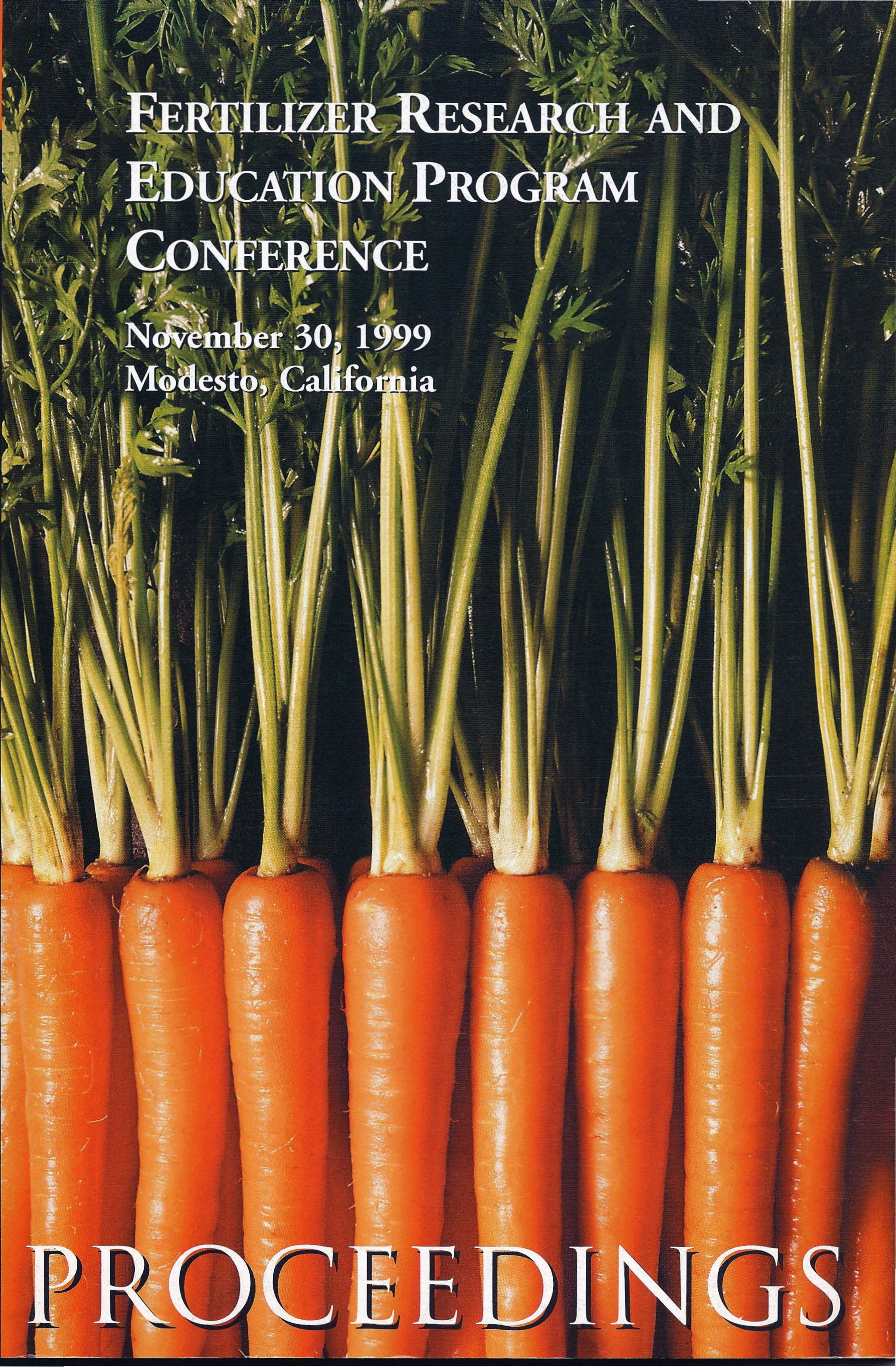
CDFA
California Department of Food and Agriculture

Fertilizer Research and Education Program Conference

November 30, 1999
Modesto, California



PROCEEDINGS

Proceedings of the Seventh Annual

Fertilizer Research and Education Program Conference

November 30, 1999
Doubletree Hotel
Modesto, California

Sponsored by:

California Department of Food and Agriculture

University of California Sustainable Agriculture Research and Education Program

California Fertilizer Association

California Certified Crop Adviser Program

Proceedings edited by M. Athar Tariq and Casey Walsh Cady.

