kernel		
		Color[1] Score	L*[2]	Chroma[2]	Hue[2]	L*[2]	Chroma[2]	Hue[2]
1. No sidedress	0	3.5	68.7	24.8	117.0	73.4	14.9	97.8
2. First sidedress	0	3.5	70.0	25.4	116.9	74.3	15.2	98.0
3. First & Second sidedress	0	3.4	70.8	24.6	115.6	74.8	15.5	97.8
4. Second sidedress	0	3.4	75.4	25.3	113.9	75.8	15.3	98.1
Average		3.4	71.2	25.0	115.9	74.6	15.2	97.9
1. No sidedress	6	3.0	72.9	25.8	112.4	75.1	15.4	97.3
2. First sidedress	6	3.1	70.2	24.1	113.3	74.6	15.8	97.1
3. First & Second sidedress	6	3.3	71.0	24.9	113.4	75.6	16.2	97.0
4. Second sidedress	6	3.1	71.1	25.1	113.1	75.1	15.4	97.3
Average		3.1	71.3	25.0	113.0	75.1	15.7	97.1
LSD.05		0.4	2.2	ns	1.5	ns	0.8	0.6

[1]Husk color evaluated on a 5 to scale, where 1=light green, 3=bright green, 5=dark green.
[2]L* represents lightness or darkness (0=black, 100=white) and chroma represents the intensity of the green or yellow color, the higher the value the brighter the color appears; hue represents true color. Chroma and hue values are calculated as $(a^{*2} + b^{*2})^{1/2}$ and $\tan^{-1}(b^*/a^*)$.

treatments also contained higher sugar concentrations and had higher % dry weights than kernels from trt #2 and #4. With an additional 12 days at 0°C, soluble solids decreased an average of 12% and sugar concentrations decreased an average of 9%. The pericarp of the kernels, as % dry weight, did not differ among field treatments, although toughness of the pericarp was highest in treatments #1 and #2 and least in treatments #3 and #4. Sugars were also determined by

Table 9. Composition and texture of sweet corn in relation to 4 nitrogen fertilization treatments (2002, Exp. 47K). Corn was stored for 0 or 9 days at 5°C (41°F) before evaluation (2 and 8 days from harvest). Data for %SS and %DW are means of 3 replicates per treatment from a composite sample. Texture data are means of 3 replicates of 6 ears and 5 determinations each (90 determinations per treatment.

Nitrogen Fertilization Treatment	*Days at 0°C (32°F)*	*Soluble Solids, %*	*Dry weight, %*	*Texture of kernels, Newtons*
1. No sidedress	0	16.4	23.5	5.27
2. First sidedress	0	16.6	24.3	5.18
3. First & Second sidedress	0	16.4	23.5	5.37
4. Second sidedress	0	16.4	23.3	5.45
Average		16.5	23.6	5.32
1. No sidedress	6	13.3	23.3	5.48
2. First sidedress	6	15.0	23.6	5.34
3. First & Second sidedress	6	13.5	21.9	5.49
4. Second sidedress	6	13.2	23.4	5.41
Average		13.7	23.1	5.43
LSD.05		0.6	0.5	0.17

HPLC (Table 4). Again, treatments #1 and #3 had the highest sugar concentrations. The proportions of sucrose, glucose and fructose were affected slightly by the N field treatments. Sucrose averaged 90-95% of total sugar concentrations, glucose averaged 4% and fructose averaged 3%. Treatment #2 (1st sidedress N) resulted in the lowest % of glucose and fructose and correspondingly the highest % of sucrose (Table 4). Sugars concentrations were highly correlated with soluble solids concentrations (Figure 1) and less highly correlated with % dry weight (Figure 2).

Preliminary sensory testing indicated that kernels from treatments #1 and #4 had stronger aroma and kernels from #2 has the best aroma, i.e., most typical of sweet corn. Flavor was similar among treatments #1, #2 and #3, and flavor of kernels from #4 was considered stronger (perhaps kernels more mature?). Kernels from all treatments were perceived as sweet, but kernels from #1 and #2 were perceived as sweeter than others. Texture and color were similar in kernels from all treatments.

Experiment 47I

There were no significant differences in maturity, tip fill, ear fill, or husk color of corn from the 4 field treatments (Table 5). Some of the kernels on the ears were observed to be dry and dehydrated, and this defect was scored. However, no differences in dehydrated kernels were found among field treatments (Table 5).

Husk and kernel chroma and hue color values were not different among field treatments (Table 6). However, soluble solids concentrations were significantly lower in kernels from treatments #3 an #4. The average soluble solids concentrations were 2-3% lower than values in corn from another experiment harvested at the same period (Exp. 47H). There were no significant differences in % dry weight (Table 6). There were also significant differences in pericarp toughness, with the toughest kernels being those from the 2nd sidedress treatment #3 (Table 6). Pericarp toughness was similar in kernels from the other 3 field treatments.

Preliminary sensory testing indicated that kernels from all treatments had typical, but not strong aromas. There were no discernible differences in aroma among the 4 field treatments. Kernels from #1 and #4 were perceived as being less sweet than kernels from treatments #2 and #3. Kernels from treatments #1 and #4 were perceived as being tougher than kernels from other treatments. Maturity may have affected the toughness evaluations since kernels from treatment #4 were smaller than kernels from #2 and #3. Color was similar among treatments except color of kernels from treatment #1 appeared to be slightly darker.

Experiment 47K

The sweet corn from this experiment was harvested at near optimum maturity (Table 7). Ears of treatment #4 were slightly but significantly more advanced in maturity than ears from treatments #1, 2, and 3. Neither tip fill nor earfill varied among treatments. After a total of 6 days at 5°C (41°F) or 8 days from harvest, corn from all treatments was rated "good" and was above the limit of salability (Table 7). There were no significant differences in the overall visual quality of corn in husks or of the decay on silks among the 4 fertilization treatments (Table 7).

Husk color scores were higher on treatments #1 and #2 at harvest but there were no perceived color differences after storage (Table 8). Hue color values of the husks (overall indication of greenness) were also higher for these 2 treatments at harvest, but there were no differences among the fertilization treatments after storage (Table 8). There were some significant but minor differences in color values of the kernels at harvest and after storage (Table 8).

Sweet corn kernel composition was not affected by N fertilization treatment (Table 9). The % soluble solids averaged 16.5% at harvest and 13.7% after storage, indicating a 17% loss of soluble solids (mostly sugars) with 6 days at 5°C (41°F). The % dry weight of the kernels also decreased significantly with storage but was not different among the N fertilization treatments.

The pericarp toughness values or texture of kernels (Table 9) from Treatment #4 were the highest among the 4 N fertilization treatments, while values for Treatment #2 were the lowest (significant difference between these 2 treatments). Values increased about 2.5% with storage at 5°C (41°F) and after storage there were no significant differences among fertilization treatments (Table 9).

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

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INTRODUCTION

In an effort to improve air quality, recent legislation has forced California rice farmers to utilize a straw management practice alternative to the traditional method of burning. At this point in time farmers can either incorporate the residual straw into their soil or remove it off-site. It is much more cost effective to incorporate rice straw as there are no baling and transportation costs inherent with straw removal. However, many farmers have expressed a hesitation to incorporate rice straw as they fear their yields will be reduced as a result of weed and disease pressure. In this study, the potential benefits of rice straw incorporation were investigated in an effort to facilitate the adoption of this alternative straw management practice by California rice farmers.

The incorporation of rice straw can potentially, 1) increase the amount of plant available K in the soil, 2) improve the plant uptake efficiency of N, and 3) decrease the severity of plant diseases without deleteriously affecting grain yield. Approximately 20% of the rice in California's Sacramento Valley is produced on a K deficient soil. The average concentration of K in rice straw is around 1.5% and the amount of straw removed by baling averages roughly 6,000 pounds per acre. Therefore, the amount of K removed in the straw from Californian rice fields can exceed 100 pounds per acre. A soil K deficiency can result when straw is removed on a continual basis. Incorporating the rice straw into the soil can reverse this loss of soil K and prevent K deficiencies on California's rice producing soils. Nonetheless, a reliable pre-fertilization soil K characterization test is critical to alert farmers when K application is required. Previous studies have shown an increase in the N uptake in rice plants when straw is incorporated rather than removed. Therefore, straw incorporation can reduce the amount of fertilizer N required for optimal grain yields. Current research indicates incorporation of rice straw increases the severity of various rice fungal diseases. However, the effect of straw management on rice diseases has not been extensively researched and requires further investigation.

OBJECTIVES

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

DESCRIPTION

A three-year study was carried out in several rice fields throughout the Sacramento Valley of California. The majority of the field research performed for this project was located at Mathews Farms near Marysville, California. Two adjacent sites were selected, each approximately 6 acres in size. In the fall of 1998, 1999, and 2000 the straw was chopped and disked into the soil followed by flooding at one 3 ha experimental site, and was removed at the other site. Each site had a factorial experiment replicated 4 times and laid out as a split plot design with 5 rates of N as the main plot treatment

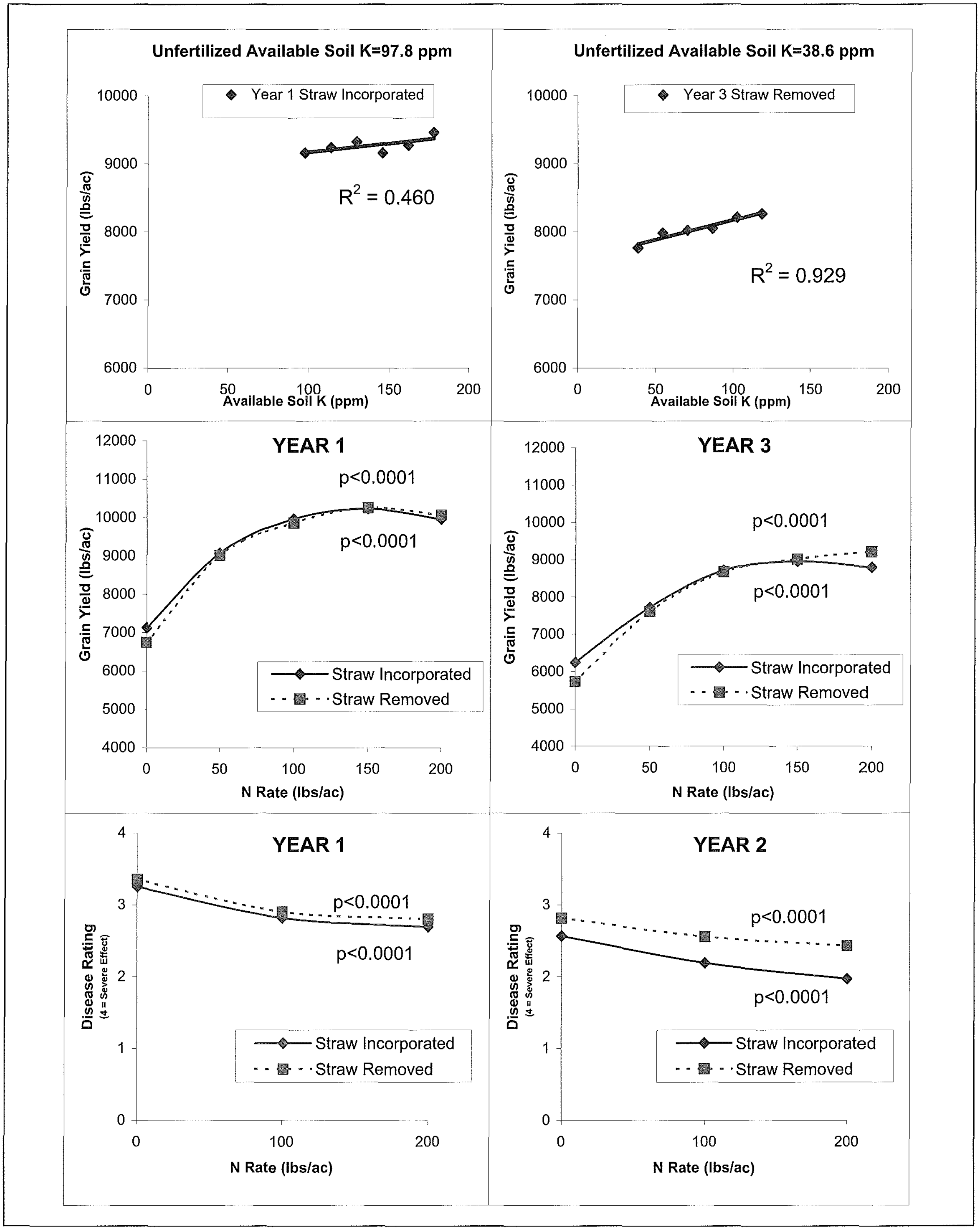

Figure 1. General trends of available soil K, grain yield, and disease severity at Mathews Farms over a three year period.

and 6 rates of K as the subplot treatment. To avoid compounding years of fertilization rates, the second and third year's factorial experiments were relocated adjacent to the previous year's factorial experiment site inside the respective large 3 ha experimental site. The following agronomic values were investigated: pre-fertilization soil K content, midseason N and K tissue contents, disease severity, grain and straw yield, harvest index (mass of grain divided by whole plant mass), harvest grain and straw N content, N requirement (amount of N required to produce a total of grain), and N fertilizer use efficiency.

RESULTS AND CONCLUSIONS

This three-year study has produced evidence for a multitude of benefits resulting from the incorporation of rice straw. The incorporation of straw in a Californian rice field clearly increased plant K availability. No difference in grain yield was observed between the two straw management practices investigated in this study. However, the incorporation of straw led to increased straw yield, and because grain yield was not affected, to a lower harvest index. A K deficiency led to an increased accumulation of N in the midseason plant and grain content when straw was removed. The K deficiency also led to decreased midseason plant K content when straw was removed. Because the increased uptake of N did not lead to a higher grain yield, a higher N requirement became evident following straw removal. Therefore, the incorporation of rice straw reduces the rates of K and N fertilizer application needed for optimal crop growth. However, the midseason plant K content did significantly increase with K application when straw was incorporated and removed. This uptake of K following K fertilization and straw incorporation indicates a possible hidden hunger for K that could manifest if this study was continued. The incorporation of rice straw did not increase the severity of aggregate sheath spot (a common rice fungal disease). There is strong evidence that rice straw incorporation can even decrease the severity of aggregate sheath spot due to the field procedure involving straw removal. In addition, the NH_4OAc test accurately predicted crop responses to various levels of K addition and AgSS severity when pre-fertilization available soil K concentrations were below 60 ppm soil. The incorporation of straw was shown to provide nutrients and/or improve soil physical properties that were beneficial to the overall grain yield but undetectable by the NH4OAc test. It can be concluded that K fertilizer application along with straw incorporation would be preferred for long-term K sustainability of this California rice cropping system.

LONG-TERM RICE STRAW INCORPORATION: DOES IT IMPACT MAXIMUM YIELD?

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INTRODUCTION

Rice growers have faced a decade of reinventing some of the aspects of growing rice. Passage of the California Rice Straw Burning Reduction Act (AB 1378) in 1991 forced growers to contend with a tremendous amount of rice residue that was usually burned. The burning of the residue serves many functions, including reducing the incidence of weeds and pathogens and to facilitate seedbed preparation. There were basically two choices for rice growers to deal with the rice residue, either leaving in the field or removal. Many variations of leaving the residue in the field have been explored, ranging from incorporation by tillage or cage rolling to leaving it on the surface. The in-field approaches were thought to potentially immobilize nutrients leading to possible yield declines. Long-term results have shown that winter flooding increases available soil N and leads to a significant yield gain over non-winter flooded fields regardless of the type of residue management employed. However, the response is higher on soils with higher clay or organic matter content. In addition, an additional yield gain is seen in fields with a minimum of 3 to 5 years of straw incorporation compared to where straw is burned or removed. These findings suggest that fertilizer rates can be reduced by 50lbs N/A depending on soil type, residue management and use of winter flooding.

Though the N story is fairly complete, as fertilizer N additions and straw incorporation reaches maximum yield potential at 100 lbs N/acre, the burned treatment continues to rise with increasing fertilizer N addition. These results suggest that straw incorporation limits yield potential, possibly from non-N limiting factors such as weed, disease or pathogen pressure.

OBJECTIVES

1. To determine if the maximum yield potential of rice under prolonged straw incorporation has been impaired.
2. To assess if the severity of weeds is a possible cause of a lower maximum yield in rice fields under prolonged straw incorporation.

DESCRIPTION

A rice residue management study was initiated in 1993 at Maxwell, CA, which terminated in 2001. Main plot treatment included winter flooding and no winter flooding. Subplot treatments included straw baling, burning, incorporating or rolling followed by incorporation. Individual plots measured approximately 2 acres. Grain and straw yield was measured and an N fertilizer rate trial was carried out in the last 4 years of the experiment.

RESULTS AND CONCLUSIONS

N fertilization and straw management

For all the years, grain yield was strongly affected by N application, independent of straw management and, on average, yield increased by 50 % following an N application of 100 lbs N per acre. When straw was incorporated, grain yield was higher when no N fertilizer was applied compared to the zero N yield when the residue was removed (Fig. 1). Furthermore, the maximum yield was observed when 100 lbs N per acre was applied and straw was incorporated, whereas the highest yield was observed when 200 lbs of N per acre was applied and straw was removed. Moreover, the maximum yield observed when straw was removed was higher than when straw was incorporated (Fig. 1). Apparently, a non-N effect occurred and its negative effect on yield was more pronounced when straw was incorporated. A similar yield response to straw management practices has been observed earlier in the Valley.

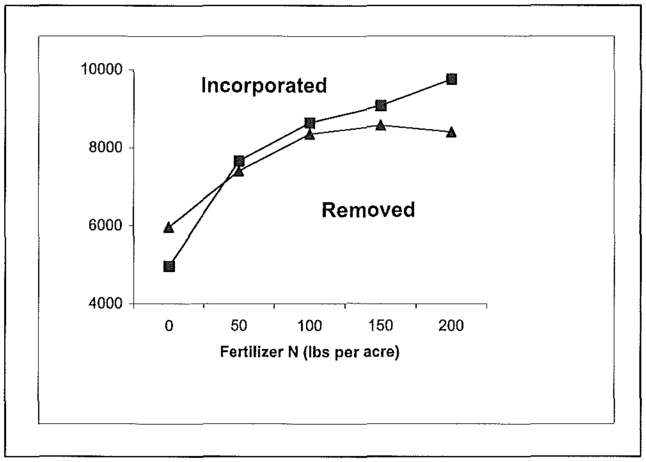

Figure 1. Yield response of rice following N fertilizer following straw removal or incorporation.

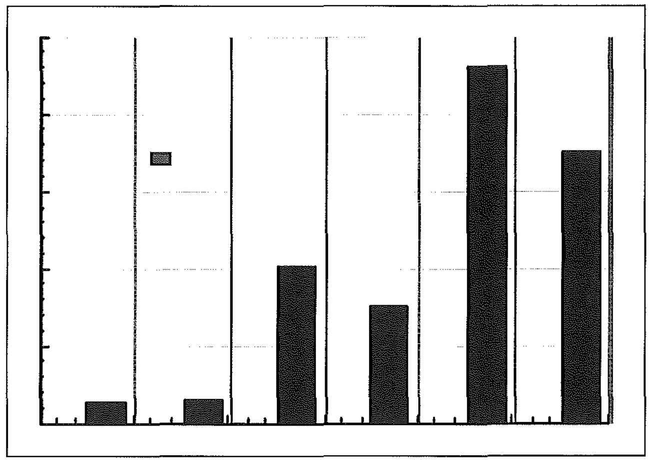

Figure 2. The incidence of water grass in the winter flooded burned (WFBurn) and incorporated (WFInc) treatments.

Occurrence of weeds and straw incorporation.

Changes in agronomic practices that impact crop yield often take up to 10 years or longer before they are realized. Furthermore, the direction of change, positive or negative, is difficult to ascertain during the transition to alternative practices such as from burning to straw incorporation. In addition, changes in soil fertility often affect other soil properties ranging from physiological stress from nutrient sufficiencies or deficiencies, to plant competitive responses to weeds and pathogens. These potential broad changes in soil properties often make diagnosing factors affecting yield potential problematic.

As part of the fertilizer N rate trials and rice yield determination done in 2001, we determined the severity of water grass under a wide range of N fertilizer application rates and long-term straw incorporation and burning. Only water grass was a problem in 2001, most likely because of large amounts of herbicide used to control a serious total weed problem. Water grass was the main weed to escape the efficacy of the herbicide formulations used. Also, no significant stem rust was found. Weeds and diseases are the most likely non-N factors that limit plant production. Figure 2 shows the incidence of water grass at the Maxwell site in 2001. The burned treatment had considerably no water grass compared to winter flooded and incorporated straw treatments. When the field was not winter-flooded, the burning did not fully suppress the weed population (data not shown). An increase in fertilizer-N increased the incidence of water grass.

Based on our previous research, other factors besides N are likely involved in controlling maximum yield potential. Possible yield-controlling factors that have to be investigated are weed and pests. It is often observed that the incorporation of residues leads to an increase in weed and disease pressure.

Field Evaluations and Refinement of New Nitrogen Management Guidelines for Upland Cotton: Plant Mapping, Soil and Plant Tissue Tests (Residual Soil Nitrogen and N Management for Acala Cotton)

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INTRODUCTION

Incentives to consider adjusting nitrogen management practices for cotton arise based upon several concerns. High soil and plant tissue N levels can delay harvest, can have negative impacts on efficacy and costs of defoliation, and can increase problems with late-season pests with potential to damage 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 and resulting potential for groundwater nitrate contamination.

The drive for greater efficiency in fertilization practices in cotton requires 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, 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, which has been referred to 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.

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 demonstrate an integrated N management system 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 to supplement supplies when plant sampling indicates good enough yield potential to warrant additional N supply.

Project Description and Approach Used. The 2001 growing season was the first year of this proposed three-year field study. Studies were set up at four locations in 2001 and 2002, but only 3 locations are to be followed to completion in 2002. Sites represent a range of initial soil residual nitrogen levels and soil types, and were located in the central and southern San Joaquin Valley.

Three basic N application treatments were used at each location:

1. *Trt. #1:* one-time (early vegetative growth) baseline application of fertilizer N (between 100 and 125 lbs applied N/acre depending upon application equipment, and levels of residual N in upper 2 feet)
2. *Trt #2:* one-time treatment receiving a full 150-180 lb N/acre application, with adjustment based upon residual soil nitrate-N in upper 2 feet of the soil profile; and
3. *Trt #3:* initial 100 to 125 lbs N/acre application at the timing of first within-season irrigation of the growing season (adjusted to account for residual soil nitrate-N in the upper 2 feet), *plus* subsequent need for additional N applications (by water run or foliar) assessed based upon measured soil N, yield potential assessed by plant mapping of fruit load, and in consideration of early and mid-bloom petiole nitrate-nitrogen. If data called for a foliar or water run nitrate-N application, it was made between 2 and 3 weeks after first bloom.