To order additional copies of this publication, contact:
California Department of Food and Agriculture
Fertilizer Research and Education Program
1220 N Street, Room A-472
Sacramento, CA 95814
Telephone: (916) 653-5340
Fax: (916) 653-2407
Web site: http://www.cdfa.ca.gov/inspection/frep
E-mail: ccady@cdfa.ca.gov

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Fertilizer Research and Education Program: 1999

Casey Walsh Cady
Fertilizer Research and Education Program
California Department of Food and Agriculture
Sacramento, CA
(916) 653-5340

PURPOSE

The Fertilizer Research and Education Program (FREP) was established in 1990 to advance the environmental and agronomic use and handling of fertilizer materials. FREP focuses primarily on improving the use efficiency of commercial fertilizing materials to minimize nitrogen losses to the groundwater.

FREP facilitates and coordinates research and demonstration projects by providing funding, developing and disseminating information. FREP serves a broad audience including growers, agricultural supply and service professionals, extension personnel, public agencies, consultants, and other interested parties.

BACKGROUND

In 1990, the Department was authorized to increase the mill tax on fertilizers to conduct research and education projects to advance the environmentally safe and agronomically sound use and handling of fertilizer materials. Since then, the program has supported over 80 projects at a projected cost of $3.75 million dollars, with $3 million dollars in matching funds. Of these projects, about 50 have been completed. Results from all of these projects can be found in these and previous years' proceedings, and on the FREP web site (http://www.cdfa.ca.gov/inspection/frep). A complete list of completed projects can be found in Section V of these proceedings.

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

PRIORITY FUNDING AREAS

Below is a list of the program's current funding priorities, which include:

- Irrigation interactions—water management as related to fertilizer use efficiency and the reduction of groundwater contamination and fertigation methodologies.
- Fertilization practices—nutrient balance, crop nutrient uptake, and partitioning including amounts, timing, and partitioning of nutrients taken from the soil, foliar nutrient management, slow release fertilizers, green manures, and the use of agricultural compost.
- Site-specific fertilizer technologies and applications.
- Heavy metals in commercial inorganic fertilizers.
- Development, testing, and demonstration of the use and benefits of practical field monitoring tools.
- Research on nutrient/pest interactions and nutrient/growth regulator interactions.
- Education and public information.
- Handling, transfer, and storage of fertilizer materials including air quality and PM 10/PM 2.5 concerns, as they relate to fertilizer applications.

EDUCATION AND OUTREACH

One of FREP's primary goals is to ensure that research results generated form the program are distributed to and used by growers and the fertilizer industry. Our annual conference is one of the primary ways in which this is accomplished. The conference typically reaches an audience of 200-250 and proceedings from the conference are disseminated throughout the year to interested parties. Articles about the various projects that FREP is supporting are commonly found in the popular agricultural media as well as scientific journals. FREP is definitely making an impact on applied agricultural research in California.

FREP also works with other organizations with similar goals. We are pleased to continue our involvement with the California Chapter of the American Society of Agronomy (CA-ASA) to disseminate new nutrient management information. At this year's CA-ASA annual conference, we will hold a session highlighting results of FREP-sponsored research, for the seventh consecutive year.

CDFA/FREP also works closely to support the mission and goals of the California Certified Crop Adviser (CCA) program. This valuable program, now in its seventh year, is helping crop production professionals improve their technical proficiency. Over 500 crop production professionals have taken the steps to become certified.

ACKNOWLEDGMENTS

We would like to acknowledge the members of the Fertilizer Inspection Advisory Board Technical Advisory Subcommittee; Carl Bruice, Al Ludwick, Steve Purcell, Brock Taylor, Jack Williams, Tom Beardsley, Jack Wackerman, David McEuen and John Weatherford. These people have exhibited dedication and professionalism and have been invaluable in helping to ensure FREP's success. The members of the Fertilizer Inspection Advisory Board are also hereby acknowledged.

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

Special recognition also goes to the leadership at the California Department of Food and Agriculture including John Donahue, Director of the Division of Inspection Services, Steve Mauch, Assistant Director of the Division of Inspection Services, and Steve Wong, Branch Chief of the Agricultural Commodities and Regulatory Services Branch. Additional support form Athar Tariq, Joanna Danquah, Maryam Khosravifard and the Branch's clerical staff is also acknowledged.

We would also like to extend appreciation to all of our conference co-sponsors and acknowledge the assistance received from Dave Chaney, Educational Coordinator of the University of California's Sustainable Agriculture Research and Education Program who provided considerable support in coordinating this year's event.

Nitrogen Management in Citrus Under Low-Volume Irrigation

Project Leaders:
Mary L. Arpaia
Department of Botany and Plant Sciences
University of California, Riverside
Kearney Agricultural Center
Parlier, CA
(559) 646-6561

L. J. Lund
Division of Agricultural and Natural Sciences
University of California
Oakland, CA

Cooperators:
C. Kallsen
UC Cooperative Extension Kern County
Bakersfield, CA

N. V. O'Connell
UC Cooperative Extension Tulare County
Visalia, CA

C. J. Corbett
Department of Soils and Environmental Sciences
University of California
Riverside, CA

OBJECTIVES

1. Using modern orchard technologies, evaluate the nitrogen needs of citrus trees, including amount and timing of nitrogen fertilizers for maximum production.
2. Determine the potential of nitrogen fertilizer timing, amounts and application techniques to add nitrates below the root zone in a citrus orchard and contribute to ground water contamination.
3. Examine the effect of nitrogen amount, timing and application method in a modern orchard on fruit quality and vegetative growth.
4. Using the objectives listed above, determine best management practices for a modern citrus orchard based on economic and environmental considerations.
5. Appraise citrus growers, packers and industry affiliates of the project's progress, results and ultimate conclusions in articles in trade magazines, newsletters and through presentations at grower meetings.

DESCRIPTION

In recent years, California citrus growers have suffered from poor postharvest fruit quality. While several factors are thought to be responsible for the poor performance, including weather and location. Nitrogen fertilization practices are believed to play a significant role. Post harvest rind breakdown and pitting of navel oranges are the symptoms. These disorders do not typically appear until the fruit has been graded, packed and shipped to export markets.

Despite the negative effects of high N on fruit quality, and the warnings of potential groundwater contamination, various factors have resulted in increased nitrogen use in California citrus groves. These are reflected in high leaf nitrogen levels, declining fruit quality and a serious risk of nitrate runoff into surface waters and percolation into groundwater.

This project is a long-term study of N management in a mature citrus grove. With the advent of fertigation, there is a potential to improve fertilizer practices in citrus. The objective is to develop best management recommendations for N fertilization which result in sustained returns from adequate yields of high quality fruit, while minimizing N loss to water reserves and reducing excess vegetative growth and pruning costs.

The five-year trial is being carried out in a mature commercial Navel orange grove in Tulare County with standard management practices. The investigators are evaluating various N fertilizer levels (0.5 - 2.5 lb N/tree), application methods (irrigation injection, foliar) and timing of N applications (continuous, monthly, seasonal split, single annual application) in a statistically replicated trial. Twenty-five treatments were applied representing a range of nitrate rates and application methods (Table 1). These treatments were replicated four times.