In addition, where possible, two additional treatments were added when willing cooperators were found. Several sites had a treatment added in which no supplemental N was added, in order to allow for yield and petiole nitrate-N analyses where only residual soil N supplies could be utilized. At all sites in 2002, another treatment was added in which the initial application rate was between 150 and 180 lbs/acre (adjusted for residual nitrate-N in the upper 2 feet of the soil profile) and petiole and fruit load information was utilized to decide if a supplemental foliar application would be made at 2 to 3 weeks after first bloom. 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 collected after planting 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 DANR State Testing Laboratory (KCl extract NO_3-N, PO_4-P , Exchangeable-K, Zn).

Samples were collected at all sites within two weeks after planting 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 were 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. Irrigation water samples were 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. Two methods are being compared as part of this experiment, strictly for comparison with the amounts of residual nitrate-N determined with our current sampling methods. Gianello and Bremner (1982) developed a "hot KCl" method to assess potentially available organic N in the soil. The procedure involves air-dried soil samples that are heated with 2N KCl to 100C for a 4-hour period, followed by cooling and determination of ammonium-N. An alternative method developed by Franzluebbers et al (1996) yields potential N mineralization based upon a 24-hour incubation, in which soil samples are placed in airtight tubes, water is added and a 24-hour incubation is done at 25 C. After this period, the amount of CO2 evolved is determined by titration.

Table 1. Site average soil nitrate-N in upper 60, 90 or 120 inches of soil at planting as function of location.

Depth of soil sampled (inches)	*2001 Field Study Sites — Average Soil Nitrate-N (lbs N/acre as NO_3-N on soil dry wt basis)*							
	Site A (Kern)		*Site B (Shafter)*		*Site C (Fresno)*		*Site D (WSREC)*	
	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	84	14	61	8	128	22	72	11
0-120	116	17	86	7	176	23	97	10

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

Table 2. Petiole nitrate-N as a function of growth stage in 2001 sites for treatment 3 (late supplemental N)

Date of petiole sampling (by growth stage)	*2001 Field Study Sites — Petiole Nitrate-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 (Fresno C) Mg/kg x 1000*		*Site D (WSREC) 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

RESULTS AND CONCLUSIONS

FIRST YEAR – Field Nitrogen Management Studies

In the four field test sites, residual soil nitrate-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.

Based upon our prior five-year study, 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, use plant mapping and petiole nitrate analyses to assess yield, 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, use plant mapping and petiole nitrate analyses

The data shown above indicates the dilemma in use of soil test data for the upper two feet of soil profile. If a crop (such as cotton) is expected to have roots active in water and nutrient uptake 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 nitrate-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, it would significantly improve nutrient management information to collect soil samples to a depth of three or four feet, instead of only 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 nitrate-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 nitrate-N from 2001 field sites for specific dates were as shown in Table 2.

Plant mapping data was used to help interpret the petiole data for use in recommendations for supplemental nitrogen. Yield potential estimates at the different sites based upon

Table 3. Lint yield and gin turnout percentage data as a function of site and treatment in 2001.

Site / location				*2001 Field Study Sites*				
	Lint Yield (lbs lint per acre)				*Gin Turnout (percent)*			
	Trt 1	*Trt 2*	*Trt 3*	*No N*	*Trt 1*	*Trt 2*	*Trt 3*	*No N*
Kern Co.	1517a	1542a	1615a	984b	33.2	33.1	32.8	34.9
Shafter	1291a	1292a	1227a	678b*	36.3	36.4	36.2	38.4
Fresno Co.	1689 a	1435b	1734a	1665a	34.6	34.1	34.5	34.3
West Side REC	1807b	1815ab	1896a	1331c	36.5	36.3	36.2	37.6

*only 2 replications available
**yields followed by a different letter were significantly different at 5% level by LSD method.

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 late side-dress fertilizer application on the Kern, Kings and West Side REC location in treatment #3.

Yield responses to the applied N treatments in 2001 indicated significantly higher yields with all N application treatments when compared with no supplemental N in three of the four locations, indicating that despite the initial residual N levels shown in Table 1 in the upper 2, 3 or 4 feet, additional N fertilizer was needed to achieve moderately high yields (Table 3). At the Fresno County site, high initial residual nitrate-N across all treatments resulted in no difference in yield between no N and moderate applied N treatments (Trts. 1, 3), but resulted in a yield decrease due to excessive vegetative growth in the high N application treatment (Trt. 2). At all four sites in 2001, use of the feedback management approach (Trt. 3) resulted in a 3 to 5% apparent yield improvement over the high N treatment , but this was significant only at two sites, the low residual nitrate-N site at the West Side REC and the high residual N site in Fresno County (Table 3). Use of the feedback approach (trt. 3) only improved yields over the low N application treatment (Trt. 1) at one site (low residual N site at West Side REC). Impacts on soil nitrate-N accumulation patterns at depths from 4 to 8 feet deep in the soil profile have not yet been analyzed, but samples were collected to provide these details on potential downward movement or leaching loss potential.

Mineralizable Nitrogen Analyses

Preliminary analysis of the results has shown positive correlations and fairly good agreement (r2 = 0.79) between mineralizable N estimates using the hot KCl and incubation methods. In analyses of 2001 samples completed to date for the upper two feet of the soil profile, mineralizable N estimates average 142 percent of soil nitrate-N values in post-planting analyses, but only 107 percent of soil nitrate-N values in samples collected after harvest but before fall tillage operations. It must be acknowledged that these 2001 analyses have been on low organic matter soils with sandy loam and clay loam textures and where land application of dairy waste or large amounts of crop residue were not part of the management. Other soil types are represented in some of the other soil samples as yet unanalyzed in this project, and one site in 2002 had significant crop residue and organic N returned prior to the 2002 cotton planting. Some results and comparisons should be available to be summarized by later in 2002. The next phase in the mineralizable N analyses will be evaluation of soil samples from 2002 project sites, and this will commence in fall, 2002.

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

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OBJECTIVES

1. Predict soil K-fixation from soil texture and mineralogy as inferred from soil surveys.
2. Test K extraction methods for predicting K-fixation capacity on soils collected from the San Joaquin Valley.

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 provided by the CDFA FREP and the California State Support Committee of Cotton, Inc.

DESCRIPTION

We have collected soil samples from 48 sites representing three categories:

1. Coarse loamy or fine loamy with coarse surface texture soils derived from granitic, Sierra Nevadan parent material (expected high K fixation potential);
2. Coarse loamy family or fine loamy with coarse surface texture derived from coastal, non-granitic parent material (expected low K fixation potential);
3. Finer-textured soils from either source of parent material (expected low K fixation potential);

Most of the sites were either in cotton production at the time of sampling or in a cotton rotation. Initially, sampling sites were selected based on map classes as defined above. Soil grab samples were collected from the 15-45 cm depth from a total of 48 separate fields in four counties (Fresno, Kings, Kern and Tulare) that received no K fertilizer in the fall of 2000, nor at any time during 2001-2002. In a reconnaissance survey at each site, three grab samples were collected 10 crop rows apart from each other. Surface texture was estimated by feel throughout the field, and at one of the three grab sample sites, texture was determined to a depth of 100 cm. Grab samples were brought to the lab, and exchangeable K^+ was extracted using 1M NH_4Cl. Locations for full profile sampling were chosen for the sites that had less than 200 mg/kg NH_4Cl-extractable K. During February-August 2002, soil samples were collected by horizons from 31 on-farm fields including at 5 trial fields. Soil pits for profile description were dug in furrows after hand-leveling cotton beds to provide a consistent reference point for depth. Selected sites representing the first soil category listed above (Sierra Nevada parent material) are mapped as Hesperia sandy loam, Grangeville fine sandy loam, Armona loam, Boggs sandy loam, Kimberlina fine sandy loam and Wasco sandy loam. Sites in the second soil category (Coast Range parent material) included Panoche loam, Kimberlina fine sandy loam, Wasco sandy loam and Milham sandy loam. Fine-texured soils sampled included Rossi clay loam, Gepford clay, Armona loam, Tulare clay, Buttonwillow clay, Panoche loam and McFarland loam.

Soil samples were separated into size fractions using a pipette method and centrifugation. Mineralogical composition of the fractions will be analyzed using a Diano XRD 8000 diffractometer producing Cu Kα radiation. The K methods

Table 1. Summary of analytical methods for potassium study.

Method / Reagent	*Form of K extracted*	*Procedure*
K^+ Release Test (H_2O)	Soluble	7 days incubation with daily shaking for 45 min. 1:10 soil:solution ratio.
1M NH_4Oac	Soluble and Exchangeable	Vacuum extraction, 1:10 soil:solution ratio.
Tetraphenyl boron (0.2M $NaBPh_4$)	Plant-available K (soluble, exchangeable and some nonchangeable)	Incubation for 5 min. Soil: extractant ratio is 1:3.

(Table 1) are being performed on whole soil samples. We are testing a recently modified method for estimating plant-available K. This test, the sodium tetraphenylboron method ($NaBPh_4$), requires a five-minute incubation and routine wet chemistry techniques. This method extracts a portion of the fixed (non NH_4OAc-extractable) K that has been shown by researchers at Purdue University to be closely correlated with plant uptake of K in greenhouse studies. The greatest advantage of the $NaBPh_4$ method is that the release mechanism of nonexchangeable K in the procedure more closely simulates the extraction of this nutrient by plant roots. Other soil properties measured include pH, CEC (NH_4OAc, pH 7), and carbonate equivalent.

RESULTS

While much of the laboratory study of this project is ongoing, the preliminary results show that sand fractions of the soils we sampled are dominantly fine sand followed by very fine and medium sand fractions. Cation exchange capacity ranges from 5 to13 $cmol_c\ kg^{-1}$ and is the highest in soils derived from Coast Range alluvium (Table 2). The sodium tetraphenyl boron test has been performed on a few profiles so far. The highest concentrations of $NaBPh_4$-extractable K, as well as soluble and NH_4-extractable K, occurred in the Ap horizons of the Wasco and Panoche series in Kings county. The K levels in these locations were unexpectedly high, which made us think that the sites were fertilized between the time of grab-sampling and full profile sampling. The portion of plant-available nonexchangeable K that was extracted by the $NaBPh_4$ method (defined as $NaBPH_4$-extractable K minus NH_4-extractable K) in the upper horizons was the highest in the Grangeville soil (71-82%). Preliminary mineralogical studies of clay fractions showed that smectites dominate the clay fractions of Wasco and Panoche soil series, whereas clay fractions of Grangeville and Boggs soils also contain a significant amount of biotite and some chlorite. The near absence of vermiculite suggests that clay fractions probably have a low K^+ fixation potential. We speculate that the silt and fine sand fractions may contribute to K-fixation in the Sierran-alluvium-derived soils, and we are pursuing mineralogical investigations to test this hypothesis.

Table 2. Particle size distribution, CEC and soil K levels in some soils of Kings County.

Lab #	*Depth, cm*	*Clay* (%)	*Silt* (%)	*Sand* (%)	*CEC, $cmol^*kg^{-1}$*	Extractable K^+: *H_2O* mg/L	Extractable K^+: *NH_4OAc* mg/kg	Extractable K^+: *$NaBPh_4$* mg/kg	*Parent material or Soil category*
		Wasco: Coarse-loamy, mixed, superactive, nonacid, thermic Typic Torriorthent							
2057	0-19	15.5	18.0	66.5	12.2	12.0	516	1183	CR*
2058	19-43	13.8	17.9	68.3	11.7	9.7	456	1053	coarse
2059	43-85	14.8	19.4	65.8	11.0	0.8	62	272	
2060	85-150	13.6	12.6	73.8	10.1	1.1	68	256	
		Panoche: Coarse-loamy, mixed, superactive, thermic Typic Haplocambid							
2061	0-25	14.4	18.2	67.3	12.2	15.0	622	1315	CR
2062	25-66	12.3	16.7	71.0	11.9	1.4	108	421	coarse
2063	66-95	13.3	18.9	67.8	12.3	0.8	70	336	
2064	>95	15.7	19.4	64.9	12.3	0.6	75	306	
		Grangeville: Coarse-loamy, mixed, superactive, thermic Fluvaquentic Haploxeroll							
2065	0-19	12.6	16.1	71.3	7.2	7.8	178	621	SN**
2066	19-40	12.7	16.2	71.1	7.5	4.3	105	430	coarse
2067	40-54	10.7	17.8	71.4	7.1	2.1	49	288	
2068	54-80	9.7	17.0	73.3	NA	1.7	42	198	
2069	80-95	11.3	30.3	58.4	NA	4.0	42	165	
2070	95-110	5.3	7.5	87.2	NA	NA	17	72	
2071	110-140	5.6	2.7	91.6	NA	3.9	11	56	

* CR – Coast Ranges parent material
**SN – Sierra Nevadan parent material

IMPROVING THE DIAGNOSTIC CAPABILITIES FOR DETECTING MOLYBDENUM DEFICIENCY IN ALFALFA AND AVOIDING TOXIC CONCENTRATIONS FOR ANIMALS

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OBJECTIVES

1. To characterize the relationship between plant tissue molybdenum and copper concentrations and alfalfa yield response where molybdenum is applied at several rates.
2. To 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. To 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, (Site or experiment #1) and a second in Siskiyou County several miles west of Fort Jones, CA, in Scotts Valley (Site or experiment #2). 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.

Yield results from site 1 (experiment #1) for 2002 are given in Table 1. In both the first and second harvests (June 14th and July 19th) there were significant yield responses to molybdenum treatments. This is similar to the yield responses for previous years given in last year's report. Note as well that the lime alone treatment resulted in equally as high a yield as the molybdenum treatments. This is often the case since raising the soil pH increases the availability of molybdenum to plants. Maximum yield was often achieved with as little as 0.2 lbs Mo/A up to the higher rates of 0.8 lbs Mo/A. Rates greater than 0.6 – 0.8 lbs Mo/A however usually increased molybdenum concentrations in the forage to undesirable levels considering the needs of animals, particularly if copper concentrations are below the 8 – 10 ppm range. Phosphorus (PO_4-P), potassium, sulfate-sulfur (SO_4-S) and boron were all in the adequate range.

Plant growth stage samples were taken at 6 inches height, 12 inches height, prebud (only a small ball was formed to indicate the new bud) and at harvest (early bud to 1/10th bloom) for the first harvest only in 2002. A herbicide treatment was applied after the third plant sampling which severely stunted the alfalfa growth and delayed the harvest about 3 weeks. 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 or older plants were analyzed for molybdenum concentrations to develop the relationships between growth stage and molybdenum concentration. Figure 1 shows the rather uniform molybdenum concentration in the top 6 inches or top 1/3 of the plant samples for the growth of the first harvest for 2001. This is particularly true for plant concentrations of less than 1 ppm, which is the normal range for alfalfa plant deficiencies. For diagnostic purposes, this is particularly helpful

Table 1. Alfalfa yield during 2002 as influenced by molybdenum and lime treatments applied on March 31, 2000.

Treatment	Mo (lbs/A)	Lime (tons/A)	June 14 Yield (tons DM/A)	July 19 Yield (tons DM/A)	Sept 3 Yield (tons DM/A)
1. Control	0	0	1.81 b	1.48 cd	1.52
2. Mo	0.2	0	1.94ab	1.45 cd	1.65
3. Mo	0.3	0	1.93ab	1.57abc	1.59
4. Mo	0.4	0	1.95ab	1.41 d	1.58
5. Mo	0.6	0	1.91ab	1.63ab	1.49
6. Mo	0.8	0	2.07ab	1.68a	1.66
7. Mo	1.2	0	1.83ab	1.51 bcd	1.50
8. Lime	0	2	2.22a	1.57abc	1.62
LSD0.05			0.396	0.124	NS(0.200)

since plant samples could be taken anytime during the growth of the crop, not just at a defined stage of growth such as 1/10th bloom stage. The plant growth stage samples, as well as the harvest plant part samples for the current year, are being processed for laboratory analyses.

The Siskiyou County site (Experiment #2) was initiated when the treatments given in Table 2 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 sulfate-sulfur (>1250 ppm midstem leaf SO_4-S) were in the above adequate range.

Yield results of the four harvests from site 2 (experiment #2) for 2002 are given in Table 2. Selected treatments resulted in significantly higher yields over the control in the first three harvests. It can be noted that neither molybdenum, boron nor lime alone resulted in as consistently high yields as when at least molybdenum and boron were applied. As was observed in experiment 1, near maximum yield was often achieved with as little as 0.2 lbs Mo/A. Observations of the trial just prior to harvest (all four harvests) 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 large vegetative yield decreases but could reduce seed yields by 25 to 50% or more.

Plant growth stage samples were taken at 6 inches height, 12 inches height, prebud and at harvest (early bud to 1/10th bloom) prior to the first and third harvests in 2002. 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. 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 or older plants were analyzed for molybdenum

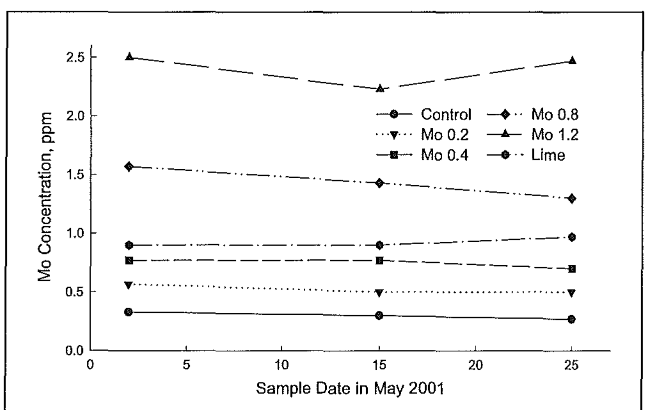

Figure 1. Alfalfa molybdenum concentrations during May 2001 as influenced by applied treatments. Expt #1

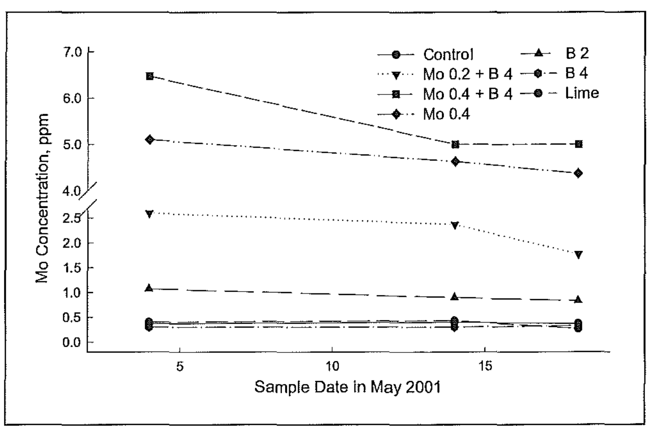

Figure 2. Alfalfa molybdenum concentrations during early May 2001 as influenced by applied treatments. Expt #2

Table 2. Alfalfa yield during 2002 as influenced by molybdenum, boron and lime treatments applied on March 9-10, 2001.

Treatment	*Mo (lbs/A)*	*B (lbs/A)*	*Lime (tons/A)*	*May 28 Yield (tons DM/A)*	*July 3 Yield (tons DM/A)*	*Aug 8 Yield (tons DM/A)*	*Sept 20 Yield* (tons DM/A)*
1. Control	0		0	1.83	1.80	1.90	1.30
2. Mo plus B	0.2	4	0	2.09	2.22	2.16	1.44
3. Mo plus B	0.3	4	0	2.16	2.26	2.04	1.39
4. Mo plus B	0.4	4	0	2.24	2.12	2.07	1.36
5. Mo plus B	0.6	4	0	2.24	2.13	2.09	1.41
6. Mo plus B	0.8	4	0	2.08	2.22	1.94	1.35
7. Mo plus B	1.2	4	0	2.12	2.20	2.09	1.40
8. Mo	0.4	0	0	1.88	1.88	1.87	1.29
9. Mo	0.8	0	0	1.96	1.89	1.96	1.31
10. B	0	2	0	2.11	2.00	1.95	1.27
11. B	0	4	0	2.14	2.10	1.99	1.35
12. Lime	0		2	1.85	1.99	1.97	1.29
13. Mo + B + Lime	0.2	4	2	2.21	1.97	2.00	1.39
14. Mo + B + Lime	0.4	4	2	2.20	2.08	1.91	1.31
$LSD_{0.05}$				0.271	0.276	0.225	0.159

*Estimated at 20% dry matter.

concentrations to develop the relationships between growth stage and molybdenum concentration. Figure 2 shows the somewhat uniform molybdenum concentration in the top 6 inches or top 1/3 of the plant samples for the growth of the first harvest for 2001. This is particularly true for plant concentrations of slightly above or less than 1 ppm, which is the normal range for alfalfa plant deficiencies. As this was also the case in Experiment #1, it becomes particularly desirable for diagnostic purposes since plants samples could be taken anytime during the growth of the crop, not just at a defined stage of growth such as 1/10th bloom stage. The plant growth stage samples as well as the harvest plant part samples for the current year are being processed or have been submitted to the laboratory for analyses.

All of the plant material collected for analysis is being saved for the preparation of several large bulk samples of known molybdenum concentration. After the analyses have been completed, samples having similar molybdenum concentrations will be combined in the range of 0.1-0.3 ppm or 0.5-0.7 ppm. These two standard forage samples are being prepared for distribution to analytical laboratories.

DEVELOPMENT OF A LEAF COLOR CHART FOR CALIFORNIA RICE VARIETIES

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INTRODUCTION

Proper nitrogen management in rice influences yields and grain quality. Excessive nitrogen and its application at an inappropriate growth stage can reduce yields, reduce market value of some varieties, and increase disease incidence. In contrast, suboptimal nitrogen levels in rice at discrete growth stages may substantially reduce plant productivity. The nitrogen status of rice at specific growth stages may be used for estimating supplemental nitrogen requirements and yield potential. Nitrogen status in the 'Y' leaf varies throughout the life cycle of rice and the rice plant transitions through the most nitrogen sensitive growth stages within a few days (Figure 1). Thus, it is essential that plants be sampled at a consistent growth stage for nitrogen management. Furthermore, time of sampling must be based on the actual plant growth stage, not days after planting. Days after planting to panicle initiation, for example, may vary between years due to weather. Estimating tissue N status at critical points of the plant's life cycle can greatly improve the economics of rice production. Therefore, fertility management decisions must frequently be made for numerous large fields in a short period of time. Tissue sampling and subsequent lab analysis may not provide the needed information in a time effective manner. Moreover, rice is grown under anaerobic soil conditions, thus rendering in-field tissue nitrate tests inapplicable. Hand held chlorophyll meters (e.g., Model SPAD-1504, Minolta Ltd.) are used to estimate leaf nitrogen in rice, but these instruments are costly and require extensive sampling and tissue analysis to accurate calibration.

To address the need for a real time nitrogen management tool, the project leader began a project in 1998 to develop a leaf color chart (LCC) to estimate leaf nitrogen content in rice based on leaf color. In a controlled experiment, the leaf reflectance characteristics of eight public rice varieties were measured with a spectrophotometer. Leaf color was described in L*, a*, b* three-dimensional color space with designations of lightness, red to green scale, and blue to yellow scale, respectively. Spectral data were used to fabricate a color chart consisting of eight acrylic plates (color cells) that accurately represents actual leaf color (Figure 2). Under experimental conditions, regression analysis relating leaf nitrogen to color revealed correlation coefficients ranging from 0.91 to 0.96 for the tested varieties (Figure 3). The University of California and a commodity board funded the development and initial production costs.

OBJECTIVES

The overall objective is to introduce and promote the adoption of a real time nitrogen tool for rice, to improve fertilizer use efficiency, reduce production costs, and minimize off-farm movement of nitrogen. Specific objectives are to:

1. Refine the chart calibration algorithms for multiple varieties across location;
2. Improve the use and sampling techniques for single leaf and whole field nitrogen determination;
3. Promote the adoption and proper use of the LCC through a series of field meetings and workshops to train growers and PCA's.

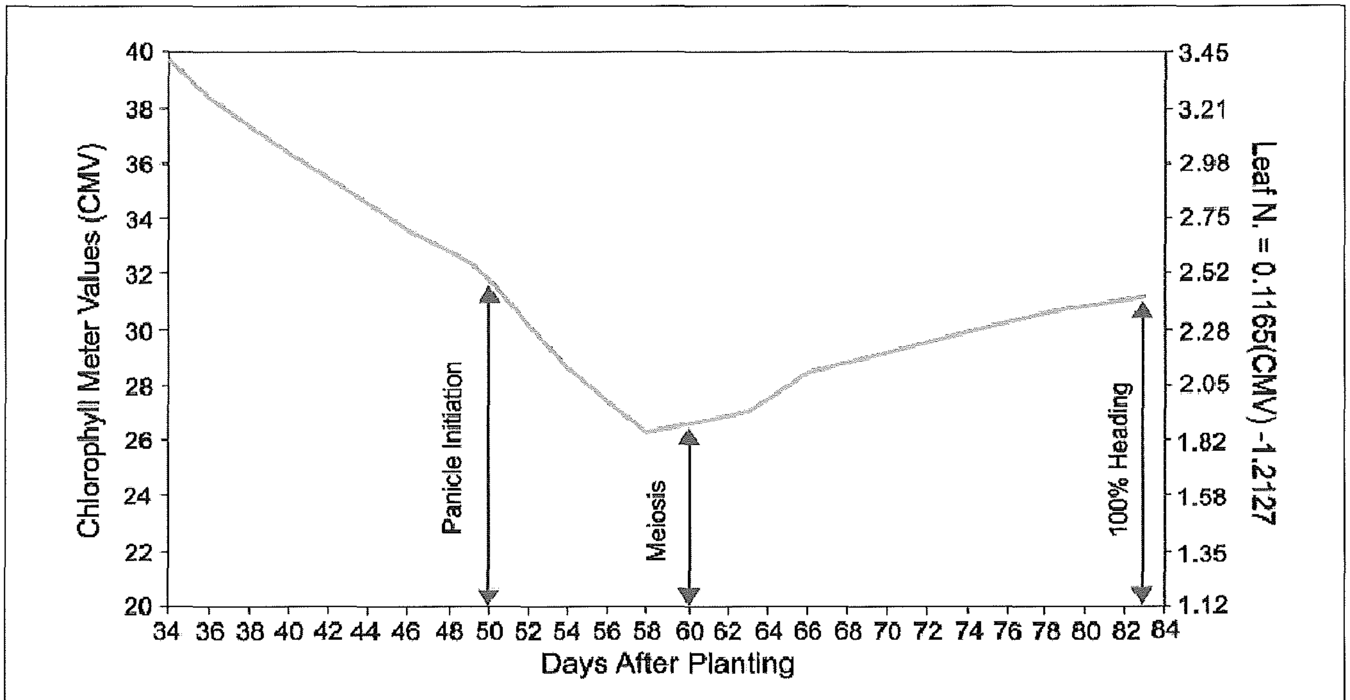

Figure 1. Seasonal variation in N content of the 'Y' leaf in rice.

PROJECT DESCRIPTION

1. The LCC was distributed to 170 rice growers and numerous PCA's sent along with detailed instructions for use throughout the Sacramento Valley.
2. Two training session/field days were held, one in Sutter County and the other in Butte County. In total over 50 growers attended.
3. Conducted individual on- farm training with over 25 growers.
4. Informed growers about the LCC four winter grower meetings (2002) and at the Rice Experiment Station Annual field day attended by over 600 people.

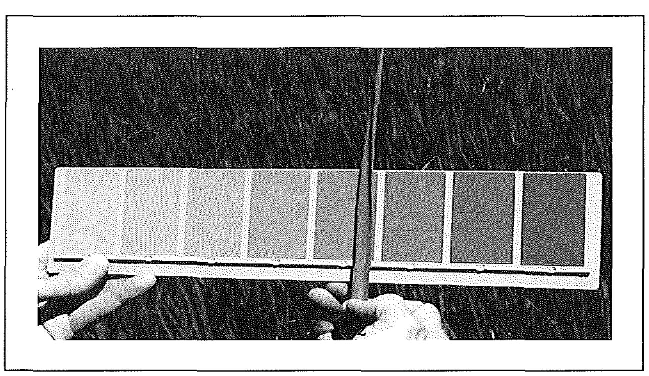

Figure 2. University of California leaf color chart.

5. Leaf samples were collected from multiple locations and varieties at different stages of growth. Leaf N was estimated with the LCC and subsequently chemically analyzed for comparison and regression analysis.
6. Controlled nitrogen by rice variety experiments were conducted in participating growers fields. Extensive leaf sampling was conducted for developing single leaf and whole field calibration of the LCC.

RESULTS

Data analysis for the first field season is in progress.

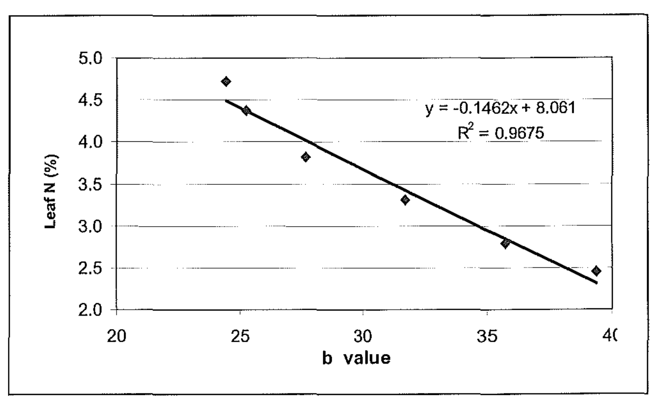

Figure 3. Relationship between leaf color and leaf N (%).

Effects of Conservation Tillage on Nutrient Losses to Runoff in Alternative and Conventional Farming Systems

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INTRODUCTION

Agricultural runoff is a major pathway for loss of nutrients from farm soils. Nutrient losses to runoff result in inefficient use of fertilizer and mean both higher costs to farmers, as they pay to replace the lost nutrients, and higher costs to society as it pays to clean up degraded waterways

Conservation tillage (CT), with necessitated changes in irrigation system design and efficiency, and cover-cropping, are two avenues for reducing runoff and decreasing nutrient losses. These management alternatives also have the potential to improve many other aspects of farm management for California growers, including reducing labor and fuel costs, increasing soil water storage, decreasing water usage, decreasing dust emissions, increasing carbon sequestration, and increasing net revenues. No studies have been done in California to evaluate the separate and/or combined effects of CT and cover-cropping, on runoff and consequent nutrient loss to surface waterways, in conventional or alternative production systems.

The purpose of this project is to quantify relationships between tillage and fertility management, and runoff and nutrient loss from soils farmed using organic, low-input, and conventional practices. Measurements will be made of runoff from plots at the Sustainable Agriculture Farming Systems (SAFS) research site at UC Davis, a long-term comparison of organic, low-input, and conventional farming systems, and from farm fields provided by SAFS grower-collaborators. Grab samples will be taken from the runoff and analyzed for suspended sediment and nitrogen and phosphorus content. The well-developed SAFS outreach structure will be used to extend the results of the study to farmers, farm advisors, policymakers, and the general public.

OBJECTIVES

1. To quantify the amount of runoff from plots and fields farmed using organic, low-input, and conventional practices, with conservation and standard tillage.

Table 1. Production practices for all treatments.

Conventional		Cover Cropped		Organic	
CT	*ST*	*CT*	*ST*	*CT*	*ST*
Corn					
DEC-Apply fallow herbicide March-plant corn with starter fertilizer and banded herbicide) April- cultivate 2x and side dress fertilizer April-July-irrigate 6x Sept- Harvest	Aug-Disc 2x Aug-triplane 2x Oct-list 60" beds Dec-apply fallow herbicide Mar-plant corn with starter fertilizer and banded herbicide Apr-cultivate 2x and side dress fertilizer Apr-July-irrigate 6x Sept-Harvest	Oct-plant Faba cover crop Mar-Apply cover crop burn down herbicide Mar-chop cover crop Mar-plant corn with starter fertilizer and banded herbicide Apr-cultivate 2x and side dress fertilizer Apr-July-irrigate 6x Sept-Harvest	Aug—disc 2x Oct—plant cover faba cover crop Mar—chop cover crop Mar—disc cover crop 2x Mar-stubble disc 1x Apr-Triplane Apr-List 60" beds Apr-preirrigate Apr-dry mulch beds Apr-plant corn with starter fertilizer and banded herbicide May-cultivate 2x and side dress fertilizer May-Aug -irrigate 6x Oct-Harvest	Oct—plant Faba cover crop Mar—chop cover crop Mar—plant corn with organic starter fertilizer Apr—spread Manure Apr—cultivate 2x Apr-July—irrigate 6x Sept—Harvest	Aug—disc 2x Oct—plant faba cover crop Mar—chop cover crop (March) Mar—disc cover crop 2x Mar—spread manure Mar—stubble disc 1x Apr—Triplane Apr—List 60" beds Apr—preirrigate Apr—dry mulch beds Apr—plant corn May—cultivate 2x May—irrigate 6x Oct—Harvest
Tomatoes					
Sept—chop residue Dec—apply fallow herbicide Apr—strip till bed centers Apr—incorporate preplant herbicide Apr—transplant tomatoes May/June—cultivate 3x May—sidedress fertilizer Apr/June—irrigate 6-7x Aug—harvest	Sept—chop residue Sept—disc 2x Sept—deep rip Sept—disc Sept—triplane 2x Oct—list beds Dec—apply fallow herbicide Apr—work beds Apr—incorporate preplant herbicide Apr—transplant Apr/May—cultivate 3x May—sidedress fertilizer Apr/July—irrigate 6-7x Aug—harvest	Sept—chop residue Nov—drill faba bean cover crop Mar—apply burn down herbicide to cover crop Mar—Chop cover crop Apr—strip till bed centers Apr—incorporate preplant herbicide Apr—transplant Tomatoes Apr/May—cultivate 3x May—sidedress fertilizer Apr/July—irrigate 6-7x harvest (Aug)	Oct—chop residue Oct—disc 2x Oct—deep rip 2x Oct—disc Oct—plant faba bean cover crop Apr—chop cover crop Apr—disc 2x Apr—stubble disc Apr—disc Apr—triplane 2x Apr—list 60" beds Apr—incorporate preplant herbicide Apr-Transplant May—sidedress fertilizer Apr/May—cultivate 3x Apr/July—irrigate 6-7x harvest (Aug)	Sept—chop residue Nov—drill faba bean cover crop Mar—chop cover crop Apr—strip till bed centers Apr—transplant Tomatoes with organic starter fertilizer May-sidedress manure Apr/May—cultivate 3x Apr/May—irrigate 6-7x Aug—harvest	Oct—chop residue Oct—disc 2x Oct—deep rip Oct—disc Oct—Triplane 2x Nov—plant faba bean cover crop Mar—chop cover crop Mar—disc 2x Apr—stubble disc Apr—disc Apr—triplane 2x Apr—spread manure Apr—list 60"beds Apr—transplant Apr/May—cultivate 3x Apr/May—irrigate 6-7x Aug—harvest

2. To quantify the amount of nitrogen, phosphorus, and sediment in this runoff.
3. To extend the results of this study to farmers, policymakers, and the general public.

PROJECT DESCRIPTION

This project is a three-year effort to quantify relationships between tillage, fertility management, runoff, and nutrient loss to surface waterways, from soils farmed using several different resource management strategies. Measurements necessary to quantify these relationships will be made in fields provided by three growers in Yolo County, and at the Sustainable Agriculture Farming Systems (SAFS) research site on the UC Davis campus. This experiment will take advantage of an established long-term research site with a history of organic, low-input, and conventional management. Organic fertility management combines manures and cover-cropping, low-input integrates cover-cropping and commercial fertilizer, and conventional management relies on commercial fertilizer alone. The plots are being converted to a study of conservation vs. standard tillage in all three management systems. The experiment will also take advantage of growers' interest in examining relationships between tillage, cover-cropping, and nutrient runoff.

At the SAFS site, plots of one-third acre each (to allow use of full-scale farm equipment) will be treated with a tillage x farming system factorial design for conventional, organic, and low-input systems. All farming systems will have had at least a 12-year history of management under their defining criteria. All farming-system treatments will use "best farmer management practices," to be determined by consensus of the research team, which includes farmers and farm advisors. The SAFS project is unique in that farmers participate in every stage of the research process, including planning and design, execution, and interpretation and dissemination of results.

The conventional systems will be managed with practices typical of the surrounding area, which include the use of synthetic fertilizers and pesticides. In the low-input systems, fertilizer and pesticide inputs will be reduced primarily by using legume cover crops to improve soil fertility, and predominantly mechanical cultivation for weed management. The organic system will be managed according to the regulations of California Certified Organic Farmers (CCOF, 1995), with no use of synthetic chemical pesticides or fertilizers. Instead, management will include the use of cover crops, composted animal manure, mechanical cultivation, and limited use of CCOF-approved products. Tillage and farming operations will be conducted for the first two years as shown in Table 1.

At growers' fields, the size of plots or fields to be dedicated to the study will be decided by the growers. The basic rotation will be a 2-year one of tomatoes and corn, starting with tomatoes. Two treatments will be used: the normal growers' practices for the site, and a conservation tillage treatment to be decided upon by consensus of growers and researchers.

MEASUREMENTS

Runoff

Runoff from each plot will be channeled through a v-shaped weir draining into a ditch at the end of each plot. Because the opening of the weir is a known dimension, the rate of runoff is proportional to the height of water flowing through the weir. The water height will be measured with a pressure transducer placed at the bottom of the weir and connected to a datalogger. This system allows readings to be taken several times a minute so that the rate of runoff can be plotted over time and directly related to rainfall intensity.

Nitrogen and phosphorus

Grab samples of 500 mL of runoff water will be taken at regular intervals during any storms of high enough intensity to generate runoff. Samples will be analyzed for total suspended solids, nitrate, ammonium, total N, and total P in the solids, and ammonium, nitrate/nitrite, TKN, and TP in dissolved form.

RESULTS

There are no results as yet. Due to delays in funding the project was not commenced until October 2002.

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 overfertilization and overirrigation. 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 workers 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.*
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 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^{-1}. One of the fertilizer solutions contained polymethyleneurea (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.

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.*

Leaching losses of N were greatest among species that received the SLF treatment, and the CRF treatment resulted in

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

Table 2. Effect of species and fertilizer treatment on leaf N concentration, expressed as a percentage of dry weight. Values followed by different letters are significantly different at P=0.05.

Species	*Leaf N*	*Fertilizer*	*Leaf N*
Magnolia	1.77a	SLF	2.26a
Pistacia	2.10b	MU	1.97b
Platanus	2.12b	CRF	1.98b
Prunus	2.42c		
Q. agrifolia	1.96d		
Q. lobata	2.55e		
Sequoia	1.56f		

Table 3. Effect of species and fertilizer treatment on total N uptake, expressed in grams. Values followed by different letters are significantly different at P=0.05.

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

Table 4. Cumulative N leached, in grams, from application of three fertilizer treatments to seven tree species. Values followed by different letters are significantly different at P=0.05.

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

Table 5. Percentage of applied N that was leached from application of three fertilizer treatments to seven tree species. Values followed by different letters are significantly different at P=0.05.

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

Table 6. N use efficiency of three fertilizer treatments, expressed as the ratio N uptake:N leached. Values followed by different letters are significantly different at P=0.05.

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

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 polymethyleneurea. 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).

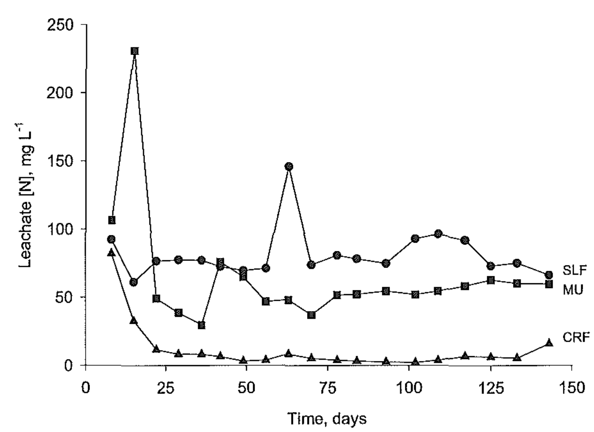

Figure 1. Leachate N concentrations among fertilizer treatments.

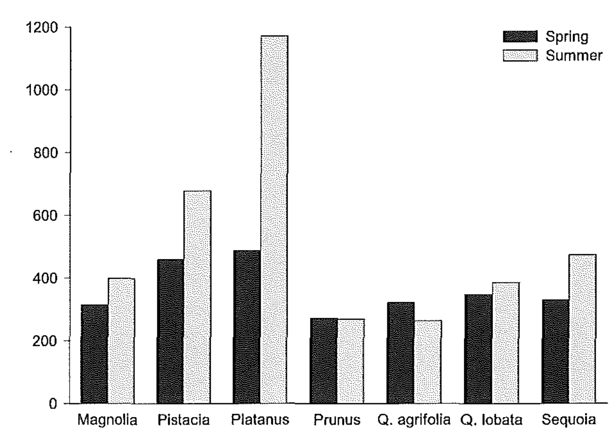

Figure 2. Average daily water use in spring and summer months for seven tree species growing in 5 gallon containers.

Concentrations were highest in the SLF and MU treatments (averaging 82 and 53 ppm, respectively), and only 6 ppm for the CRF treatment.

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).

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 polymethyleneurea. 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 with either the traditional soluble N or polymethyleneurea 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.

After analysis of N in plants, leachate, and soil, we were able to account for 92% of the N applied as CRF, but only 62% of the N applied in the polymethyleneurea liquid feed. N recovery in the traditional liquid feed treatment was 78%. Although we did not measure directly the N volatilization in the experiment, we assume that most of the unrecovered N was lost to the atmosphere.

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.

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

Precision Horticulture: Technology Development and Research and Management Applications

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INTRODUCTION

Precision farming is information-based management techniques that have the potential to increase productivity and reduce environmental pollution. Recent studies have determined that accurate yield monitoring is a key element in precision farming. Studies showed that it is possible to reduce fertilizer input and maintain yield under site-specific nutrient management.

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. Our inability to determine tree yield on a scale smaller than the standard block or orchard, severely impedes our ability to optimize productivity and minimize costs.

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 most direct benefit of this approach would be the ability to optimize fertilization strategies on a site-specific basis. This is the key to improve 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 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 the 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.

PROJECT OBJECTIVES

The aim of the project is to develop the harvesting machinery, initiate statistical and mapping methodologies to allow

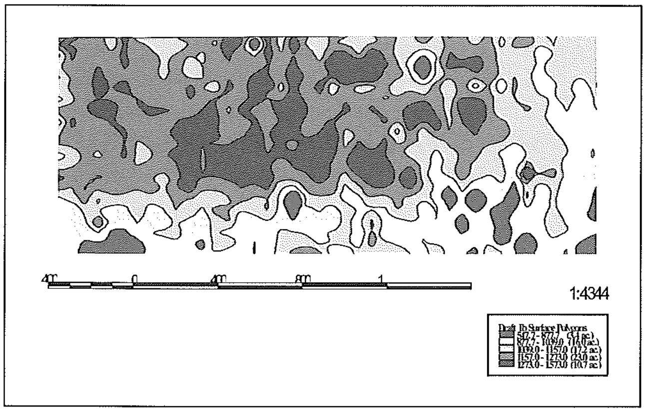

Figure 1. Soil compaction determined using a tractor mounted draft resistance Device with GPS equipped data logger.

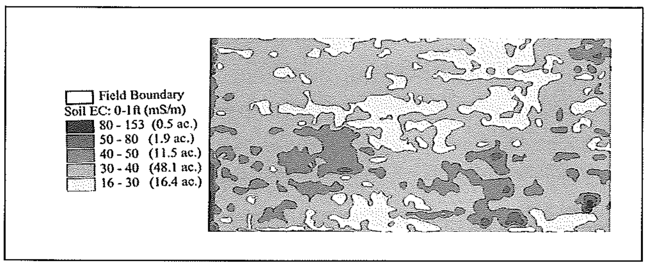

Figure 2. Soil Electrical Conductivity measured at 3 feet using EM 30 remote sensing device and GPS equipped data logger.

growers to view and interpret the annual productivity of each tree in their orchards. This will then be used to optimize management 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 development of 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

In the first year, 2001, we selected an 80 acre pistachio orchard containing 12,000 trees located at the Paramount Farming Company, Lost Hills California. This orchard was 12 years old, uniform in appearance and with a good production history. Global Positioning System and Geographic Information System technologies were used to determine tree-by-tree yield.

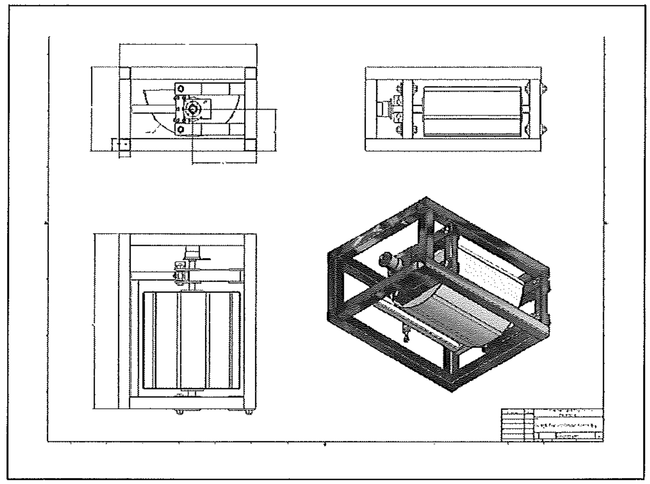

Figure 3. Weigh Bucket Design

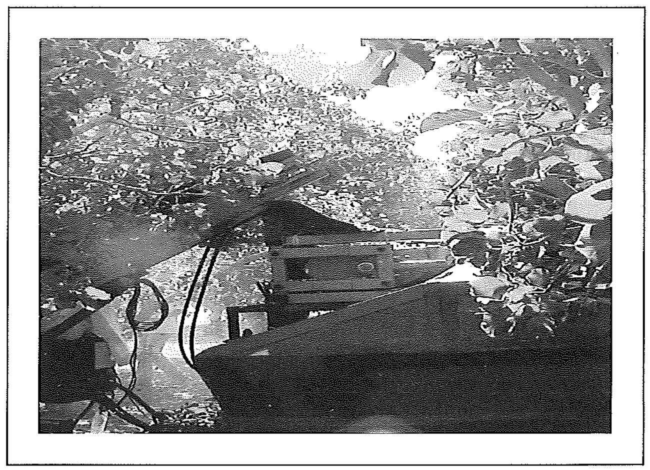

Figure 4. Pistachio Yield Monitor in Position.