To estimate potential N losses beyond the root zone in citrus, nitrate levels are being monitored. Fruit yield, quality, tree size and leaf nutrient levels are also being measured to determine the most profitable fertilization program. The end result of the study will be the development of best management practices for citrus growers that minimize nitrate groundwater

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		*Soil Only*	
# Applications[z]	*Lb N/tree/yr*	*Lb N/tree/year*	*Timing[y]*
0	0	0.5	1, 2, C
1	0.25	1.0	1, 2, C
2	0.50	1.5	1, 2, C
4	1.00	2.0	1, 2, C

Combination Treatments

Soil Application (lb N/tree/yr) [x]	*Foliar Applications (# applications)[z]*	*Total lb N/tree/yr*
0.5	1, 2, 4	0.75 - 1.50
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.

contamination while maintaining yields and quality. Grower outreach is an important aspect of the project.

In 1998, two additional study sites were added to the project to serve as a commercial-scale verification of the initial study site and as demonstration orchards.

RESULTS AND CONCLUSIONS

Fruit Harvest, Yield and Quality

The yield data for 1998 from the main project site are presented in Table 2. There were no statistical differences in yield between the control and any of the N treatment regardless of N amount, timing or method of appli-cation. There were some statistical differences in fruit size distribution, but none of these differences were consistent across treatments so it is difficult to assess the meaning of these differences. The size distribution data can be effectively analyzed only after the completion of the project. The peak fruit sizes were sizes 56 and 72, similar to our results in 1997. Although statistical differences were detected at $P< 0.05$ these differences are again not related to treatment effects. There were slight block effects with Blocks 3 and 4 yielding slightly lower amounts of fruit per plot.

The fruit quality data for the initial and final fruit evaluations and the combined analysis show that as with the yield and size distribution data, there were statistical differences detected between treatments, although these differences were slight and not related to the differential nitrogen treatments. The largest differences, not surprisingly, were related to the duration of storage. As expected, the soluble sugar content and titratable acidity content of the juice (SSC, TA, respectively) changed with storage. It was also noted that fruit decay was greater following storage although the amount of decay was relatively minor. Puncture resistance of the peel and peel thickness was also measured. There were no consistent differences detected between treatments or field blocks.

The fruit storage results obtained in 1998 show that the Woodlake and Orange Cove sites had little postharvest problems with the fruit and no clear trends across the various parameters were apparent. Fruit from the Porterville site developed extensive postharvest pitting in storage. Treatment 1 had the lowest levels of pitting (reflected in the lower percent of fruit with an average grade of 2 or above), although this did not differ greatly from the other treatments. As with the data from the main site, multiple years of data will be required to draw any inferences as to the effect of the nitrogen treatments on postharvest fruit quality.

The lack of clear trends in the 1998 storage data may reflect the need for allowing the field differential in nitrogen status of the tree to further develop prior to seeing large and statistical differences in overall fruit quality.

Table 2. Yield (lb. of fruit per tree pair) and size distribution from March 1998 harvest of Frost Nucellar navel orange on Troyer citrange rootstock.

	Yield	*Size Distribution (% of total fruit)*										
TRMT	*lb. fruit*	*163*	*138*	*113*	*88*	*72*	*56*	*48*	*40*	*36*	*32*	*24*
1	750.0 abc	0.8 ab	1.2 ab	3.6 abc	8.5 e	16.8 cd	21.8 ab	11.8 a	9.8 a	13.8 ab	7.5 abcd	4.4 abc
2	813.8 abc	0.9 ab	1.3 ab	5.0 abc	16.3 abcde	22.4 abcd	22.3 ab	10.0 abc	6.6 ab	8.7 bcde	4.2 abcd	2.4 bc
3	680.3 bc	1.2 ab	1.7 ab	6.7 abc	17.7 abcde	23.7 abc	22.1 ab	8.9 abc	5.6 ab	8.2 bcde	3.1bcd	1.2 c
4	823.8 abc	1.6 ab	1.9 ab	5.7 abc	17.4 abcde	24.0 abc	22.8 ab	8.6 abc	6.7 ab	7.4 bcde	2.6 d	1.4 c
5	721.8 abc	1.8 a	2.6 a	8.4 a	22.5 a	22.5 abcd	18.3 b	7.1 c	5.2 b	5.8 e	3.8 bcd	2.1 c
6	746.0 abc	1.1 ab	1.7 ab	7.2 abc	18.5 abcde	25.5 ab	22.7 ab	7.8 abc	5.5 b	6.6 bcde	2.6 d	0.9 c
7	704.3 abc	0.6 ab	1.3 ab	4.7 abc	14.7 abcde	23.4 abc	23.8 ab	9.2 abc	7.5 ab	8.8 bcde	4.2 abcd	2.0 c
8	826.3 abc	0.8 ab	1.2 ab	4.5 abc	16.8 abcde	23.4 abc	23.8 ab	8.7 abc	6.7 ab	8.3 bcde	3.7 bcd	2.2 c
9	756.0 abc	0.7 ab	1.2 ab	4.6 abc	13.7 abcde	22.3 abcd	22.3 ab	9.8 abc	7.7 ab	11.1 abcde	4.8 abcd	2.0 c
10	879.5 ab	1.0 ab	1.3 ab	5.7 abc	20.0 abcd	25.3 ab	22.1 ab	8.1 abc	6.1 ab	6.0 de	2.9 bcd	1.5 c
11	933.3 a	1.0 ab	1.4 ab	6.5 abc	20.0 abcd	26.6 a	22.2 ab	7.2 c	5.6 ab	6.1cde	2.6 d	1.0 c
12	766.0 abc	1.2 ab	2.0 ab	7.7 ab	21.0 ab	24.1 abc	19.8 b	6.8 c	5.3 b	7.0 bcde	3.4bcd	1.8 c
13	807.0 abc	1.2 ab	1.9 ab	5.9 abc	16.5 abcde	20.0 abcd	21.6 ab	8.8 abc	7.5 ab	9.8 abcde	4.7 abcd	2.3 c
14	608.8c	1.3 ab	2.1 ab	7.5 abc	20.0 abcd	22.6 abcd	20.2 ab	7.1 c	5.1 b	7.7 bcde	4.2 abcd	2.4 bc
15	800.8 abc	1.1 ab	1.8 ab	7.1 abc	20.5 abc	25.5 ab	20.3 ab	7.5 bc	5.6 ab	6.6 bcde	2.9cd	1.2 c
16	949.8 a	0.5 ab	0.8 ab	3.3 abc	9.3 de	18.2 bcd	23.9 ab	11.6 ab	9.3 ab	13.3 abcd	6.6 abcd	3.1 abc
17	837.3 abc	0.4 b	0.7 ab	3.0 abc	11.6 bcde	18.4 bcd	22.0 ab	9.7 abc	8.8 ab	13.4 abcd	7.4 abcd	4.9 abc
18	815.8 abc	0.7 ab	1.6 ab	5.5 abc	15.7 abcde	21.4 abcd	21.2 ab	9.1 abc	6.6 ab	9.3 abcde	5.6 abcd	3.5 abc
19	857.5 abc	1.4 ab	2.1 ab	6.9 abc	20.2 abcd	24.1 abc	21.0 ab	7.6 abc	5.4 b	6.4 bcde	3.2bcd	1.9 c
20	906.8 ab	0.5b	0.8 ab	3.6 abc	15.5 abcde	24.5 abc	26.2 a	9.3 abc	7.0 ab	7.7 bcde	3.1bcd	2.2 c
21	863.0 ab	0.3b	0.9 ab	2.7 bc	9.9 cde	17.8 bcd	21.2 ab	10.0 abc	8.1 ab	13.1 abcde	8.4 abc	7.8 a
22	765.5 abc	0.3b	0.7 ab	2.2 bc	10.1 bcde	17.2 cd	21.3 ab	10.3 abc	8.8 ab	13.5 abc	8.6 ab	7.2 ab
23	747.8 abc	0.5b	0.9 ab	3.4 abc	13.5 abcde	21.8 abcd	24.1 ab	10.4 abc	8.3 ab	10.0 abcde	4.8 abcd	2.4 bc
24	737.0 abc	0.3b	0.4b	1.9c	7.9 e	15.2 d	22.0 ab	11.1 abc	9.8 a	16.5 a	9.8 a	5.2 abc
25	794.5 abc	0.5b	0.8 ab	3.3 abc	13.1 abcde	20.1 abcd	21.7 ab	10.4 abc	8.4 ab	12.3 abcde	6.2 abcd	3.2 abc
BLOCK												
1	766.9 a	1.0 a	1.6 a	5.8 a	18.5 a	24.3 a	22.2 ab	8.0 a	6.1 b	7.4 b	3.3 b	1.9 a
2	804.2 a	0.6 a	1.1 a	3.9 a	14.4 b	21.6 b	23.2 a	9.4 a	7.6 a	10.1 a	5.1 ab	3.0 a
3	813.2 a	0.9 a	1.3 a	5.1 a	14.8 ab	20.6 b	20.8 b	9.4 a	7.4 ab	10.6 a	5.7 a	3.4 a
4	799.1 a	1.0 a	1.5 a	5.4 a	15.3 ab	21.3 b	21.8 ab	9.3 a	7.0 ab	9.7 ab	5.0 ab	2.8 a