RESULTS AND DISCUSSION

In 2001, Texture and Compaction Index (TCI) (Fig.1) and Electrical Conductivity (EC) (Fig. 2), were made using GPS-sensor- based systems. A new electronic weigh bucket was designed (Fig. 3). The harvesting equipment for pistachio was modified to include the electronic weigh bucket system (Fig. 4) to allow real-time tree-by-tree harvest data. This system was then mounted on the bank-out wagon and a mass flow tree harvesting was performed. In addition, soil and leaf samples were taken to analyze the soil fertility and leaf nutrition status.

The harvesting equipment developed was shown to be rugged and reliable. Problems with GPS determinations in the field persist and will require further engineering improvements to resolve. A primary constraint to the current yield monitor is the inability to completely clear the catch frame of harvested nuts prior to harvest of the following tree. This

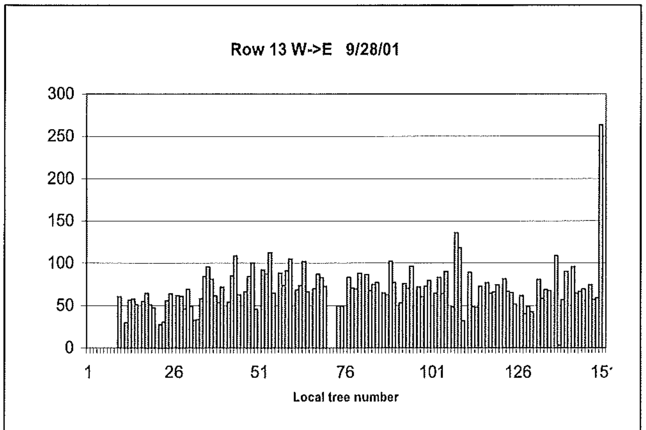

Figure 5. Individual tree yield down the length of one row of 151 trees. High yield of tree 151 is an error caused by machine turning. Yield varies by 200% between neighbors, individual tree yields as high as 120 lbs tree were recorded.

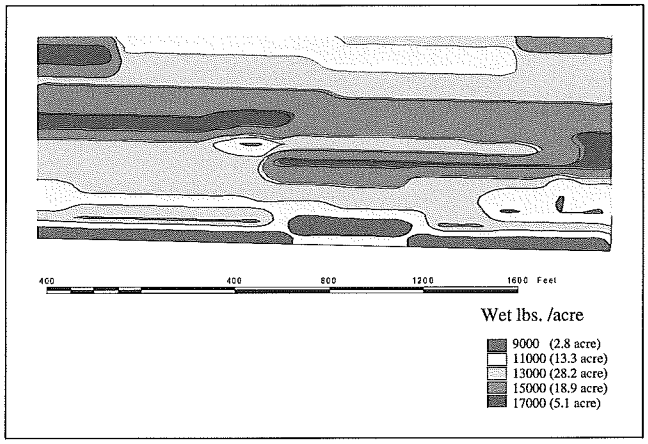

Figure 6. Yield map.

problem results in mixing of yields and loss of tree-to-tree resolution. This represents an engineering challenge that can be addressed with a slightly modified harvesting system.

The data collected this year provides excellent information at a resolution of about 5 x 5 trees. A higher degree of resolution is possible utilizing mathematical procedures and through engineering refinements. We have commenced GIS analysis of yield and variation in environment (Soil, water, nutrition)—this will be presented at the annual conference.

Tree Yield Varies Dramatically Across the Orchard

Tree yield varies dramatically within a single row (Fig 5) and yield variations of > 200% between 5 neighboring trees is not uncommon. Tree yield varies markedly over the orchard as a whole (Fig 6), and regional per acre yields varied from 9000 lbs per acre (in-field, in-hull) in the poorest area to 17000 lbs per acre (in-field, in-hull) in the best area.

The results presented here demonstrate that yield is highly variable in Pistachio. It should be remembered however that this is only the first year of analysis. Data from the second year is being analyzed and a second year is essential to correct for alternate bearing effects. The challenge for a grower and for a researcher is to determine what are the causes of this yield variation and what can be done to optimize profitability.

Data of the current year, 2002, was collected and is being analyzed. Eighty acres were harvested and yield of 6040 trees were determined on tree-by-tree basis. This data was collected using modified harvesting machinery based on our learning experience from last year. The machinery modification includes an increase of 50 % in the capacity of the Weight Bucket, higher speed of the conveyer belt, efficient cleaning system by reducing the transport lag phase. The transport lag phase allowed determination of tree-by-tree yield without a significant yield carry-over from the previous tree. Also, a GPS-radar system was integrated into the system to determine accurately the position of the harvested tree. The details of the modified system will be discussed at the tenth annual conference. Conclusions will be made once the data is analyzed. Therefore, it is too early yet to define which variables are most important though preliminary information may indicate that the source of variation could be due to a combination of soil and biological system variables. By comparing patterns of yield and measured soil and biological system variables, a greater understanding of the crop conditions and potential causes of yield variability can be gained.

Minimizing Nitrogen Runoff and Improving Nitrogen Use Efficiency in Containerized Woody Ornamentals through Management of Nitrate and Ammonium-Nitrogen

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OBJECTIVES

1. Determine the fate of ammonium (NH_4^+) and nitrate (NO_3^-) from controlled release fertilizers (CRF) and liquid feed (LF) fertilizers in containerized woody ornamentals growing in acid (5.0) or neutral (7.0) pH media during a 12-month period.
2. Develop fertilization and irrigation guidelines for woody ornamental crop production that will minimize NO_3-runoff and improve nitrogen use efficiency.
3. Disseminate guidelines to growers, fertilizer producers, consultants, farm advisors, educators and extension specialists involved in woody ornamental crop production.

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 proximity to each other. Due to these geographical constraints, along with the high use of fertilizer and water by the industry, nitrate (NO_3^-) leaching from agricultural lands continues to threaten local drinking water supplies and the neighboring ecosystems.

Federal and state laws now prohibit excessive polluting of surface waters. Federally enforced laws are issued through the Clean Water Act of 1972 and state regulations are enforced through the state's Porter-Cologne Water Quality Act of 1969. Lawsuits have been pending in the regions of San Diego and the Central Coast. 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.

In the following project, field trials are being conducted to determine the fate of different types of coated, controlled-release fertilizers (CRF) and liquid fertilizers (LF) as affected by acid pH (5.0) and neutral pH (7.0) media. The fate of nitrogen (N) in the crop is being determined by performing weekly measurements of nitrate in the leachates and monthly measurements of total N in the media and the plants. With this information, we will know the time period in the production cycle when N leaching is most likely and the time period when N uptake into plants is at its optimum. The information from this experiment will help us develop irrigation and fertilization programs that will minimize the likelihood of nitrate leaching and maximize nutrient uptake efficiency. This will not only help growers comply with new water quality regulations but also improve potential profits through more efficient use of water and fertilizer resources. These guidelines will be actively communicated to growers, CE advisors, consultants, the fertilizer industry, teachers and students through extension programs, workshops, seminars, and publications (newsletters, trade magazines and journals).

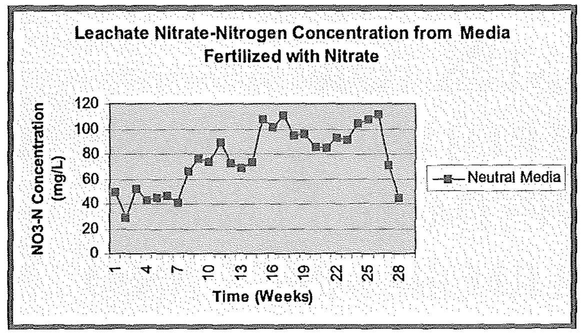
Research plots are set up at the Agricultural Experiment Station at the University of California at Riverside. A total of 910 plants, at the liner-stage, were obtained from commercial nurseries. Two different plant species are being used, one typically produced in acid pH media (Azalea 'Phoenicia') and one typically produced in neutral pH media (*Ligustrum japonicum*). Treatments are a 2 x 7 factorial of 2 different media pH (5.0 and 7.0) and seven different fertilizer treatments (Table 1). Substrates for the low pH-medium consists of a

Table 1. List of fertilizer treatments. Nitrate = NO_3 and ammonium = NH_4.

Treatment	Fertilizer Rate	Fertilizer Type
1	100 ppm N as 75% NH_4 and 25% NO_3	LF
2	100 ppm N as 50% NH_4 and 50% NO_3	LF
3	100 ppm N as 75% NO_3 and 25% NH_4	LF
4	3.0 lb N/yd^3	Osmocote CRF
5	3.0 lb N/yd^3	Polyon CRF
6	3.0 lb N/yd^3	Nutricote CRF

mixture of 2:1:1 volumes of composted pine bark, peat, and sand, respectively. The neutral pH-medium consists of 3:1 volumes of composted forest products and sand respectively. Lime was added to adjust pH. Micronutrients were added to all treatments at recommended rates. For treatments 1-3, the liquid fertilization (LF) is injected through the irrigation system. For treatments 4-7, one of four different 12-month CRF was incorporated into the planting media at the initiation of the study. Drippers are located in each container and irrigation is controlled electronically to water at specific time intervals, depending on crop water requirements.

The first phase of this project has been completed and we are currently analyzing the data. We are also currently repeating the study. However, based on preliminary experiments, we have seen that the conversion of ammonium to nitrate may occur in planting media. In this preliminary trial, even though media was steam sterilized, the conversion of ammonium to nitrate in ammonium-fertilized containers became evident after 12 weeks of fertilization (Figure 1A and B). This data suggests that fertilization with fertilizers consisting of ammoniacal nitrogen may initially reduce the potential for nitrate leaching, but will eventually be converted to nitrate (nitrification) after a given time period. With the current



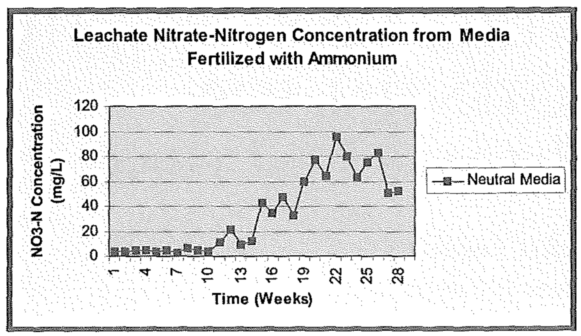


Figure 1. Nitrate concentrations in leachates collected from media fertigated with 100 mg N/L as (A) calcium nitrate or (B) ammonium sulfate. Fertilization trials began on January 17, 2001 (Week 1) and continued until August 6, 2001 (Week 29). Containers received fertigation via drippers every other day at a rate of 1000 ml/container/week.

trial being conducted, we will be able to determine the extent of the conversion of ammonium to nitrate and the extent of nitrate leaching from the different types of controlled release fertilizer and the different types of liquid fertilization regimes.

Development of BMPs for Fertilizing Lawns to Optimize Plant Performance and Nitrogen Uptake While Reducing the Potential for Nitrate Leaching

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INTRODUCTION

The definition of the phrase "best management practice" (BMP) varies depending on the specific context involved and the currently accepted standards and goals of agronomic management. In general, BMPs are considered to be a set of guidelines or procedures which have been determined, as part of an overall program, to be an effective and practical (technically, socially and economically) method for reducing, preventing, or controlling undesirable effects of management; promoting or maintaining beneficial effects of management; and/or protecting the environment or natural habitat. Turfgrass-related BMPs encompass a wide variety of activities, including fertilization, irrigation, mowing, pest control, and soil management. One of the most important set of turfgrass BMPs are those relating to providing adequate nitrogen (N) to provide the healthy, moderate (i.e., neither minimal or excessive) growth necessary to provide both acceptable visual appearance and the ability to cope with stresses such as drought, traffic, and disease.

Promoting moderate growth (and optimal uptake of N by the plant) is, in fact, one of the best defenses against N sources contaminating the environment. Nitrogen that isn't taken up by the plant is either stored in the soil or thatch, lost to the atmosphere [NH_3 volatilization and denitrification (the reduction of nitrates to gaseous nitrogen)], or lost to surface water in runoff or groundwater via leaching.

In the soil environment, the primary forms of N are organic N (the dominant form), ammonium-N (NH_4^+-N), nitrite-N (NO_2—N), and nitrate-N (NO_3—N). Unlike organic N and NH_4^+-N, nitrates do not bind to soils and thus have a high potential for leaching into groundwater. However, it should be noted that organic N and NH_4^+-N are potential nitrate sources, since they can be transformed to nitrate in soil and waters. Nitrate is also likely to remain in the water supply until consumed by plants or other organisms since they do not volatilize. According to the U.S. Environmental Protection Agency (EPA), nationwide over 112 million pounds of nitrate and nitrite were released to water and land from 1991 through 1993. Notably, one of the largest releases of inorganic nitrates (from sources such as fertilizers) was in California.

Excessive N in the environment can have serious consequences, including altering ecosystems, eutrophication [an over-enrichment of water sources with nitrogen and phosphorus which causes accelerated growth of plant life (such as algal blooms) and which can disturb the balance of organisms and water quality], contributing to acid depostion and ozone depletion, and, as already noted, contamination of surface water and groundwater. According to the U.S. Department of Health and Human Services, N fertilizers have contributed to a 40-year trend of increased nitrate levels in surface water and groundwater of agricultural regions.

Given the potential implications of nitrate contamination, turfgrass fertilization BMPs must take into account ways to minimize nitrate contamination of surface water and groundwater. Research has shown that nitrate contamination of surface water due to runoff is rare due to the relatively high infiltration capacity of turfgrass ecosystems (with the exception of severe slopes, which require careful irrigation cycling). The results of research on nitrate leaching, however, are more variable, with soil type, irrigation, N source and rate, and season of application all potentially affecting nitrate leaching.

OBJECTIVES

The objectives of the research project are to 1) evaluate the annual N rate and source on tall fescue to determine which treatments optimize plant performance and N uptake while reducing the potential for nitrate (NO_3–) leaching; 2) quantify the effect of N fertilizer rate and source on visual turfgrass quality and color, clipping yield, tissue N concentration, N uptake, and concentration of NO_3^--N at a depth below the rootzone; 3) develop BMPs for lawns under representative irrigation practices to optimize plant performance and N uptake while reducing the potential for NO_3^--leaching; and 4) conduct outreach activities, including oral presentations and trade journal publications, emphasizing the importance of the BMPs and how to carry out these practices for N fertilization of lawns.

DESCRIPTION

The project is being conducted at two sites with different climates and turfgrass maturity, but which are being maintained similarly. One site is a newly established tall fescue plot (sodded late Sept. 2002) in northern California at UC Davis and the other is a mature tall fescue plot (seeded Apr. 1996) in southern California at UC Riverside. Both sites were established to tall fescue, since it is the most widely used lawngrass in California, especially for urban landscapes. The plots at both sites are irrigated at [100% ET_{crop}/DU] minus rain, with the amount of irrigation determined weekly based on the previous 7 days' cumulative ET_0. There are two irrigation events per week, which are cycled to prevent runoff. The experimental design at both sites is a randomized complete block (RCB) design with N treatments arranged in a 4×3 factorial (four N sources and three rates; see Table 1). A no-nitrogen check treatment is also included to allow for additional statistical tests. The application of treatments and data collection will be coordinated between the two sites in order to allow for the most robust statistical analyses possible for comparing the results from the two sites.

Both quick release and slow release N sources are included in the study, both of which have distinct advantages and disadvantages relative to the other. Quick release N sources provide a rapid but short-term turfgrass response while slow release N sources provide a slow but long-term response. Quick release sources are generally less expensive and more efficient (in terms of the percentage of applied N recovered in grass clippings) than slow release N sources, but also have the greater tendency for foliar burn, volatilization and leaching. The specific N sources used in the study include: ammonium nitrate, a fast-release, water soluble N source; Polyon, a slow-release, polymer-coated N source; Milorganite, a slow-release, natural organic N source; and Nutralene, a slow-release, water insoluble, methylene ureas N source (Table 1).

Each fertilizer will be applied at three annual N rates, including a low (4.0 lb N/1000 ft^2), moderate (6.0 lb N/1000 ft^2) and high (8.0 lb N/1000 ft^2) rate (Table 1). The moderate rate of 6.0 lb N/1000 ft^2 has been found to be sufficient to provide acceptable visual turfgrass quality and color while maintaining a healthy, moderate growth rate. It is expected that the 4.0 lb N/1000 ft^2 rate will not provide acceptable visual turfgrass quality and color and that the 8.0 lb N/1000 ft^2 rate will result in excessive growth and potentially greater nitrate contamination than the other fertilizer rates.

In order to measure nitrate leaching below the rootzone, suction lysimeters were installed so the distal tip of the porous cup of each lysimeter was at a depth of 2.5 feet below the soil-thatch layer (approximately 0.6 inch deep). The lysimeters (constructed using high-flow ceramic cups and 2-inch diameter PVC pipe) were installed at a 45° angle so the lysimeter cup is below undisturbed soil. Twenty-four hours

Table 1. Protocol for 13 N fertilization treatments (four N sources x three rates plus no-nitrogen check).

Date of application	*N source*z *(N-P2O5-K2O)*	*Rate (lb N/1000 ft2)* a	b	c
1 March	No nitrogen check	0.0	0.0	0.0
	A. Ammonium nitrate 33-0-0	1.0	1.5	2.0
	B. Polyon 43-0-0	1.0	1.5	2.0
	C. Milorganite 6-2-0	1.0	1.5	2.0
	D. Nutralene 40-0-0	1.0	1.5	2.0
15 May	No nitrogen check	0.0	0.0	0.0
	A. Ammonium nitrate 33-0-0	1.0	1.5	2.0
	B. Polyon 42-0-0	1.0	1.5	2.0
	C. Milorganite 6-2-0	1.0	1.5	2.0
	D. Nutralene 40-0-0	1.0	1.5	2.0
15 Aug.	No nitrogen check	0.0	0.0	0.0
	A. Ammonium nitrate 33-0-0	1.0	1.5	2.0
	B. Polyon 42-0-0	1.0	1.5	2.0
	C. Milorganite 6-2-0	1.0	1.5	2.0
	D. Nutralene 40-0-0	1.0	1.5	2.0
15 Oct.	No nitrogen check	0.0	0.0	0.0
	A. Ammonium nitrate 33-0-0	1.0	1.5	2.0
	B. Polyon 43-0-0	1.0	1.5	2.0
	C. Milorganite 6-2-0	1.0	1.5	2.0
	D. Nutralene 40-0-0	1.0	1.5	2.0
Total	No nitrogen check	0.0	0.0	0.0
	A. Ammonium nitrate 33-0-0	4.0	6.0	8.0
	B. Polyon 42-0-0 and 43-0-0	4.0	6.0	8.0
	C. Milorganite 6-2-0	4.0	6.0	8.0
	D. Nutralene 40-0-0	4.0	6.0	8.0

zAmmonium nitrate is a fast-release, water soluble N source; Polyon is a slow-release, polymer-coated N source; Milorganite is a slow-release, natural organic N source; and Nutralene is a slow-release, water insoluble, methylene ureas N source.
Note: KCl (0-0-60) and treble superphosphate (0-45-0) will be applied to all plots at an annual rate of 4.0 lb K_2O/1000 ft^2 and 3.0 lb P_2O_5/1000 ft^2.
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prior to each sampling day, a vacuum of approximately –40 KPa is applied to the lysimeters. Leachate is removed from the lysimeters using via vacuum, and samples are then acidified to pH 2, frozen, stored, and shipped via next-day air to the DANR Laboratory for NO_3^--N analysis by diffusion-conductivity analyzer (Table 2).

Rounding out the "point-in-time" data from the lysimeters, measurements required to account for a hydrologic balance (including soil water content) and soil NO_3-N measurements are being taken (Table 2). The hydrologic balance is used to estimate the total NO_3^--N mass leached. Soil volumetric water content is determined weekly using time domain reflectometry (TDR) with four to eight sensors installed in null plots (plots within the research area which are not associated with any of the treatments). Soil NO_3^--N is determined at four rootzone depths: 0 to 12, 12 to 24, 24 to 36, and 36 to 48 inches below the soil-thatch layer (approximately 0.6 inches below the surface). Three cores are taken from each plot using a King Tube (i.d. 0.84-inch), cut and pooled by depth, dried at air temperature, sieved, and sent to the DANR Laboratory for NO_3^--N analysis by equilibrium extraction with KCl and diffusion- conductivity analyzer. Soil NO_3^--N provides a direct physical/chemical measurement of the movement (a layer) of NO_3^--N through the soil profile. It is useful for determining the accumulative effects over time.

Several additional measurements are being made throughout the course of the study (Table 2). Visual turfgrass quality and color ratings are taken once every two weeks, in order to estimate plant performance and response to the N-fertility treatments. Also, clipping yield is taken weekly during four growth periods, with each period spanning four consecutive weeks and beginning one month following a N-fertility treatment application. The weekly clipping yields are dried and

Table 2. Protocol for measurements collected during the study.