Mean Separation using Duncan's Multiple Range Test, $P < 0.05$.

Monitoring of Soil Nitrates

Soil solution samples have been collected periodically during the funding year and analyzed for nitrate (NO_3-N) and chloride (Cl). The NO_3-N and Cl concentrations were found to be quite variable. Differences in N application, water leaching and soil characteristics would all impact these concentrations. One way to evaluate fertilizer treatment effects on NO_3-N leaching is to examine NO_3-N to Cl ratios under different N application rates. By using NO_3-N to Cl ratios, Cl, a conservative ion, is used as a tracer and differences in leaching volumes among different plots are effectively eliminated. Preliminary analysis of these data suggest that the trends which was reported in previous reports continue to be evident. The more N which is applied, the greater the amount of N found in the soil solutions. The amount found in the soil solution is also dependent on the method of application. For the soil applied N treatments, the single N application yielded the highest amount of N in the soil solution sample. The samples taken from the continuous fertigation treatment had the lowest amounts of N in the samples. The lowest amount of N in the soil solution sample was found in the foliar applied treatments. A more complete analysis of these results will be provided later this year.

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

Project Leader:
Carol J. Lovatt
Department of Botany and Plant Science
University of California
Riverside, CA
(909) 787-4663

Cooperator:
John Grether
Grether Farming Company, Inc.
Somis, CA

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.

SUMMARY

To reduce potential nitrate pollution of groundwater, avocado growers apply nitrogen (NH_4NO_3) fertilizer to the soil in several small doses annually. This strategy ignores tree phenology and the possibility that the tree requires more N at certain times of year. At the request of the California Avocado Commission (CAC), a 4-year study was conducted to determine the impact of supplying extra soil N to 'Hass' avocado trees at key times in the phenology of the tree, relative to supplying an equal amount of N in six small doses/year. The results clearly identified specific times when N fertilization reduced yield (January and February), and times when extra soil-applied N increased yield, increased the number of larger commercially valuable fruit, and reduced alternate bearing (April or November). Double applications of N in November or April increased yield 201 lb and 133 lb more fruit/tree/4 years. Since orchards have more than 100 trees/acre, the yield increases are economically significant.

In 1997, the CAC funded a 6-year study to replicate the previous study and to quantify the effects of additional strategies with the overall goal to even out alternate bearing and to increase annual and cumulative yield without reducing fruit size and quality. The concern is that it is not known 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 increased leached nitrate. Since yield increased, the interpretation is that the tree utilized the extra N. This project is coordinated with and complemented by the CAC project. The project is aimed at quantifying the amount of nitrate and ammonia leaching past the root zone of 'Hass' avocado trees under the various nitrogen fertilization strategies. The results of this research will identify Best Management Practices (BMPs) for nitrogen for the 'Hass' avocado in California. The avocado growers of California are seeking this information to work out a ratio of enhanced-yield benefit to environmental cost for each N fertilization strategy. The results of the first harvest (1997-98) in the current study clearly demonstrate the time of N fertilizer application is more important than the amount of N that is applied (See Table). The CDFA-FREP research was initiated in April 1999. Thus, it is premature to report soil leachate results. The second harvest (1998-99) is scheduled for September 20, 1999.