Measurement	*Frequency*	*Method and other comments*
1. Visual turfgrass quality	Once every 2 weeks	1 to 9 scale, with 1 = worst quality and 9 = best quality for tall fescue
2. Visual turfgrass color	Same time as turfgrass quality	1 to 9 scale, with 1 = worst color (brown) and 9 = best color (dark green) for tall fescue
3. Clipping yield, TKN, and N uptake	Four growth periods, with each period spanning four consecutive weekly clipping yields. All periods start one month following each of the four N-fertility treatment application dates (Table 1). Generally, periods are 1 to 30 Apr., 15 June to 15 July, 15 Sept. to 15 Oct., and 15 Nov. to 15 Dec.	Weekly clipping yield, representing 7-d growth, is collected with the same mower used for routine mowing, except a specially constructed collection box is attached to the mower. Not less than 25% of the total surface area of each plot is subsampled. Weekly clipping yields are dried and weighed via standard procedures. The four weekly yields within each growth period are pooled by the 48 plots and prepared for TKN analysis via standard procedures. TKN analysis is conducted at the DANR laboratory located at UC Davis. With appropriate calculations, N uptake during four 4-week growth periods is determined.
4. NO_3^--N concentration of soil water below rootzone	Once every 2 weeks	One suction lysimeter was installed in each plot so the distal tip of the lysimeter cup is at a depth of 2.5 feet below the soil-thatch layer [approximately 0.6 (1.5 cm) inch deep]. The lysimeters were installed at a 45° angle so the lysimeter cup is below undisturbed soil. They were constructed using high-flow ceramic cups and 2-inch diameter PVC pipe. A vacuum of approximately –40 KPa is applied to the lysimeters 24 h before the leachate sampling day. Samples are acidified to pH 2, frozen, stored, and shipped via next-day air to the DANR Laboratory for NO_3^--N analysis by diffusion-conductivity analyzer.
5. Hydrologic balance	Not less than once every 7 d	Estimate of water percolating through soil by hydrologic balance. Determined via changes in soil water content and other data used in a model. This, with NO_3^--N concentration, is used to estimate NO_3^--N mass leached. Soil volumetric water content is determined using four to eight time domain reflectometry (TDR) sensors (MoisturePoint MP-917 TDR unit with Type 2 probe) installed in null plots within the research plot (there are a total of eight null plots, two per replication).
6. Soil NO_3^--N	Twice every 12 months	Using a King Tube, three 0.84-inch (2.14 cm) cores are taken from each plot and separated by four rootzones: 0 to 12 inches (0 to 30.5 cm), 12 to 24 inches (30.5 to 61.0 cm), 24 to 36 inches (61.0 to 91.4 cm), and 36 to 48 inches (91.4 to 121.9 cm) below the soil-thatch layer [approximately 0.6 inches (1.5 cm) below the surface]. Cores from each plot are pooled by depth, dried at air temperature, sieved through a Tyler-equivalent 20 mesh screen and sent to the DANR Laboratory for NO_3^--N analysis by equilibrium extraction with KCl and diffusion-conductivity analyzer. A grid is used to ensure that no part of the plot is sampled more than once for the duration of the study.
7. Weather data	Continuous	Data obtained from a CIMIS station located at the UCR Turfgrass Research Project. Soil-temperature data loggers also are installed on the research plot.

All measured variables, except weather data, are statistically analyzed according to a RCB design with treatments arranged in a 4×3 factorial. The no-nitrogen check treatment is compared to fertilizer treatments, products, and rates by a statistical contrast procedure. A repeated-measures design also is used within and between years when appropriate. Weather data are summarized by week.

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weighed to provide an estimate of plant growth for the previous 7 days. The four weekly yields within each growth period are then pooled by each plot and analyzed for total Kjeldahl nitrogen (TKN) analysis at the DANR Laboratory. With appropriate calculations, N uptake during the four 4-week growth periods is then determined. Finally, weather data is taken continuously from an on-site CIMIS station and a datalogger is installed at the research plot which is recording soil temperatures at the 4-inch depth.

RESULTS AND CONCLUSIONS

When completed, this project will add to our current understanding of NO_3^- leaching from turfgrass (tall fescue in particular). The resulting BMPs will include the best way to fertilize tall fescue (rate and source) for optimal plant performance and N uptake while reducing the potential for NO_3^- contamination of groundwater. The BMPs have the potential to have a wide impact since they will be directly relevant to California home-lawn owners.

Site-Specific Variable Rate Fertilizer Application in Rice and Sugar Beets

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INTRODUCTION

Large fields are rarely uniform, yet they are often 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 intial 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 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? To further broaden the study we have included standard rice varieties as well.

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 sugar beet 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 one and one-half to three feet of the soil surface is sampled. The complexity of the problem is increased greatly when nitrate in the second three feet is included. Sugar beets 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.

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 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 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 adequately forecast, 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 bulletin or technical manual on variable rate nitrogen application. We will target this manual to fertilizer companies, precision ag companies, and growers.

RESULTS AND CONCLUSIONS

Sugarbeets:

Imperial Valley site:

1. Previous yield maps and a new electrical conductivity survey were carried out and used to to develop a treatment plan for the Imperial Valley site.
2. 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 of the U.S. Salinity Lab, in Riverside. These twenty sites represent the range in salinity conditions found in the field.

3. Supplemental nitrogen fertilizer (at the rate of 100 lb N per acre, applied in addition tothe baseline rate of 150 lb N per acre) was applied to half of the twenty sites, which were divided to reflect approximate balance between each group of ten plots with respect to salinity conditions.
4. 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 were analyzed for salinity, clay content and nitrate.
5. 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 depth and are being analyzed for salinity and sodium content.
6. 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.
7. At harvest, a yield monitor was used to map sugarbeet yields and those yield maps will be combined with the previous year's maps for sugarbeet and wheat and soil electrical conductivity to evaluate the effects of soil variability, including residual and applied N on on crop performance.
8. Hand harvests were be taken at the twenty plot sites and analyzed for yield, quality, and root characteristics, root NO_3 content.
9. All data are being combined and analyzed.

El Nido site:

1. In the spring of 2000, an EM 38 survey was carried out on a 60 acre site in El Nido, California by Dennis Corwin of the U.S. Salinity Lab, in Riverside.
2. Following the survey, soil samples were collected at 16 sub sample locations chosen using the ESAP v2.01 software. Samples were analyzed for salinity, texture and nitrate.
3. Sugarbeets were planted at the El Nido site in May, 2001. They were harvested in mid-May 2002.
4. Stand counts were made at emergence in June 2001 and will be correlated with soil properties.
5. 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 are being compared to neighboring rows using hand harvests at each location. Background variation in soil residual N and the variable amounts surface applied will be used to assess crop fertilizer response.
6. A yield map of the field was made at harvest. Data are being analyzed.

Summary:

Neither fertilizer N nor gypsum affected sugarbeet root yields significantly at the IV and EN sites. Petiole NO_3-N levels were increased, and sugar contents decreased with increasing fertilizer N. or amendments were applied (gypsum and N in the IV, and N only in El Nido). Soil physical and chemical conditions limiting crop growth and yield could not be significantly modified to overcome salinity and drainage limitations at the IV site, nor soil structural and hardpan problems at the EN site. A complete report is in preparation.

Rice

Nitrogen trials were established in two commercial rice fields in the Sacramento Valley. One field was Akitakomashi and one M202. 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 carried out by the growers as a part of their regular operation. The layout of the experiments has been designed to take into account 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 are measured using a yield monitor at harvest and data is 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.

Two different field trails were carried out during the 2001-growing season and they were repeated during this current season.

Trial 1: Schohr Ranch, Gridley CA: 3 different pre-plant N rates were tested, 57, 100, and 167 lb/a N (Figure 1). Cultivar: M 202.

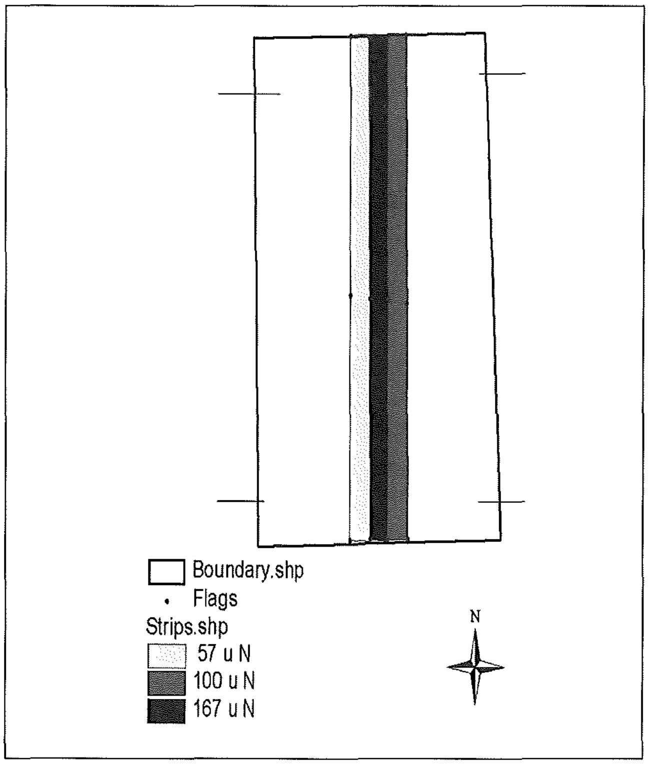

Figure 1. Schohr Ranch

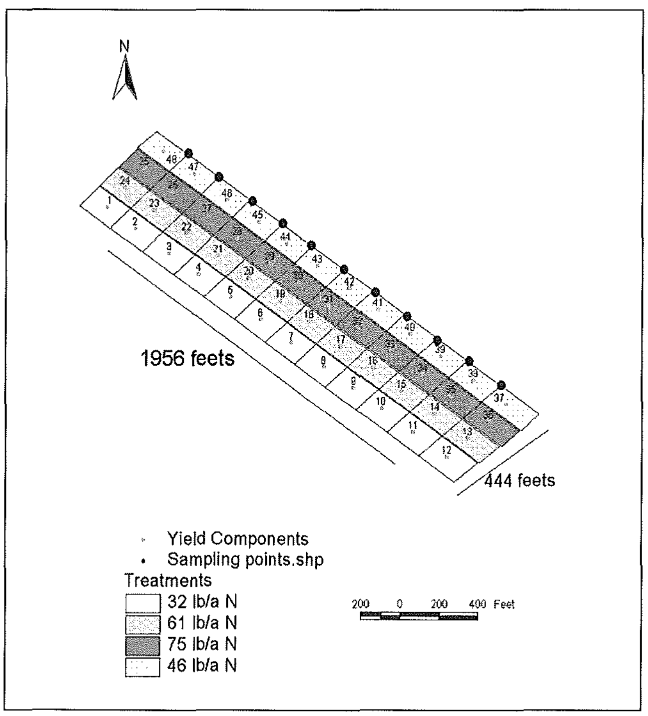

Figure 2. Gorril Ranch

Trial 2: Gorril Ranch, Richvale CA: A combination of 4 different pre-plant and 3 different top-dressing treatments was tested. Pre-plant: 32, 46, 61 and 75 lb/a N. Top-Dress: 0, 20 and 30 lb/a N.(Figure 2). Cultivar: Specialty rice Akita.

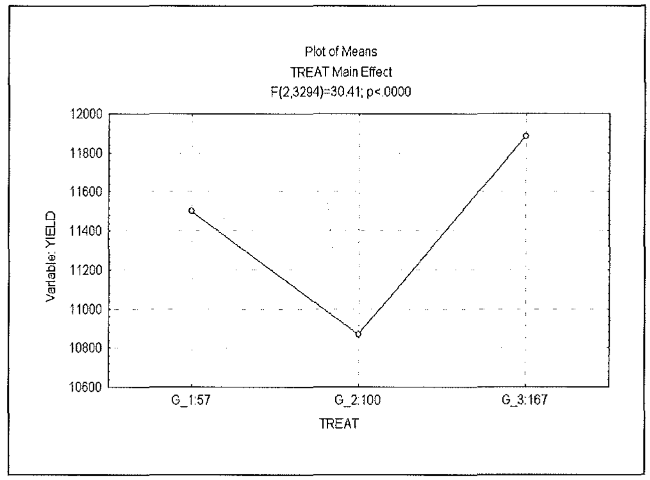

Figure 3. Schohr Ranch, Yield at the different pre-plant N levels.

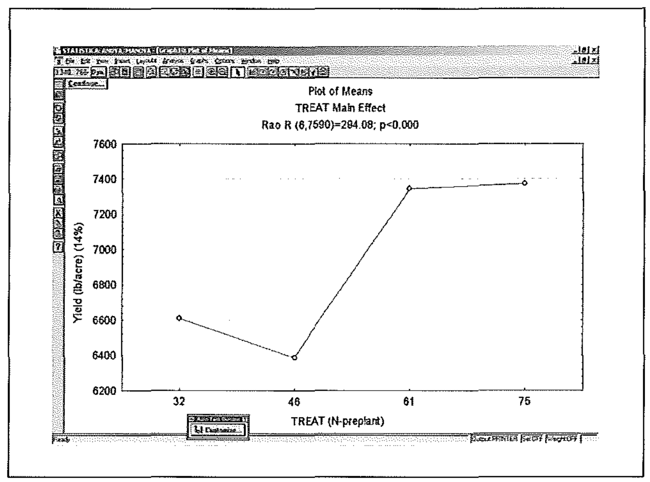

Figure 4. Gorril Ranch, Yield at the different pre-plant N levels.

Both fields were harvested with combines using yield monitors. Besides the yield and moisture data from the yield monitor, samples were taken at each sub-plot for yield components analysis using a DGPS. At early, mid and late growing season stages multi-spectral aerial images were taken. At the Schohr trial soil and tissues samples were taken at the same locations where the yield components samples were taken.

RESULTS

Trial 1: Significant yield differences were found at this site (Figure 3). The 57 lb N that was the lowest application rate presented an intermediate yield. The farmer pointed out that in this treatment the harvest operation was much quicker than in the other two due to the lower amount of plant material that entered the combine. In order to quantify this, 310 meter strips of each treatment were analyzed from the yield map. The combine registered a yield data each second.

Table 1 shows the combine velocity at each treatment.

N level	57	100	167
# of yield data points	347	379	433
Distance	310	310	310
Velocity (m/s)	310/347= 0.89	0.82	0.71

The higher velocity registered at the lowest N application can have potential economical advantages when it is extrapolated to the whole ranch area. For a closer look at this issue an economic analysis of the impact of the different pre-plant treatment will be carried out.

Trial 2: Significant yield differences were found in the pre-plant treatments (Figure 4). An interaction between pre-plant and top-dress treatments were found. While at the 32 and 46 lb N they were an increase of yield with the top-dress applications up to 30 lb N; at the 61 lb N treatment the maximum yield was achieved at the 20 lb N top-dress application.

These data suggest that this cultivar requires a total of approximately 80 lb N to achieve its yield potential.

Site-Specific Variable Rate Fertilizer Nitrogen Application in Cotton

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INTRODUCTION

The use of yield monitors, global positioning systems, remote sensing, and other attributes of site-specific crop management is increasing in California. California farmers who have adopted yield monitoring and mapping technology have frequently observed a high level of yield variability in their fields. In some cases growers have been able to interpret these yield maps based on their knowledge of the field and use this interpretation to improve their management and enhance profitability. However, the level of knowledge of this technology has not yet reached the state where growers can confidently adopt on a wide scale true site-specific management practices, that is, practices in which management is adjusted "on the go" to match the specific needs of each location in the field.

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. Scientific investigations of the profitability of variable rate nitrogen application in the Midwest have produced equivocal results, with some investigations indicating a profit and others not. Much of the work in the upper Midwest has been motivated by regulatory concerns associated with potential contamination of ground and surface waters. Variable rate nitrogen application offers the potential for increasing profitability and reducing environmental effects of crop production if the increased costs associated with the practice can be offset by reduced input costs and/or reduced regulatory pressure.

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. Supported by FREP and other agencies, we have been investigating site-specific management of California field and row crops since 1995. This represents one of the longest and most extensive site-specific management research programs in California. Initial research focused on determining whether California fields have high yield variability, since they do not have the topographic variability often associated in the Midwest with high levels of yield variability. Our research and that of others has indicated that 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.

Also supported by FREP as well as other agencies, several of us have been carrying out research to more precisely quantify the nitrogen dynamics of modern California cotton varieties. Results of this research indicate that in some cases current nitrogen fertilization practices in California may not maximize fertilizer use efficiency. The application of nitrogen fertilizer at a site-specific rate may provide the opportunity for the grower to increase profits and maintain economic viability. At the same time, it provides the opportunity to demonstrate to the public and to regulatory agencies that the agricultural industry can use voluntary methods to reduce potential environmental contamination resulting from inputs to crop production systems.

The experiments carried out in this research project focus on using high spatial precision bulk data (yield maps, remotely sensed images, and soil EC_a values obtained from EM38 or Veris instruments) together with soil nitrate levels in the top two feet, obtained from soil cores taken through a directed sampling plan, to determine variable application rate in the first N application at layby. The experiments are carried out in commercial fields and the other aspects of crop management are the same as that of the rest of the field. In particular, any additional N applications based on petiole sampling and/or other information will be made at a uniform rate in the same manner as the rest of the field. Each experiment is carried out as a randomized complete block design with three levels: variable N rate, low fixed N rate control, and nominal fixed N rate. The low fixed N rate are calculated to maintain a total soil N level of 50 lbs./acre. This rate providsd an adequate control without forcing the cooperating grower to sustain an unacceptable economic loss. The nominal fixed rate treatment will be at the rate used by the grower in his own production The variable rate treatment is applied at a rate determined by an application rate map constructed according to soil productivity and estimated residual available N. Where salinity is high this dominates bulk EC measurements. In California fields where salinity is not a factor EC_a generally is a reflection of soil clay content (Rhoades and Corwin, 1990). In any case variations in EC_a often can be interpreted as indicating variations in soil properties within a field. We used data from bulk EC and yield maps from the previous year or years to develop a directed soil sampling plan.

OBJECTIVES

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

1. Develop a practical method for creating variable rate fertilizer nitrogen application maps based on existing yield maps, remotely sensed NDVI images, and /or soil bulk electrical conductivity maps and soil nitrate N levels obtained through directed pre-season sampling.
2. Conduct replicated experiments in large (typically quarter section) commercial fields in which the treatments are variable rate fertilizer application, fixed rate fertilizer application, and control.
3. Conduct a partial budget economic analysis based on established methods to determine the economic viability of variable rate fertilizer application for California cotton production. Determine the breakeven acreage at which this method is profitable and the payoff period for purchase of equipment as well as the breakeven custom rate.

RESULTS

We selected three fields on which to carry out the experiment. One is located at Sheely Farms in Lemoore, one is at M&M Farms near Hanford, and one is at Woolf Brothers Farm in Lemoore. Fields were selected after testing soil at eight fields. Selection was based on availability of previous years' yield maps and on existence of a high level of variability in the field. In each of the fields we tested we took a total of 9 soil samples (three each in areas of high, medium, and low yield), and developed nitrogen application maps based on yield, soil nitrate N, and soil EC variability. We then selected the four fields having the most intrinsic variability in N rate. Soil testing was completed as specified. In each case we collected soil samples to measure nitrate N, as well as soil EC, collected with an EM38 inductance meter. Randomized complete block experiments were laid out as specified in each of the four experimental fields.

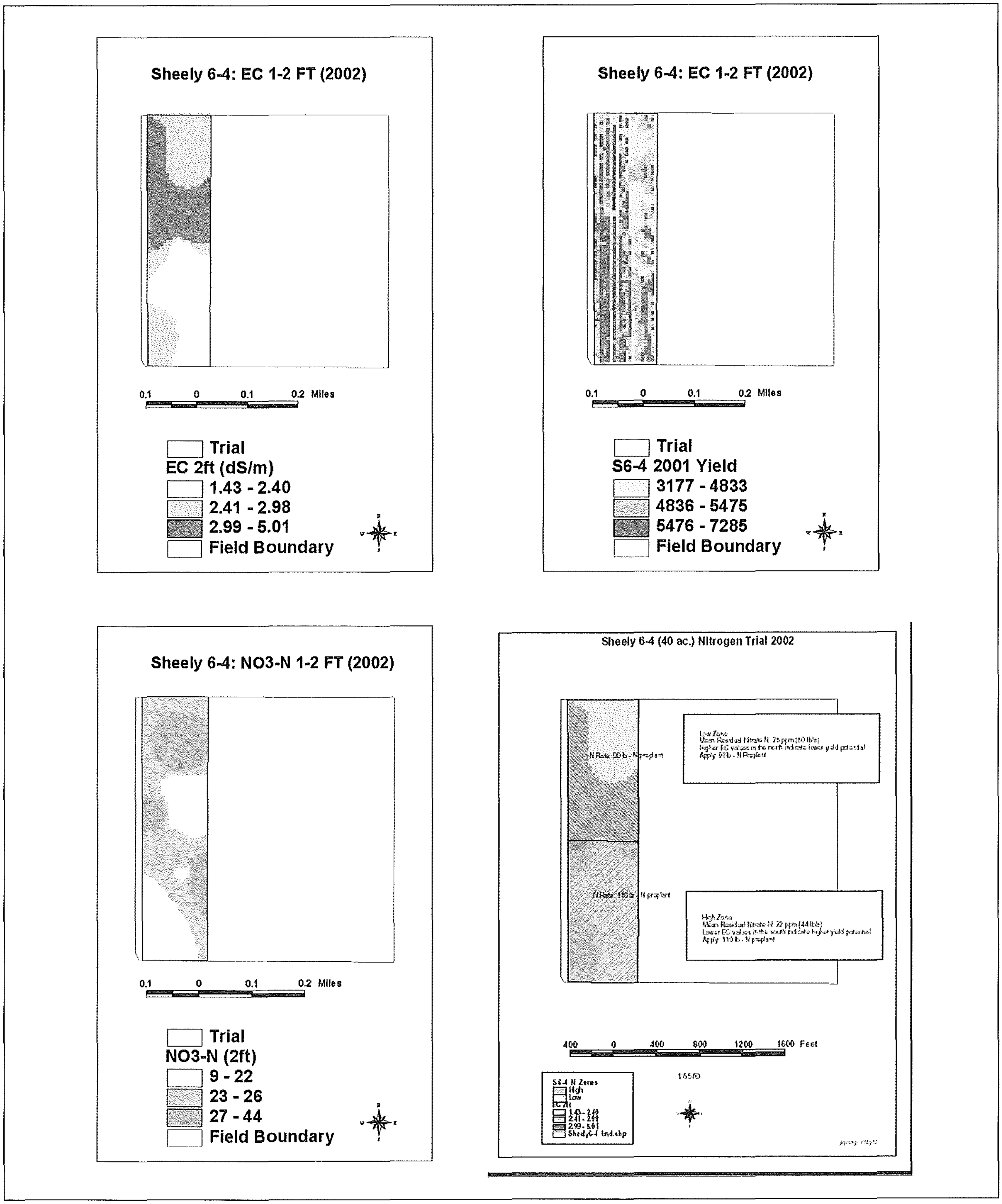

Figure 1 shows the soil bulk EC map, the previous year's yield map, and the resulting fertilizer rate map for one of the fields, the one located on Sheely Farms. Data are being collected during the course of the season including plant maps and petiole N levels. The final data set will be the yield maps for each trial. These data will be analyzed at the end of the season.

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

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INTRODUCTION

The rising appreciation for the strong controls on yield exercised by short-range spatial variability of natural resources in agricultural fields led to the developing field of site-specific farming or precision agriculture. The variable application of fertilizer, seed varieties, pesticides and other management practices has shown great potential for creating more efficient and sustainable agroecosystems. This shift in focus of agriculture from uniform site management to site-specific management has led to a similar shift in data needs for farmers and researchers. Although accuracy and reproducibility are still essential, more attention has been paid to fast, inexpensive, if possible on-the-go analyses of soil and crop parameters. Some of the most popular methods of analysis have been data sources that can be used to predict a variety of soil/crop parameters simultaneously, such as remote-sensing imagery and electromagnetic measurements. Infrared (IR) spectrometry in the near- and mid-infrared range shows considerable promise for making fast, inexpensive and accurate predictions within a precision agriculture context. Within agriculture, IR spectrometry is already routinely used in predicting protein content, moisture levels and fat content of food products and forage crops. More recently, there has been interest in using IR spectrometry for predicting soil properties, especially C and N content and moisture.

The mid-infrared (MIR) spectrum has been often used for qualitative analyses of organic substances. Due to relatively simple sample preparation procedures, diffuse reflectance Fourier transformed (DRIFT-MIR) approaches have been especially popular. There are a number of studies on DRIFT-MIR spectrometry for characterizing organic matter decomposition. To our knowledge, there are no reported studies linking DRIFT-MIR spectrometry of soils to crop properties in the subsequent growing season.

OBJECTIVES

1. To compare the performance of NIR and DRIFT-MIR spectrometry of soils for predicting soil and crop properties in rice systems,
2. Assess possibilities for NIR and/or DRIFT-MIR spectrometry under specific precision agriculture conditions.

DESCRIPTION

Two transects of 400 m each in a rice field, located in the Butte County, were left unfertilized, and 100 sample locations were established. Soil samples were taken in spring, and crop and weed samples at harvest. IR spectra were linked to total soil C and N, mineralizable N, P Olsen, effective cation exchange capacity (eCEC) and exchangeable cations (Ca, Mg, Na and K), as well as yield, N uptake, biomass and weed biomass using partial least squares regression (PLSr). The PLSr models were calibrated using 50 random observations, and validated using the remaining 50 observations.

RESULTS AND CONCLUSIONS

For soil, predictions for eCEC, Ca and Mg were the most accurate, with r^2 values of 0.83, 0.80 and 0.90 for NIR and 0.56, 0.60 and 0.61 for DRIFT-MIR. Correlations for P Olsen were 0.71 and 0.55, and for mineralizable N 0.46 and 0.21, respectively. No significant correlations were found for total soil C or N. For crop parameters, only weed pressure (r^2 of 0.55 and 0.44) and straw biomass (0.30 and 0.34) yielded significant correlations. The correlation with weed pressure was an indirect effect due to better competition by weeds compared to rice under low soil fertility levels. For most parameters, standard errors of prediction were lower than reported in the literature. This indicates that the small range of variability within a field might be the limiting factor in predicting these parameters. It also illustrates the limited use of correlation coefficients in PLSr model validations. We concluded that NIR spectrometry shows promise for site-specific Management practices, although its predictive power for parameters may vary from site to site. Moreover, predictive models remain unique for specific agroecosystems, and therefore have to be calibrated for every area. The fast and accurate predictions for Ca and Mg concentrations in the soil could be especially important in diagnosing and combating grass tetany, which strongly depends upon Ca and Mg concentrations in the soil.

Implications for use in site-specific management

It is clear from this study that NIR performs better in terms of predictive power than DRIFT-MIR. The r^2 values of 0.83, 0.82 and 0.71 for eCEC, Mg and P are much higher than the corresponding numbers of 0.56, 0.61 and 0.55 for DRIFT-MIR. In terms of prediction error, this corresponds to an improvement of approximately 30 % for NIR. Combined with the more complicated sample preparation and the more expensive equipment for DRIFT-MIR, and the possibilities for installing NIR sensors on farm equipment (Ehsani et al., 1999), NIR spectrometry is preferred.

As noted above, the low prediction accuracy for most crop parameters and soil total C and N might be due to the relatively small variation in these parameters within our study area. Since our prediction error for total soil N and N uptake was similar or lower than those reported, differences in these parameters in our fields may simply be below the detection limits for IR spectrometry. This could have important consequences for its use in site-specific management (SSM).

However, the significant results for Ca, Mg, eCEC and P Olsen certainly warrant the use of IR spectrometry in SSM. In this respect, it is important to stress that predictive models

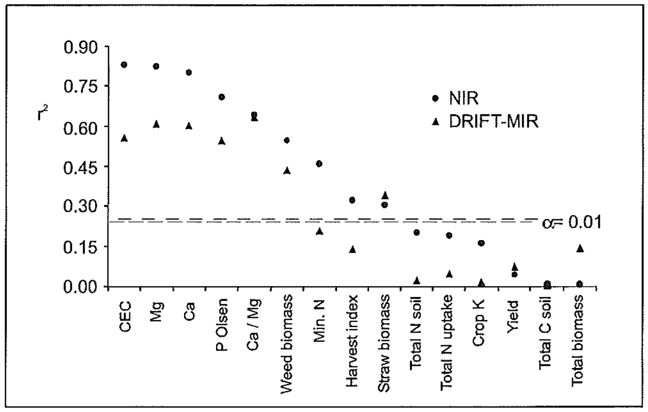

Fig. 1. Regression coefficients for the DRIFT-MIR spectrum in the PLS models, for soil parameters with a significant correlation with the spectra.

built with PLSr are unique to the area on which they were calibrated. Texture, mineralogical composition, organic matter content and other variables all strongly influence the reflectance spectra, and will therefore have an effect on the optimal model parameters. For example, Ben-Dor and Banin (1995) reported 2333, 2097 and 1431 nm as the most important wavelengths for predicting CEC. In our case, the most important wavelengths are around 900, 2420 and 2290 nm. For effective use in precision agriculture, PLSr models need to be calibrated for the area over which they will be used. However, it is expected that, once calibrated, these models can be used for predictions over different growing seasons.

CONCLUSIONS

Both NIR and DRIFT-MIR spectrometry, combined with PLSr modeling, could simultaneously predict a range of soil and crop properties under conditions typical for precision agriculture (i.e. relatively minor variations within a field). Compared to other studies, we had low correlation coefficients but very good SEP's. This indicates that variation within a field might be too small to be detected precisely by IR spectrometry for some properties. It also illustrates that correlation coefficients are of very limited value in describing the accuracy of such predictive models. In our study area, NIR performed better, with r2 values higher than 0.90 for eCEC and basic cations higher than 0.80. NIR spectrometry, especially implemented as a sensor in farm equipment for on-the-go analysis, offers considerable perspective in precision agriculture for instantaneous, simultaneous and inexpensive prediction of a variety of soil and crop parameters. PLSr models need to be built using a calibration set specific to the research area in order to yield reliable predictions.

Field Deployment and Evaluation of Conventional and Precision Application Systems for Liquid and Anhydrous Fertilizer in Sacramento Valley Cropping Systems

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INTRODUCTION

Whether a uniform rate or variable rate of fertilizer is being applied to a field, accuracy of the application is critical to optimizing crop response and profit. The basic premise of "precision agriculture" is that prescriptions of how much fertilizer to apply to specific areas of the field will be based on historical data of previous years' application rates and crop response. This analysis assumes that the fertilizer rate (either constant or variable) at specific locations in the field is accurately known. Often, this is not true. Especially when handling materials such as anhydrous ammonia, the growers only know average application rates since they may only be able to measure or record tank refills per field or some other relatively crude quantity. If the actual, correct rates of applied fertilizer are not known, then future calculations of crop response to application rates will not be correct and the foundation of a precision agriculture program will be weak.

Even if a grower is not practicing the complete cycle of precision agriculture by altering fertilizer rates in response to measured crop and soil properties, accuracy and uniformity in fertilizer application is important for environmental and economic considerations. Especially, if a grower is observing variations in yield, it is important that any unrealized variations in fertilizer application rate not be confused with soil or crop variability.

This project is implementing application monitoring and improved metering systems in the field. New technology and typical commercial application equipment are being used to make large-scale applications in cooperating growers' fields. A system is being developed to create "as-applied" maps with greater accuracy, resolution and more machine-performance information than that from existing commercial equipment. This "stand-alone" application monitor will be developed for recording vehicle location, ground speed and application rate. These mapping systems will be used to compare the grower's intended application rates to the actual rate across the field. Additionally, the benefit of the improved technology will be determined. The maps will also provide insight into vehicle and worker productivity.

Data from the monitoring system will be used to document accuracy and precision of fertilizer rates and more importantly, determine the cause of any inaccuracies or errors. For example, speed variations, poor calibration of systems and accidental flow variation will be detected and recorded by the system. Various designs and manufacturers of rate control equipment will also be examined for performance against desired rates.

OBJECTIVES

1. Develop a stand-alone monitoring system that can be fitted to any application to record vehicle location, speed, fertilizer flow rate, liquid pressure and, in the case of anhydrous ammonia, ammonia temperature and pressure at critical locations in the system.

2. the monitor on the cooperating applicators' and growers' fertilizer application systems and record the characteristics of typical application jobs using both conventional and improved rate control methods.
3. From the collected data records, develop maps and summary statistics showing the accuracy and uniformity of the fertilizer application and the conditions of the machine across the field.
4. Use the results and maps to compare application techniques and guide recommendations for improving accuracy of fertilizer application and comparing rate controller system design and manufacture.

PROJECT DESCRIPTION

This project is designing a "black box" for fertilizer application that will log all the important data during application. From the data, we will be able to map the accuracy of fertilizer rates whether the grower is using any electronic equipment or not. While there are commercial systems that create "as applied" maps, they are limited to data from existing rate controllers that have delays and limitations on the data they provide.

Information from the "black box" will be used to compare application equipment, determine sources of errors and how to best improve application of fertilizer.

RESULTS AND CONCLUSIONS

Some feasibility work has been completed on the concept of quality control and mapping of agrochemical applications. In this case, a simple data collection system and laptop computer were used to make limited tests to develop the concept. While the system is too complex for grower use it does provide information that we are using to develop the more simple and rugged model.

Example results of a test run are shown in Figure 1, which is a south to north transect of an application pass across a north-south oriented field. A conventional automatic rate controller was used and set to maintain a constant application rate of liquid. The controller, a standard model commonly sold in California, is designed to increase liquid supply pressure in accordance with speed changes. In this test run, the operator started at 3.5 mph, then at approximately 1/3 of the way into the field, increased the speed to 13 mph and then 2/3 of the way into the field decreased the speed to 6.5 mph. During this run, the ground speed (from a GPS system) and the liquid pressure were monitored and recorded.

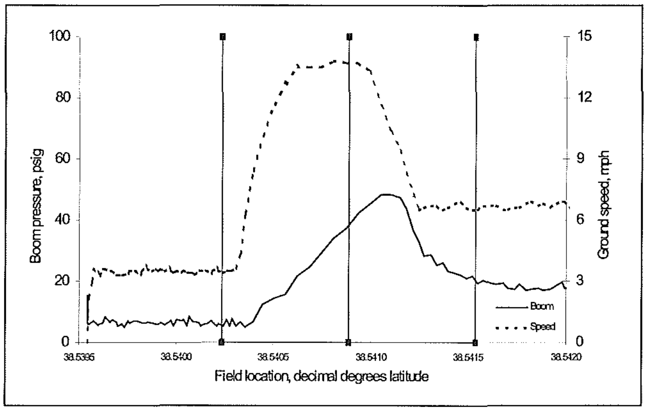

Figure 1. Transect representation of a desired constant rate liquid application with a conventional electronic rate controller where varying ground speed resulted in varying pressure with poor response to ground speed changes.

Delays in the controller response were obvious. During the entire time that the speed was at the 13 mph level, the pressure was increasing as the controller attempted to adjust the liquid flow rate to maintain the desired application rate. This delay in response and insufficient pressure represents a significant underapplication. Likewise, the system was slow in responding to the decrease in speed and produced a significant overapplication of product. If a grower was conducting yield monitoring and noted variation in yield in this field after this application, the grower might incorrectly attribute the variability to some other parameter such as soil conditions or pest damage. This map is revealing in that areas of underapplication, overapplication and nonuniformity are present even though the grower might incorrectly assume that the use of a rate controller would guarantee uniform, constant applications rates.

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

In 1998, the Santa Ana Regional Water Quality Control Board (RWQCB) passed a Resolution amending the Santa Ana River Basin Plan to include a Nutrient Total Maximum Daily Load (TMDL) for the Newport Bay/San Diego Watershed. The goal of the TMDL is to reduce the nutrient loading capacity to a level at or below the assimilative capacity of the waterbody, returning the impaired waters to a condition where beneficial uses are no longer impacted by nutrients. Development of a TMDL requires the identification of all point and nonpoint sources of pollution. Each identified source receives a pollutant load allocation based on available data at the time of TMDL development.

Due to litigation, nutrient source identification and the estimation of nutrient loading from identified sources proceeded rapidly with little or no baseline data. As a result the nutrient content of agricultural surface runoff was predicted with mathematical models using estimated input values. In order to address this problem, the RWQCB 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 data 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.

OBJECTIVES

1. 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 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 water quality-monitoring program, established in Spring 2000, involved the selection of agricultural sites based on the following factors: accessibility of the site; the ability to install

Table 1

Site	Plot	Crop(s)[1]	Flow[2]	Sampling	BMP Implementation
A	R-1	S	March 2000-present	Weekly if present	Sediment Controls (Sandbags/Polyacrylamides)
	R-2	S	March 2000-present	Weekly if present	None
B	R-3	S	March 2000-present	Weekly if present	Sediment Controls (Sandbags/Polyacrylamides) Soil Moisture Monitoring
	R-4	S	April 2000-present	Weekly if present	None
C[3]	R-5	C, B, S	Feb 2000-present	Weekly if present	Sediment Controls (Sandbags/Polyacrylamides)
	R-6	C, B, S	Feb 2000-present	Weekly if present	None
D[4]	R-7	S	October 2000-present	Weekly if present	Sediment Controls (Sandbags/Polyacrylamides)
	R-8	S	October 2000-present	Weekly if present	None
E	N-1 (upstream)	CN	June 2000-present	Weekly if present	None
	N-2 (downstream)	CN	July 2000-present	Weekly if present	Polyacrylamides, Settling trap and pond, 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.

water monitoring equipment without drastic changes in a grower's existing drainage design; and the willingness of the grower to implement BMPs upon completion of baseline data collection. Each site chosen consisted of two plots for monitoring baseline flow and nutrient data (Table 1). The plots ranged in size from 2 to 32 acres. The grower's existing management practices were implemented on both plots during baseline monitoring. Upon completion of the baseline monitoring, one of the plots received an additional BMP that targeted an area of management that required attention.

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 was measured continuously with an area-velocity flow meter thus allowing for the estimation of nitrogen and phosphorus loads. Under conditions when monitoring equipment could not be utilized, such as during field preparation, monitoring was replaced with grab samples in the presence of surface runoff. Water quality parameters consisted of pH, electrical conductivity (EC), $(NO_2 + NO_3)$-N, NH_4-N, TKN, PO_4-P, and total-P. All nutrient analyses were conducted by a local water district's EPA approved water testing laboratory, while EC and pH measurements were completed in the field.

Initially scheduled for completion at the end of 2000, the baseline monitoring was continued through June 2001 in order to capture an entire strawberry production period (October 2000 to June 2001). The implementation of row crop BMPs on treated plots began in 2001 following an evaluation of the baseline flow and nutrient data. Best Management Practices were implemented at the nursery following a short calibration period from March 2000 to July 2000. Existing nutrient baseline data collected by the nursery allowed for earlier implementation of BMPs at the nursery site.

Prior to the completion of the baseline-monitoring program in 2001, the educational component of the project was initiated to begin informing the local growers on the impact of upcoming water quality regulations. Outreach consisted of a series of forums and workshops. Forums consisted of informal short meetings between agriculture operators, nursery growers, UCCE project staff, and representatives from the RWQCB to address a specific water-related issue. The meetings were designed to provide updates on this project as well as a method of updating growers on developing TMDLs or other water quality issues.

Workshops focused on management strategies for both agriculture and nursery operators in reducing nutrient loads in surface runoff. The meetings provided growers with information and demonstrations of new technologies to assist them in sound nutrient management decisions.

RESULTS AND CONCLUSION

Baseline Flow and Nutrient Loading

Agricultural nutrient load allocations are split into a summer (April-September) and winter (October-March) period in order to reflect differences in wet and dry season flow. The majority of flow and nutrient loading from strawberry fields, the

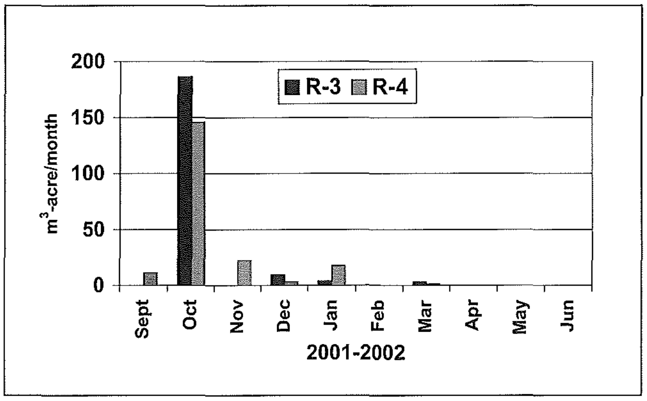

Figure 1. Total surface runoff - Site B.

dominant row crop in the watershed, occurs during the winter season as shown in Figure 1. Surface runoff from row crops during the winter season can be attributed to precipitation and the use of overhead sprinkler irrigation under three specific conditions: the establishment of strawberry transplants in late September early October, prevention of plant desiccation during dry Santa Ana Winds, and to minimize frost damage. Irrigation during the remaining period is solely drip irrigation and if managed correctly, results in no surface runoff. The occasional presence of surface runoff during the summer period is a result of leaking irrigation systems, flushing of sand filters, or rain events occurring in April and May.

During the (2000-2001) winter season, a season of normal rainfall, the average discharge of total nitrogen from row crops was sixteen pounds per acre. In contrast, limited rainfall during the (2001-2002) winter season resulted in an average of five pounds per acre of total nitrogen discharged. The winter season load allocation for agriculture was established in 1999 at 38,283 pounds or three and half pounds of total nitrogen per acre by 2012. Agricultural acreage in 1999 was estimated at 11,000 acres, but has decreased to just over 4,000 in 2000. The 2012 winter allocation will likely be reached by further expected reductions in agricultural

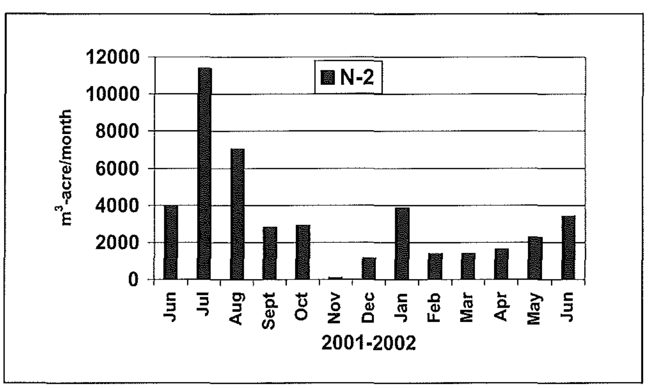

Figure 2. Nursery surface runoff - Site E.

acreage. Monitoring shows that the 2002 loading allocation for the summer season has been met and if the current acreage remains constant at 4,000 the 2007 load allocation will only be exceeded by 500 pounds.

Surface runoff from the nursery site was present during both the summer and winter seasons (Figure 2). A slightly higher water usage during the summer period resulted in increased surface runoff and nutrient loading. The nursery employs a computer-controlled system to apply short (less than 15 minute) pulses of irrigation in order to reduce the presence of surface runoff and excessive leaching from the containers.

Implementation of BMPs

Row Crops

The monitoring program coupled with observational data taken by field staff revealed that growers needed to improve management practices related to erosion and sediment control. Sediment control is important in minimizing soil loss as well as reducing the movement of chemical compounds bound to the sediment, such as phosphorus and some pesticides. Polyacrylamides (PAM) were utilized on the treated plots to reduce the amount of sediment moving off-site. A granular formulation was tested on treated plots to determine the degree that sediment movement could be reduced in tail furrows. Further testing is needed to determine the frequency of application required to maintain a reasonable rate of sediment flocculation. Two row crop growers have adopted the use of polyacrylamides as one of their management practices as a result of this demonstration project.

Additional research is being proposed to look at reducing the application frequency and rate of overhead irrigation during the establishment of strawberry transplants. Targeting this phase of production should result in a significant reduction in surface runoff and sediment.

Container Nursery

Surface runoff from the nursery (Site E) was treated with a series of mitigation practices in an effort to improve its quality prior to leaving the site. The installation of a vegetative filter in a concrete-lined channel was installed to act both as a biological active filtration system as well as a source for the production of plant material. The vegetative filter consists of baskets of Canna lilies sunk directly into the channel. The channel is divided into smaller basins allowing for the harvesting of one basin every eight weeks with the goal of maintaining the vegetative filter with a significant portion of mature plants at all times. The vegetative filter covers 186 m^2 of the concrete channel.

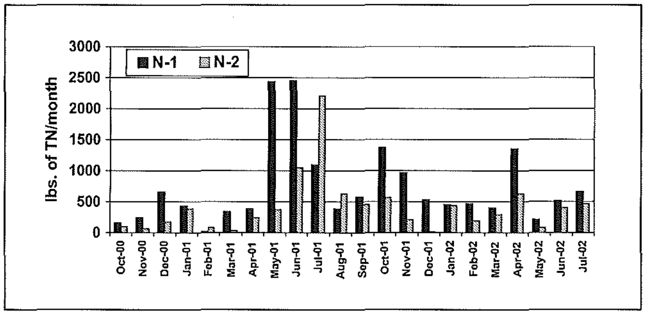

Figure 3. Average total nitrogen per month - Site E.

During both the summer season and the winter season, the vegetative filter strip is effective in reducing the average lbs. TN/month leaving the nursery (Figure 3). 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. The result is lower nitrogen loading at N-2. During the winter season, rainfall and cooler temperatures reduces the effectiveness of the vegetative filter due to reduced root and shoot growth of the Canna lilies. Occasionally, a higher load of total nitrogen was detected at N-2 compared to N-1 as a result of inputs below the N-1 monitoring station. Inputs ranged from rainfall events, drainage from roads, and excessive irrigation of plant material adjacent to the filter.

A settling pond and trap installed upstream of the vegetative filter act as reservoirs for sediment. Surface runoff is treated upstream of the reservoirs with a 10 ppm solution of polyacrylamide to flocculate the sediment and remove it prior to the vegetative filter where its removal is more difficult. Polyacrylamide application was not initiated until January 2002.

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

The final workshop was held on November 28th at Edison International Field in Anaheim. The workshop focused on a combination of nutrient and irrigation practices that will assist growers in reducing nutrients in runoff or reduce the volume of runoff generated on their site. Seminars included such topics as the contribution from nutrients from composting, using reclaimed water in agriculture and horticulture, the utilization of soil wetting agents, maximizing water use efficiencies, current water quality issues in Ventura and Santa Barbara counties, and BMPs to reduce nutrients and pesticides in run off water.

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.

A forum meeting was held on March 4th exclusively for nursery growers in the Newport Bay/San Diego Creek Watershed. A total of eight nursery growers attended the meeting to hear from a representative from RWQCB and Cooperative Extension staff on current water quality issues affecting nurseries. The growers were also shown a video demonstrating the use of polyacrylamides to reduce sediment and erosion. Each attendee received a pocket pH/EC for testing source irrigation water and surface runoff. The meter provides a quick method for measuring two water quality parameters that can be utilized as indicators for further testing. For example, salinity levels that are above normal may indicate that the runoff contains high levels of nutrients.