The results of the first harvest (1997-98)

Treatment	Total lb N/acre	lb fruit/ tree	No. fruit/ tree	Net increase (or decrease) compared to control	
				lb fruit (%)	No. fruit (%)
2x N in August (all years)	40.0	73.6 a[z]	158 a	22	26
Grower fertilization practice[y]	42.5	70.7 a	145 a	18	16
2x N in November (prior to "on" years) and April ("off" years)	40.0	68.1 a	143 a	15	14
2x N in November (all years)	40.0	62.3 ab	130 ab	4	4
Control[x]	80.0	58.8 ab	125 ab	–	–
2x N in April and November (no N in February and June) (all years)	80.0	58.8 ab	124 ab	0	0
2x N in April ("off" years) and 3x N ("on" years)	60.0	58.6 ab	123 ab	0	-2
2x N in April (all years)	40.0	56.8 ab	117 ab	-4	-6
2x N in April ("off years) and 3x N ("on" years) applied foliarly	100.0	42.3 b	85 b	-30	-32
P-value		0.06	0.06		

[z]Values in a vertical column followed by different letters are significantly different at the specified P level by Duncan's Multiple Range Test.
[y]Grower's fertilization practice is 40 lb N as ammonium nitrate/acre split as two applications in July and in August.
[x]Control trees received 80 lb N as ammonium nitrate/acre, divided into four, 20 lb/acre applications made in mid-April, mid-July, mid-August, and mid-November.

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

Project Leaders:
Lisa Stallings/ Pat Delwiche/ Richard Rosecrane
California State University
School of Agriculture
Chico, CA
(530) 898-6218

Fred Thomas
CERUS Consulting
Richvale, CA

OBJECTIVES

1. Design and lay out an experiment to test the hypothesis that certain management practices within a prune orchard can affect potassium deficiency
2. Determine the effects of the four treatments on potassium content of leaf tissue
3. Determine the effects of the four treatments on soil solution potassium and on soil exchangeable potassium
4. Determine the effects of the four treatments on potassium deficiency symptoms in the leaves
5. Conduct educational/outreach sessions on K deficiency and on this research project, as part of UC Cooperative Extension Field days, the new UC Environmentally Sound Prune System Program (ESPS), the Biological Prune Systems (BPS) Project in cooperation with CSU, Chico, through prune cooperatives and processors and handlers, and through the outreach activities of commercial fertilizer suppliers and Pest Control Advisors.
6. Determine the effects of the four treatments (compost, cover crop, clean-cultivation, and band application) on soil water relations in prune orchards
7. Determine the effects of the four treatments on fruit yield and quality

DESCRIPTION

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

Potassium deficiency symptoms may be expressed as yellowing of the leaves and marginal burn. Severe deficiencies may cause defoliation and limb dieback. Potassium deficiency can also cause decreases in both yield and fruit quality. Previous University of California research has shown that banding K at rates of up to 2,500 lb /acre will increase yields in prune orchard for 3-4 years and decrease foliar dieback during the heavy crop years.

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

RESULTS AND CONCLUSIONS

This three-year study, initiated in 1999 is evaluating the ability of alternative management strategies of cover cropping and compost applications to enhance K uptake in French prune. The study will also determine whether these soils have the capacity to fix K by performing mineralogical analyses, and K adsorption and release studies. Leaf K, exchangeable K, soil-solution K, foliage symptoms, and fruit yield and quality measurements will be taken as part of the study. At the time of compilation of this report the trials are still ongoing.