Field staff has continued visiting farming operations in the watershed to assess grower practices and look for areas where the University of California can provide assistance in reducing or eliminating surface runoff. Thirty-eight site evaluations have been completed to date. Under a continuing project, the completed assessments will be entered into a database in order to track changes that are made by growers over the next year. The main goals of the assessments are to identify areas were UCCE could offer technical assistance to improve runoff quality or reduce its quantity, promote communication between growers and the project staff, and document the adoption of additional BMPs.

A quarterly newsletter was also initiated in June 2002 to provide the latest water quality information such as updates on nursery waste discharge permits or the status of TMDL development in the watershed.

V. Conclusions

The agricultural baseline-monitoring program and the accompanying outreach program successfully provided growers in the Newport Bay/San Diego Creek Watershed with vital information on the nutrient loads found in surface runoff during the production of row crops and container nursery plants. At the same time, the program created grower awareness on the impact of their management decisions on water quality. Although the program initially targeted reductions in nutrient loading to receiving waters, the mitigation practices implemented should also assist in the reduction of off-site movement of sediment and sediment-bound toxics. Post BMP monitoring will continue for an additional one-year period in order to provide further evidence of BMP effectiveness.

Crop Nitrate Availability and Nitrate Leaching under Micro-Irrigation for Different Fertigation Strategies

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Project Objectives

1. To determine fertigation strategies for microirrigation systems using state-of-the-art modeling tools to improve water and nutrient use efficiencies and to reduce leaching of nitrates and other nutrients and chemicals;
2. To develop jointly a publication and slide show for our target audience, highlighting the recommendations using color graphics of two-dimensional simulation results to illustrate the effect of proposed fertigation strategies on the movement of nitrate for various microirrigation systems.

Project Description

Various fertigation strategies for microirrigation systems to improve water and nutrient use efficiencies and to reduce leaching of nitrates will be modeled to determine patterns of nitrate about drip lines. The modeling of these fertigation scenarios will be conducted using the computer simulation model, HYDRUS-2D. The model will be used to determine nitrate and water patterns, crop nitrate availability and to quantify nitrate leaching under microirrigation. Hypothetical scenarios will be developed and modeled to highlight the effects of improper water and fertigation management on water and nutrient availability, and deep percolation losses of water and nitrates. Moreover, model results will be used to develop guidelines for proper fertigation management practices.

After the modeling and evaluation of results are completed, a UC publication will be prepared to illustrate the project results, such that the effects of fertigation management on nitrate availability and leaching can be easily understood, and their adaptation becomes intuitively attractive. This is especially important, since the underlying flow and transport processes are extremely complicated and difficult to explain. This publication will include a description of the pertinent soil and crop properties and processes and their interactions, and contain colorful illustrations of the pertinent two-dimensional patterns of water and nitrate, and guidelines on fertigation timing and duration for growers.

Results and Conclusions

Various strategies and the boundary conditions needed by the model for those strategies have been developed. The computer modeling is underway.

Nitrogen Mineralization Rate of Biosolids and Biosolids Compost

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INTRODUCTION

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 was conducted 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.

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 are predictive of field mineralization rates.

METHODS

A total of 104 microplots (approximately 2.5 ft^2 volume) 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 (Table 1). Air-dried and dewatered biosolids (samples A through D) 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, composts (samples E and F) were applied at a rate equivalent to 16 dry tons per acre. There were 4 microplots for each soil/biosolids combination. Immediately following application the samples were manually incorporated into the soil to simulate disking in the field.

In June 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. A leaching port was installed in each microplot, and all leachate was collected for analysis of mineral N concentration (NH_3-N and NO_3-N).

On August 24 the above-ground sudan grass biomass was harvested, oven-dried, and analyzed for total N concentration. The sudan grass was allowed to regrow until October 25, when it was harvested again and biomass N content determined. At the final harvest the soil profile of each microplot was sampled and analyzed for mineral N concentration.

The remaining microplots were allowed to remain fallow until November, 2000, when they were planted with wheat. (Only biosolids samples A, C and E were evaluated in wheat

Table 1. Initial biosolids characteristics.

Biosolids sample	Type	% N (dry wt basis)	Initial % dry weight[z]
		2000	
A	Air-dried	5.7	78
B	Air-dried	4.6	71
C	Dewatered	3.9	20
D	Dewatered	4.8	21
E	Composted	2.2	63
F	Composted	0.9	48
		2001	
G	Air-dried	6.2	94
H	Dewatered	4.6	19
I	Composted	2.3	74

[z]calculated as (dry wt / wet wt)*100

Table 2. Apparent N availability from biosolids samples in the 2000 and 2001 sudan grass and wheat bioassays.

Soil	Biosolids sample 2000	Biosolids sample 2001	Type of material	Apparent biosolids N availability (% of initial N) Sudan 2000	Wheat 2000-2001	Sudan 2001
Sandy loam	A	G	air-dried	21	24	24
	B		air-dried	20		
	C		dewatered	29	22	
	D	H	dewatered	30		22
	E	I	composted	13	12	9
	F		composted	3		
Clay loam	A	G	air-dried		16	22
	B		air-dried	19		
	C		dewatered		22	
	D	H	dewatered	30		39
	E	I	composted		10	5
	F		composted	2		

microplots). A rain exclusion shelter was constructed over these microplots to allow for control of soil moisture status; irrigation was applied as required to keep the wheat actively growing, with any leachate collected. Total above-ground wheat biomass was harvested on May 22, 2001, and total N content determined. The soil profile was then sampled and assayed for mineral N concentration; leachate from the microplots was also analyzed.

Apparent biosolids N availability was calculated for the sudan and wheat assays as:

[(crop biomass N)+(mineral N in leachate)+(mineral N in soil profile at end of season)]

minus those quantities from unamended (control) microplots. This amount of N was expressed as a percentage of total N (organic and mineral forms) initially present in the biosolids materials.

Additional biosolids materials were evaluated in 2001 (Table 1). In June, selected sudan microplots received biosolids applications at rates of 8 dry tons (dewatered and air-dried material) or 16 dry tons (compost) per acre. One material of each biosolids type was used. The samples were manually incorporated immediately after application. Sudan was again planted, and managed as previously described. Biomass harvests taken on September 7 and November 8 were weighed, dried, and analyzed for total N concentration. At the final harvest soil samples and seasonal leachate were collected for mineral N analysis. Apparent N availability was calculated as previously described, but now there were two sets of controls: 1) microplots with no amendment in either year, and 2) microplots that received amendment in 2000 but not in 2001. This allowed estimation of N availability of the 2001 biosolids materials, as well as estimation of the residual contribution from the biosolids materials applied in 2000.

A parallel laboratory study was conducted in which the rate of net N mineralization of organic N in biosolids was estimated from aerobic incubation of biosolids-amended soil under constant temperature and moisture. The sandy loam soil used in the microplot studies was moisture equilibrated in a pressure apparatus at 25 centibars tension (approximately field capacity). Dried, ground biosolids were thoroughly blended with this moist soil at 0.4% by dry weight. After sampling for initial mineral N concentration, these soil/biosolids blends were placed in sealed glass jars and incubated at 25oC (77oF); there were 4 replicate jars per soil per biosolids blend, and 4 jars of unamended soil. At 4, 8, 12, and 16 weeks the soil blends were sampled for mineral N concentration. Any increase in mineral N above that in unamended soil represented net N mineralization of organic N from the biosolids.

RESULTS

In 2000 the three types of biosolids materials (air-dried, dewatered, and composted) behaved quite differently in the sudan assay (Table 2). 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 two samples of dewatered biosolids 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 a compost (2.2%), indicative of 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.

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.

Similar results were seen in the over-winter wheat assay. Sample A (air-dried material) averaged 20% apparent N availability over the two soil types, and sample E (composted material) averaged 11%. Sample C appeared somewhat less active in the wheat assay than in the sudan assay, averaging only 22% apparent N availability. This may have been due to the prolonged period between application of the material to the microplots and planting of the wheat, during which the material dried out completely in the soil under high temperature, summer conditions. Once dry, it behaved similarly to the air-dried sample A. Again, soil type appeared to have negligible influence on biosolids N availability.

The Sudan results in 2001 followed the same pattern. Air-dried and dewatered samples showed apparent N availability between 22% and 39% of initial N content. Sample H, a 2.3% N compost, had 5-9 percent N availability. Estimates of the residual N contribution of the non-composted biosolids materials applied the previous year (2000) ranged from a high of 12% (sample A) to 6% (sample D). Of the composts, sample E showed 6% of initial N availability in the 2001 growing season, contrasted with sample F, which caused apparent N immobilization. Averaged over the two growing seasons sample F (mostly urban green waste) was essentially N neutral, providing no agronomic benefit.

In the laboratory incubation of the 2000 biosolids samples the air-dried and dewatered materials mineralized approximately 20-30% of initial organic N in 16 weeks (Fig. 1). As was the case with the wheat field assay, there was no clear difference between the two types of materials, probably because all samples were dried and ground before use, negating the 'freshness' aspect of the dewatered material that was clearly evident in the sudan field assay. Sample F (the low N compost) was again nearly N neutral, while sample E (the higher N compost) showed substantial N mineralization, although at a rate slower than the air-dried and dewatered samples. In general, mineralization was rapid for the first 8 weeks of incubation, then slowed considerably. From 8 to 16 weeks, the average N mineralization rate across all samples was 1-2% per month, roughly the rate of mineralization of soil organic N in the unamended soil. These results were consistent with the relatively small residual N contribution of the biosolids applied in 2000 to the Sudan crop in 2001.

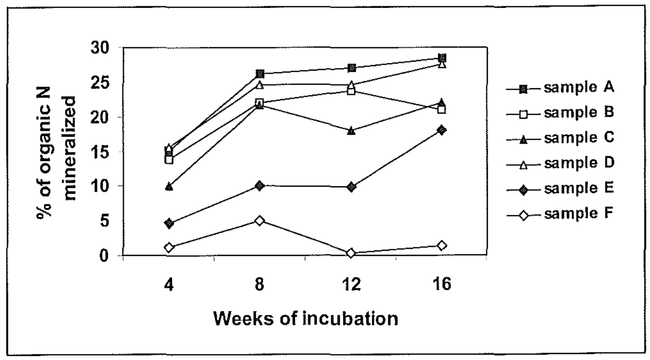

Figure 1. Net mineralization of organic N from biosolids, 2000 laboratory incubation.

In summary, N availability from the common types of biosolids products available for field application can apparently be predicted with reasonable accuracy from their initial characteristics. Under Sacramento Valley conditions, dewatered and air-dried biosolids can be expected to provide 20-30% of their initial N content in the growing season following spring application, with composted biosolids considerably less active.

Ammonia Emission Related to Nitrogen Fertilizer Application Practices

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INTRODUCTION

This project involves the adaptation of techniques developed to measure trace gasses in the atmosphere of urban areas to the monitoring of 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 (ARB) project to develop and validate a method for monitoring NH_3 volatile losses from fertilizer applications. This CDFA-FERP project continues 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, 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. In the second year of the project 10 crops and 3 natural vegetation communities were monitored several times each to begin to establish the seasonal levels and variability of atmospheric ammonia.

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 effect 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.

DESCRIPTION

The initial ARB 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 fer-

Table 1. Summary of Field Sampling Site Emission Estimates

SITE	CROP	N #/Ac	N g/m^2	Soil pH	Irrigation	NH_3 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%

tilizers resulted in a matrix of 240 cells. Changes in the matrix during the sampling period produced a final matrix of 936 (nine crops X thirteen fertilizer/application methods X two pH categories X four soil texture) categories. Three sites were located on the CSUF farm/laboratory, the rest were in commercial 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. Table 1 is a list of the sites sampled in 2000. Table 2 is a listing of ammonia emissions by county. These were calculated by applying the appropriate emission factor from the field monitoring to the crops identified in the database developed from the DWR crop maps.

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 disk by the volume (meter^3) of air through the denuder in the sampling period to get $\mu gNH_3/meter^3$ 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 $\mu gNH_3/meter^2/second$. 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.

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.

RESULTS AND DISCUSSION

Table 1 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.

Evolution of the study from data collection and a database of NH_3 emission factors for the ARB (Table 2) to an investigation of seasonal, volatile losses is the primary characteristic of the current 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 six more portable sampling systems have been built. Two primary sampling units were constructed with five wind speed sensors. Four secondary units were built with simpler weather stations that monitor wind speed at only two heights. Each set of the 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 ARB 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 need to sample air immediately above the soil surface has also been addressed with several chamber and shield systems evaluated. A shield constructed of 6mm Lexan in a 1m circle that can be adjusted from 5cm to 20cm above the soil/vegetation surface has been adopted. A denuder is located at the center of the shield so that air must pass between the surface and the shield for 0.5m before it enters the denuder. The data from these devices is still being analyzed and will be reported next year.

Table 2. Estimated NH3-N emission directly from chemical fertilizer application in counties of California.

	DWR area total (ha)	*NH3-N Emission 106 kg*	*Ave. NH3 Emission Factor*
San Joaquin Valley			
San Joaquin	232,531	0.66	2.41%
Stanislaus	158,549	0.40	2.38%
Madera	145,660	0.27	2.30%
Merced	226,158	0.65	2.64%
Fresno	538,163	1.46	2.47%
Kern	398,140	1.14	2.71%
Kings	236,465	0.74	3.06%
Tulare	307,772	0.78	2.35%
TOTAL	2,243,437	6.11	2.54%
Sacramento Valley			
Butte	106,658	0.41	2.26%
Colusa	130,851	0.61	2.58%
Glenn	111,747	0.42	2.30%
Sacramento	80,029	0.22	2.34%
Solano	83,183	0.26	2.40%
Sutter	119,301	0.55	2.74%
Yolo	147,605	0.49	2.43%
TOTAL	779,373	2.96	2.43%
Central Coast			
Monterey	107,251	0.28	1.57%
San Luis Obispo and Santa Barbara	125,976	0.34	1.45%
TOTAL	233,227	0.61	1.51%
Imperial Valley			
Riverside and San Bernadino	54,482	0.31	2.33%
Imperial	211,559	1.70	2.53%
TOTAL	266,041	2.01	2.43%
STATE TOTAL	3,522,079	11.7	2.38%

The FREP sponsored project, at this point, has completed the development of the field sampling systems and has sampled at several sites on a regular basis through the current 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. The field sampling with the denuder systems will be supplemented by a tunable diode laser to monitor ammonia through open-path spectroscopy. This will allow real time monitoring of ammonia over much shorter intervals than the denuders. Much of this work will be done in connection with monitoring dairy operations but several crop systems will also be included. The completion of the crop monitoring and correlation with the TDL project will be reported next year.

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 up to 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 transmitted directly to groundwater. Few studies have surveyed nitrogen levels or denitrification rates at such depths or monitored leaching of nitrogen to a deep water table. Field-scale spatial variability of nitrate levels due to natural variability of soils and vadose zone sediments also remains unaccounted for in most work on groundwater quality impacts of agricultural nitrogen management. The objectives of the proposed research are:

1. Investigate the fate of nitrogen throughout the entire deep vadose zone at a well controlled, long term research orchard with a stratigraphy typical of many areas on the east side of the San Joaquin Valley and in 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

PROJECT DESCRIPTION

Background: During 1997-98, we drilled and characterized approximately 3000ft. 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 beneath 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 1999-2001, we completed both chemical and hydraulic laboratory analysis. Chemical analysis focused on microbial carbon and total carbon distribution as an 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 120 multistep outflow experimental results. This past year (2001-2002) we used 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. During the coming year we will implement vadose zone modeling. We will also implement a geostatistical analysis of the extensive field database this project has provided. 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 60 cores is the result of the geologic-hydraulic-geochemical architecture.

RESULTS

Work Progress, Hydraulic Characterization: The multistep outflow experiments were implemented on 120 undisturbed cores representing 9 major textural classes identified in the

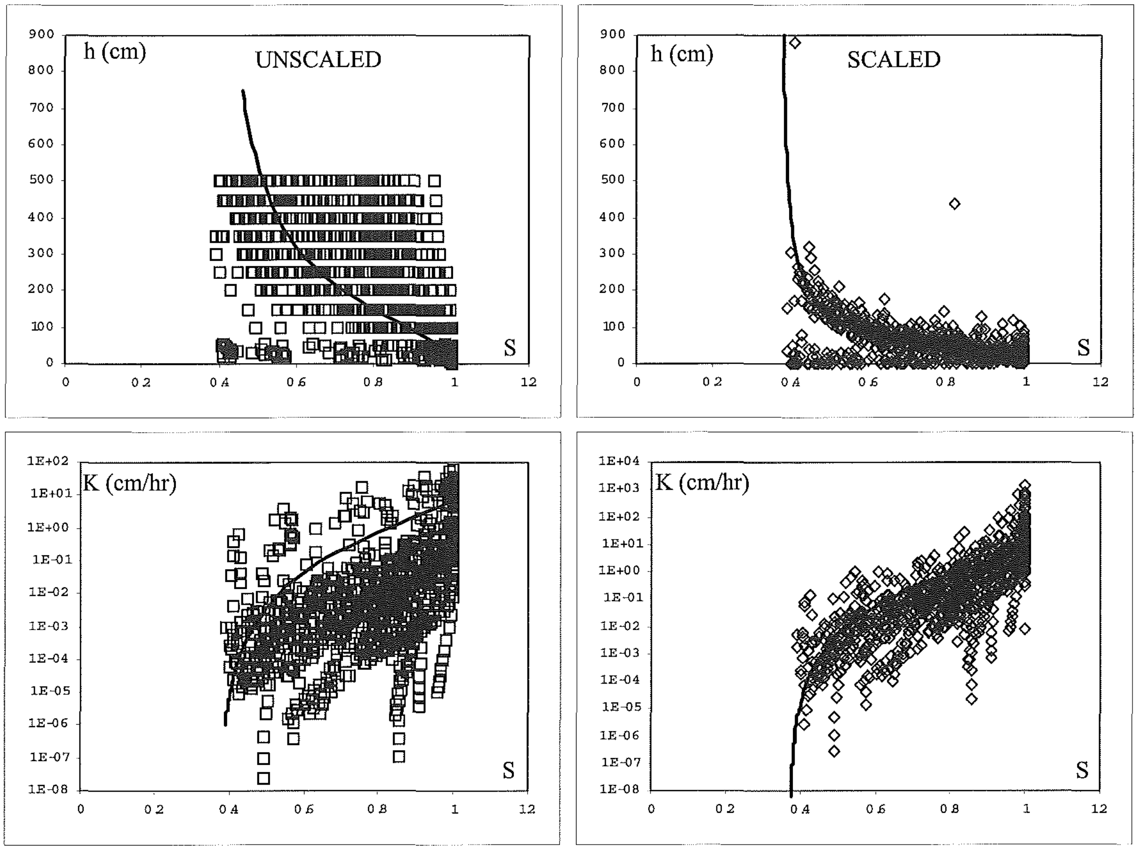

Figure 1. Original and scaled soil water pressure head and hydraulic conductivity for all 120 samples.

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 incrementally 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 drains from the core as a result. Soil moisture and outflow are recorded automatically with sensors 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". The end product of the inverse modeling is a set of hydraulic parameters (soil water retention and unsaturated hydraulic conductivity) that can be used to describe flow beneath the orchard.

The soil water retention and unsaturated hydraulic conductivity curves obtained for the 120 soil cores were scaled simultaneously yielding a single set of scale factors thus simplifying the description of heterogeneity from a set of multi-variate functions to a single set that relate to a reference soil. That is, scale factors are conversion factors relating the characteristics of one system to characteristics of another system. In the case of soil hydraulic parameters the scale factors relate the multi-variate functions of soil water retention and hydraulic conductivity to a reference soil via a single fac-

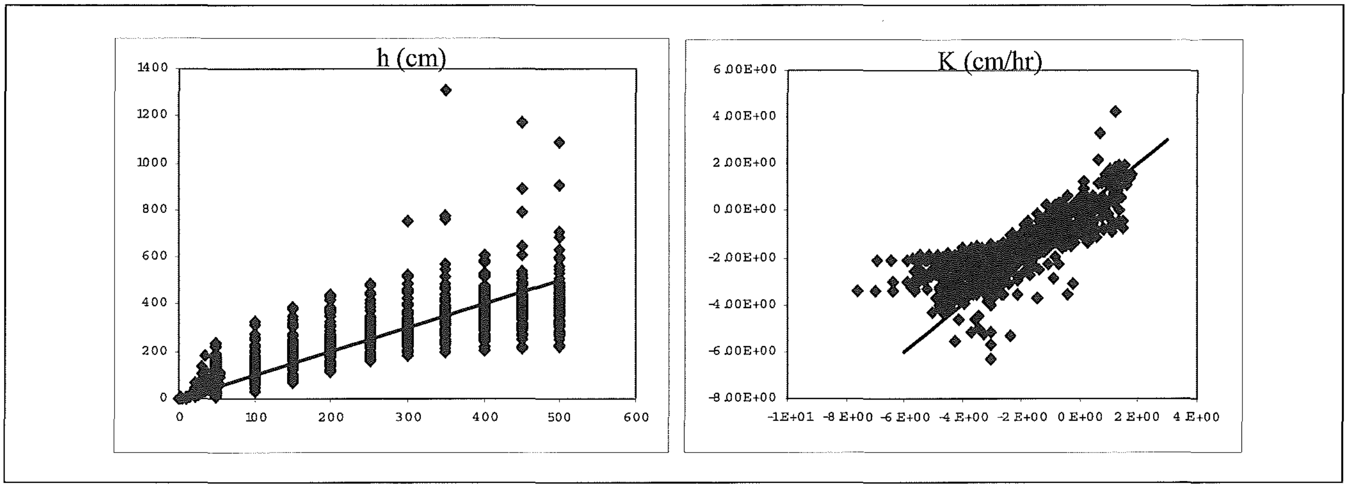

Figure 2. Original and descaled soil water pressure head and hydraulic conductivity for all 120 samples. The original values are on the x-axis and the descaled values are on the y-axis.

tor. Take, for instance, a group of X soils whose hydraulic functions are to be scaled. The result is X scale factors relating the original functions to one reference soil that is determined using Powell's method in combination with a Newton-Raphson procedure. In our case there are 120 samples representing 9 major textural classes. These 120 samples were grouped in two ways:

1. Soils scaled all together. No a priori knowledge, such as texture, was used.
2. Scaled according to initial field determined texture.

Figure 1 shows scaled and unscaled water pressure and unsaturated hydraulic conductivity data for Case 1. Soil water retention curves were scaled over 11 equally spaced pressure increments (0, 50,..., 500 cm) with the exception of the sands which were scaled over 16 steps (0, 10, ..., 150 cm). Hydraulic conductivity curves were scaled at degree of saturation (S) values corresponding to these same pressure increments. The solid curves represent the best fit through the unscaled data and the optimized scaled mean curves. The open squares indicate the unscaled data and the open diamonds represent the scaled data. The percent reduction in the sum of the squares (SS) is one indication of the degree of success of the scaling procedure. The reduction for this case is 92.9%. Another indicator for the degree of success is the correlation between the original data and the estimated or descaled values. The estimates are calculated by multiplying the mean curve by the appropriate scale factor. Original and descaled values for h and K are shown in Figure 2. Similar results for the other grouping are available but are not shown.

The large set of hydraulic parameters we have amassed 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.

Development of Lime Recommendations for California Soils

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OBJECTIVES

1. Evaluate soil acidity on 100 soils from across the Central and Northern California, with emphasis on tree and vine crops
2. Evaluate six buffer pH methods cited in the literature on California soils
3. Evaluate lime equilibration models based on soil buffer pH
4. Validate model buffer pH using twenty additional California soils
5. Provide buffer pH method and model calibration to California soil testing laboratories.

INTRODUCTION

Acid agricultural soils although small in acreage across California, dominate vineyards in the North coast region, coarse textured field soils of San Joaquin Valley (SJV) and Sacramento valley. Increasingly strongly acid soils have been noted in Sonoma, Marin, Mendocino and Lake Counties, volcanic soils of Modoc and Lassen counties and moderately acid soils in Glenn, Butte, Stanislaus, Merced, Fresno and Tulare counties. In specific instances pH values are sufficiently low to produce aluminum toxicity. This occurs on soils with pH (1:1) less than 5.50.

Soils of the North coast are dominated by serpentine parent materials low in base saturation and moderately weathered. Particularly noteworthy are low pH values which impact vineyard production in Mendocino, Lake and Sonoma counties. Soils of the east SJV tend to be coarse textured, poorly buffered and receive moderately high amounts of ammoniacal nitrogen which acidify the soil. Low soil pH results in decreasing availability of calcium, magnesium, phosphorus, potassium, molybdenum, decreased nitrogen fixation and a decrease the activity of soil bacteria. Grapevine root growth can be seriously impeded by soil acidity. Management of soil acidity by liming and rootstock selection are important factors in viticultural management.

Lime recommendations made by testing labs and consultants in California are made using the SMP Buffer pH method. This method was originally developed in 1961 for soils in Ohio and Mid Atlantic states and utilized in California over the last 30 years. Little or no lime requirement calibration data for this method is available for California soils and crops. Nor is it known whether the SMP method is the best analytical method to assess lime requirements on California soils. It is likely to over predict lime requirements on soils acidified through fertilization. No calibration data is available as to its effectiveness on serpentine soils of the North Coast area. With increasing occurrences of acid soils and intensities there of in California, soil buffer pH methods (and lime recommendations) need to be evaluated for California and their performance assessed with respect to soils, climate and cultural practices. This project will assess the performance of soil analysis methods as to their ability to predict neutralization of soil acidity across the North coast region, SJV of California and Sacramento Valley. Specific attention will made to reducing soil exchangeable aluminum.

One-Hundred soils are to be collected across California representing soils where soil pH (saturated paste methods and pH 1:1) has been reported to be less than 6.0 in the past five years. Special emphasis will be given to soil pH values less than 5.50, soils which have high KCl extractable aluminum (> 20 mg/kg) and soils where large amounts of ammoniacal nitrogen fertilizer has been applied in North coast region of California, soils of the north Sacramento Valley and coarse textured soils of the SJV.

Soils will be characterized with respect to soil pH (1:1), saturated paste characteristics, organic matter, KCl extractable aluminum, base saturation, CEC, total exchangeable acidity, extractable cations and sand silt and clay content. All soils will be analyzed using 10% standard reference standards secured from the North American Proficiency Testing Program. Soil buffer pH will be evaluated using six reference methods: SMP Buffer pH; Modified SMP Buffer; Adams-Evans Buffer; Mehlich Buffer; Woodruff Buffer; and Modified Woodruff Buffer. Lime Equilibration will be based on the application of 100% Calcium Carbonate equivalent at five rates to 1.0 kg of each soil and equilibrated for 60 days.

Regression models will be developed which predict lime application and the buffer pH test method which prescribes soil acidity and best prescribes lime requirement will be selected. Models will also be developed predicting TEA.

Twenty new soils will then be selected and the model retested using a second lime equilibration study. The models will be re-evaluated to assess their accuracy and validity.

RESULTS

The project began in May 2002, and has collect 70 of the 100 soils (pH less than 6.0) from the Central coast, San Joaquin Valley, Sacramento Valley and the North Coast. Soil materials have been provided by commercial labs, field agronomists, consultants, UC extension personnel and fertilizer industry representatives. Soil analysis commenced in October 2002 and lime equilibration studies will initiate in March 2003.

DEVELOPMENT OF AN EDUCATIONAL HANDBOOK ON FERTIGATION FOR GRAPE GROWERS

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INTRODUCTION

In the 1990s, drip irrigation became widely used in the vineyard industry due to its potential for accurate and uniform placement of water beneath the vines, wetting only the soil and not the vine. Low precipitation rates also made it possible to irrigate soils on hillsides and other locations without excessive runoff or erosion. Drip system characteristics of low pressure and flow rates help stretch limited water supplies, and use smaller pumps that use less energy than conventional sprinkler systems. It is no wonder that the vineyard industry readily adopted drip irrigation.

When drip systems are properly designed, installed and maintained, they can apply water very uniformly to a vineyard. Another potential advantage is that they can also deliver water soluble fertilizers uniformly through the system to the vines, and assist the grower in providing adequate nutrition for plant growth along with the water needed for optimal fruit yield. This practice is known as fertigation.

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

Selecting the proper fertilizer, injecting the material in the right concentration and in a manner that ensures that it is uniformly distributed through the vineyard requires both knowledge, skill and care.

While there is a considerable amount of information on this subject, it is not in one publication specific for wine grapes. The purpose of this publication is to assist the vineyard manager in perfecting their fertigation practices. The content of this book is focused specifically on microirrigation systems, especially drip systems.

PROJECT OBJECTIVES

The objective of 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 on 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:

1. Nutritional needs of grape vines, and how to determine nutrient status in grape vines and soils
2. Equipment selection for fertigation and how to design and install it (including backflow prevention)
3. Fertilizer materials and their suitability for drip irrigation
4. Recommendations for organic fertigation materials
5. Irrigation scheduling and strategies for applying materials
6. Evaluating water quality, filtration, and cautions to prevent system clogging
7. Drip system maintenance, including chlorination and flushing the system
8. Charts and tables to assist growers in determining fertilizer concentrations and amounts to apply
9. Best Management Practices, and environmental and safety cautions on the storage and use of fertilizers, especially concentrated materials
10. Monitoring to measure the effectiveness of the fertilizer applications and system performance

The contents of the book have been assembled from an extensive review of existing literature, and modified specifically for grape vine culture. The publication will be about 60 pages long, and be printed in paper back format. It will probably sell for around $20.

Other contributing authors in the book include Larry Schwankl, Terry Prichard, Pete Christensen, and Bill Peacock.

The book has been submitted to UC ANR Publications, and has begun the process of peer review. In this way, material in the publication will be assured rigorous review for accuracy and content. Upon publication, the book will be catalogued and internationally distributed.

RESULTS AND CONCLUSIONS

With the increasing popularity of fertigation, this book will be very useful to grape growers around the state. Besides having accurate information on fertigation materials and procedures, Best Management Practices, water quality, safety and environmental protection are also emphasized so that growers will know how to safely fertigate their vineyardss.

By having this handbook produced by UC ANR Publications, quality production and wide distribution is assured.

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 Eastins' 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 CDE. 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 is housed at AGRIscapes, a 40 acre demonstration and education center for food, agriculture, and the urban environment on the Cal Poly Pomona campus. AGRIscapes opened to the public in winter 2001-02 and includes 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 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 are still undergoing development. We are in the process of planning hands-on, curriculum-linked, field trip activities by grade level, which began in October 2002 and will continue starting early spring 2003.

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. We have a resource center designated as part of the AGRIscapes facility.
2. Present workshop component on soils, fertility and soil/water relations.
3. Include presentations on these topics at 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 (which are ongoing), a primary focus of the project is a workshop series for teachers who wish to incorporate garden-based themes into their classrooms. In spring 2002, we held three workshops:

Everything You Wanted to Know About
Starting a School Garden...
January 25, 2002, 6 hours
17 teachers in attendance

Teaching Nutrition in the Garden
March 16, 4 hours
15 teachers in attendance

AGRIscapes Educational Charette
(designing ideal field trip experiences)
April 5, 3 hours
22 teachers in attendance

Upcoming events include:

September 28, hosting a Project Food, Land and People workshop (the first in southern California)

October 14-18, field trips for over 1000 students to visit our pumpkin fields and learn about how pumpkins are produced, from seed to product on the table.

October 18, participation the California Foundation for Agriculture in the Classroom conference in Irvine with an exhibit and roundtable sessions.

November (exact date TBA), hosting Closing the Loop workshop in cooperation with the California Integrated Waste Management Board

November (exact date TBA), a repeat of the Everything You Wanted to Know About School Gardens workshop

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 to 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 which continues

In October 2002, planning for demonstration gardens will commence to provide a focus for spring field trips. This will include hands-on science field stations exploring soil and water issues.

California Certified Crop Adviser (CCA) Program

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INTRODUCTION

The CCA program is an outreach program. Nationally over 12,000 Crop Advisers are certified under its authority. In California there are over 400 individuals currently certified under the CCA program. The success of this program will be judged in two ways. First, the consistent increase in the number of participating CCA's in California. Second the retention of CA CCA's will be a criterion for gauging the success of this project. Net growth (through retention and new certification) will help the CA CCA program move towards a self-sufficient program.

PROJECT OBJECTIVES

The overall objective of this project is to support the broader mission of the California Certified Crop Adviser program by:

1. Administering the California CCA program through managing the testing and certification of new members, tracking individual continuing education units, marketing the program, and updating the web site.
2. Coordinating the CCA activities within the policies and goals of the International CCA as well as the State CCA Board.
3. Developing and implementing a strategic and tactical plan for a self-funded CCA program.

PROJECT DESCRIPTION

The Certified Crop Adviser Program was introduced in California in 1992 in an effort to address increased concerns regarding agriculture's contributions to a variety of environmental problems including non-point source pollution. By mid 1994 the California Certified Crop Adviser program was established with support from the California Department of Food and Agriculture, the American Society of Agronomy and the California agricultural industry. The program was intended to raise the awareness and professional standards of individuals making recommendations for the use of agricultural fertilizers, pesticides and related products. The CA CCA program currently provides the highest standards for certification that are available in California and includes rigorous testing and education requirements. The initial certification of an individual requires a minimum level of education combined with experience in a relevant agricultural discipline as well as passing both State and International exams. The exams cover four competency areas including 1) nutrient management; 2) soil and water management; 3) crop management and 4) integrated pest management. Maintaining certification requires that participating individuals accumulate a minimum of 40 hours of continuing education every two years covering each of the competency areas.

Since the implementation of the CCA program in California, over 500 individuals have obtained certification. These individuals have now been involved in the program for several years and form the core membership on which to build a broader program. In the last several years, the CCA program in California has focused on developing a management system that provides for testing, continuing education and tracking of individual crop advisers certifications (CEU's accumulated, tests, status etc). Additionally, in the last year the CA CCA office has focused on service to its member base by providing advance course certification, regular newsletters and quick professional response to member inquiries and concerns. This solid management provides the basis for the expansion of the program and the strategic movement towards a self-run program.

In that regard, the Western Growers Association through a FREP grant has provided administration and oversight for the program. The daily and routine activities associated with program management include preparing and submitting CDFA, ICCA and CA CCA Board reports, coordinating the activities and efforts of all cooperator groups in relation to the CCA program, providing communication between the state and national boards, providing program information to participants and the State CCA Board and maintaining CEU tracking systems and the CA CCA Web Site. In addition, the Board directs the staff in marketing efforts, strategic planning and other projects at their discretion.

The Chairman of the California State Board represents the states interests on the International CCA Board and serves on the National Policy Council. The State Board is responsible for maintaining credibility through the implementation of sound policy and oversight of program activities. The American Society of Agronomy, in coordination and cooperation with the California Certified Crop Adviser Program, administers the certification of CCA's under prescribed international standards.

In support of the local CA CCA Program, WGA and the CA CCA are working to support a national marketing effort for the certified crop adviser program. This program is designed to help re-enforce the value of the CCA program across the country and to generate enthusiasm for the field. It will include national efforts as well as the development of "state modules" that can be used to market the program in state.

RESULTS AND CONCLUSIONS

During the first year of the current FREP agreement the "California Certified Crop Adviser Program" made many significant program advancements, including the relocation of administrative offices to Sacramento, improvement of administrative functions and interaction with the Board and volunteer leadership. After meeting with representatives of CDFA and the industry, the program administrator has worked diligently to improve performance and move the CCA program forward in California. The CA CCA Board has expressed satisfaction with current program performance and progress. However, the Board remains concerned regarding potential complete privatization of CA CCA funding, and select members of the Board have raised this concern with FREP. Upon request of the CA CCA Board, the WGA submitted a new funding request to FREP in an effort to ensure continuity for the CA CCA program in California. If left entirely to private support, the Board felt program activities could begin to falter. Today, however, the CA CCA program continues to gain credibility and exposure due to the combined efforts of a committed Board of Directors and a revitalization of the administrative effort.

CALIFORNIA STATE FAIR FARM UPGRADE PROJECT

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INTRODUCTION

In 1984, "The Farm" was introduced at Cal Expo. The 3½-acre demonstration farm received the Merrill Award, the highest honor awarded by the Western Fair Association, for clearly demonstrating leadership vision and excellence. During the last seven years, "The Farm" has been highly utilized, benefiting California residents and 5,000 school children annually. Unfortunately, there has been a lack of individual funding and limited staff. As a result, "The Farm" is in need of several specific improvements in the areas of educational school tours & workshops, a new irrigation system, compost exhibit, insect pavilion and increased staffing. In addition, current technology needs to be implemented in order to educate both the public and private industry on the art and science of California farming.

OBJECTIVES

The specific objectives of "The Farm" Upgrade Project are to:

Irrigation System—Create a partner/sponsor with an irrigation company to install an irrigation and fertilizer injection system. The systems control panel will be incased behind glass so the public would be able to view the unit. Sections of pipe will also be exposed for the public's viewing to provide a better understanding how the system functions. Interpretive signs will be incorporated into the demonstration sites. The system will be controlled with a computer that would allow the user to make accurate adjustments. With a new irrigation and fertilizer injection system, fertilizers will be monitored, which would reduce the amount of fertilizer leaching into watersheds. Workshops will be offered for homeowners, landscapers, fertilizer dealers and other interested parties demonstrating irrigation system installation and maintenance.

Educational School Tours/Workshops—Increase the number of educational hands-on interpretive tours/workshops being offered for children, teachers, homeowners, fertilizer dealers, landscapers, Master Composters, Master Gardeners and other gardening organizations.

Compost Exhibit—A new compost exhibit will be developed to demonstrate different methods and types of composting that will be useful to homeowners, schools, businesses, ranches and farmers. Interpretive signs will be incorporated so the exhibit can be used on a year round basis.

Insect Pavilion—The Insect Pavilion will display the direct positive and negative impacts insects have on California agriculture production geared towards homeowners, landscapers, fertilizer industry and other interested parties in a fun and educational manner. The 2002 renovation will bring added excitement to the exhibit along with improving insect viewing. With additional interpretive signs, viewers will have an increased understanding of insects in our world and the role they play in our lives. Interpretive information will focus on Integrated Pest Management (IPM) and good culture practices.

Staffing—A temporary employee will be hired for an additional 2 months. This individual will dedicate 100% of his/her time to implement the fertilizer project. Duties would include planning, logistics and implementation of the project.

RESULTS

As the State Fair ended on September 2, 2002, thus ending the eighteen-day run of the 149th California State Fair, the consensus was the fair was a huge success. Fair officials report a total attendance of 1,003,022. This year's Fair saw five days with record attendance figures and ten out of eighteen days reflecting higher attendance numbers than those recorded in 2001. A total of 70% - 80% of fair goers visited the California State Fair Farm.

Partnerships were created with Ewing Irrigation Products, FertiGator and Griswold Controls to purchase discount irrigation supplies and provide consulting services free of charge. An IDC Irrigation Data Control and Fertilizer Injection System was purchased and installed in a newly renovated Irrigation Control Shed. The system has been incased behind glass that enables the public to view the operating system. New and updated irrigation supplies were purchased at a discounted rate and installed that allowed the new system to function at full capacity. Interpretive signs were incorporated with the controller and injection system demonstration site.

An increased number of educational hands-on interpretive tours/workshops were offered in the spring and fall for children, teachers, homeowners, fertilizer dealers, landscapers, Master Composters, Master Gardeners and other gardening organizations.

The City of Folsom, Recycle Division and Sun-Up Forest Products donated a total of 60 yards of compost that was incorporated into the existing soil to improve soil quality. A compost exhibit was developed to demonstrate different methods and types of composting and interpretive signs were incorporated into the compost demonstration site.

Partnerships were created with the California Department of Food and Agriculture (CDFA) Pest Prevention, and Sacramento-Yolo Mosquito & Vector Control District (Mosquito Vector) who contributed funding, consulting and materials to enhance the "Insect Pavilion". The "Insect Pavilion" successfully displayed the direct positive and negative impacts insects have on California agriculture production geared towards homeowners, landscapers, the fertilizer industry and other interested parties in a fun and educational manner. The 2002 renovation improved insect viewing and additional interpretive signs allowed viewers to increase the understanding of insects. Interpretive information focused on Integrated Pest Management (IPM) and good culture practices.

CDFA funding through the Fertilizer Research and Education Program allowed the California State Fair "Farm" to showcase California agriculture. A temporary employee was hired for two months to perform tasks funded by CDFA grant and due to the many successful upgraded projects funded by this grant, just under 1 million, California Residents now have a better understanding of fertilizers and the role they have in California agriculture.

Completed Projects

The following is a list of FREP projects completed prior to October 2002. Summaries of many of these projects appear in the 2000 and 2001 FREP Conference Proceedings. Previous conference proceedings and final project reports are available by calling FREP at (916) 653-5340.

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

Relationship between Fertilization and Pistachio Diseases
Themis J. Michailides

VEGETABLE CROPS

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

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

Soil Testing to Optimize Nitrogen Management for Processing Tomatoes
Jeffrey Mitchell/Don May/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/Laosheng Wu

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

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Timothy K. Hartz

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Charles Sanchez

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Warren Bendixen

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Dan Putnam

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Bill Weir and Robert Travis

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William Rains, Robert Travis and Robert Hutmacher

Nitrogen Fertilization and Grain Protein Content in California Wheat
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Larry Godfrey and Robert Hutmacher

IRRIGATION AND FERTIGATION

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

EDUCATIONAL/MISCELLANEOUS

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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
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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.

Air Quality and Fertilization Practices: An Inventory of Fertilizer Application Practices for Agriculture in the San Joaquin Valley
Jack King, 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

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

From the Ground Up: A Step-by-Step Guide to Growing a School Garden
Jennifer Lombardi

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

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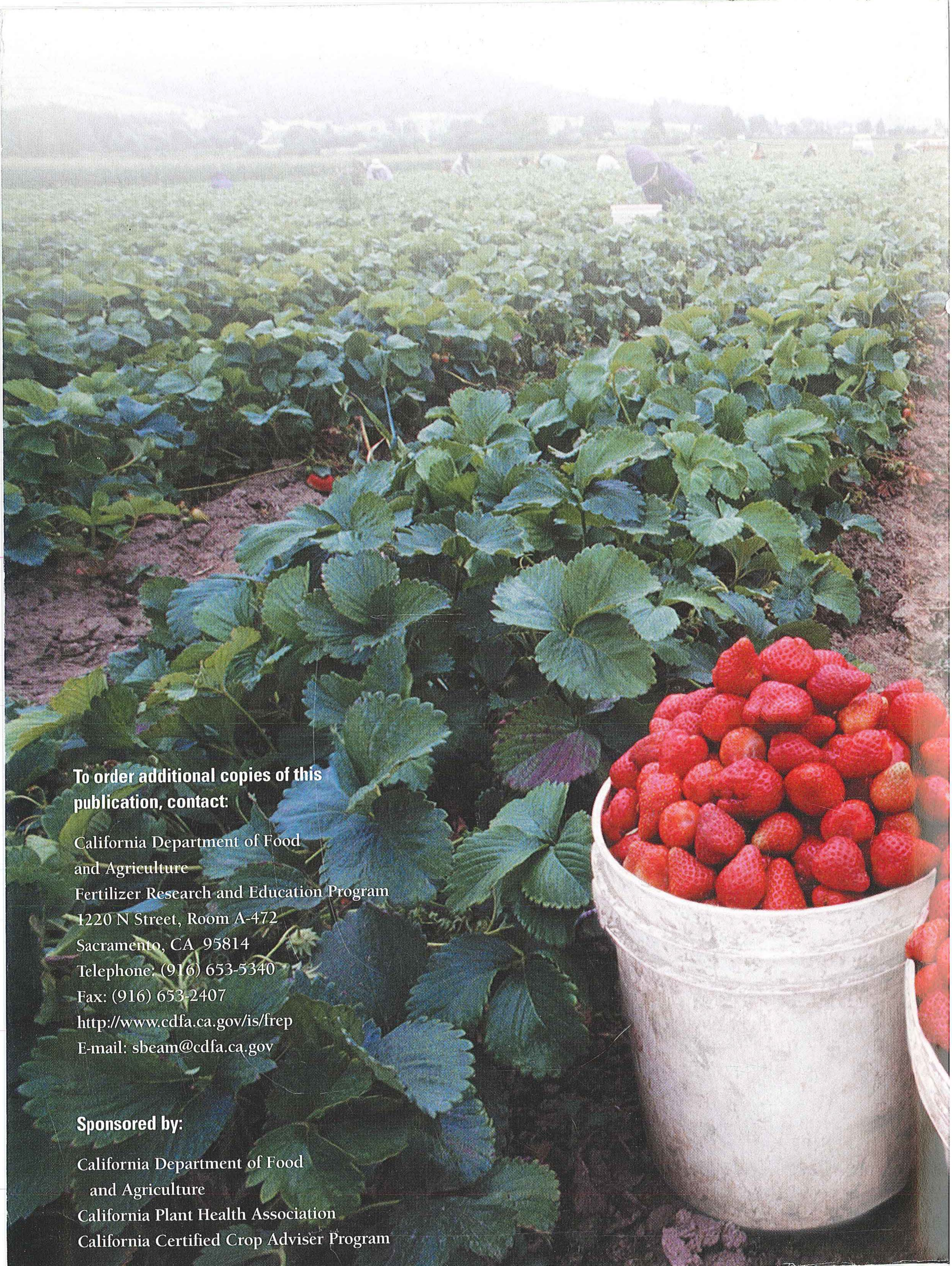

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