Development of a Nitrogen Fertilizer Recommendation Model for California Almond Orchards

Project Leaders:
Patrick H. Brown
Department of Pomology
University of California
Davis, CA
(530) 752-0929

Steven A. Weinbaum
Department of Pomology
University of California
Davis, CA

Cooperators:
Qinglong Zhang
Department of Pomology
University of California
Davis, CA

Lonnie Hendricks
Merced County

Objectives

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

Summary

Research results relating to objectives 1 and 2 were reported in the 1998 FREP Conference Proceedings and will only be briefly described here. Contrary to earlier results, studies conducted here demonstrated that nitrate analysis is an unreliable indicator of tree N status due to large variations in tree nitrate concentrations over time and a strong interdependance on plant water status.

The second aim of this research was to determine the seasonal patterns of N demand in mature almond. To achieve this goal, sequential whole tree excavations were conducted on 1/21, 3/20, 5/20 at the Delta College orchard in Manteca, California. Another excavation will be done in the spring of 2000. The weight of individual trees excavated ranges from 1257 lb to 1762 lb dry, with corresponding total N content of 20 to 28 lb N. The highest proportion of total N was present in the roots and rootstock in January and March. The fruit and canopy had the largest proportion of total N in May. Nitrate and total soluble N represented only a small proportion of total N presented in the whole tree.

Analysis of seasonal N uptake dynamics and total yearly N demand has been completed. This information has now been integrated into a user-friendly interactive computer program that is available for distribution. In summary, the determination of N fluxes in almond demonstrates that the majority of N uptake and demand occurs from late February through to early September and that the primary demand for N is for nut fill and nut development. Nitrogen demands can therefore be predicted by estimating yield and can be applied during the periods of greatest N uptake from the soil which occurs during nut development.

By timing N applications with periods of great demand, and matching N application rates with crop load, the growers get a tool that will encourage maximum efficiency of use of N fertilizers. Maximum efficiency of use will result in a minimization of N loss from the orchard system.

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

Project Leader:
Larry E. Williams
Department of Viticulture and Enology
University of California-Davis
Kearney Agricultural Center
Parlier, CA
(559) 646-6558

INTRODUCTION

There are approximately 701,000 acres of grapevines grown in California with 42 percent of that acreage devoted to wine grape production. Presently, the most rapidly growing segment of the wine industry is the sale of premium wine. The majority of grapes used to produce premium wine are grown in the coastal valleys of California. Unfortunately, a large portion of the vineyards in those areas are having to be replanted on rootstocks resistant to Phylloxera, a root feeding louse. Most of the fertilization recommendations for grapevines in California were developed for vines growing in the San Joaquin Valley on their own roots. Thus, there is an urgent need to develop fertilization recommendations for premium wine grape cultivars grown on different rootstocks in the coastal areas of California.

The primary fertilizer used in California vineyards is nitrogen. Therefore, the timing and amounts of N fertilizer application are critical in optimizing its uptake to avoid leaching below the root zone and possible ground water contamination. The only direct way to measure fertilizer use efficiency is with the use of ^{15}N-labeled N fertilizer. ^{15}N is a non-radioactive isotope of N and can be quantitatively measured in plant tissue. The proposed research was designed to determine fertilizer use efficiency using ^{15}N labeled fertilizer in four different vineyards (two Chardonnay and two Cabernet Sauvignon vineyards) growing on different rootstocks, and at different locations in California. In addition, N and K budgets were to be determined on those vines and compared to more conventional means (petiole analysis at bloom time) to determine vine nutritional status.

OBJECTIVES

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

DESCRIPTION

At berry set in the 1997 growing season ^{15}N labeled fertilizer was applied to six, individual vine replicates for each rootstock at all locations subsequent to berry set (from two to four weeks after anthesis or bloom). The amount of N applied per vine was determined by estimating yield at each site and the corresponding amount of N that would be removed in the fruit at harvest. This ranged from the equivalent of 27 to 40 lb N/acre, depending upon location. Petioles were collected in 1997 at 30 to 80 percent of full bloom, prior to when the fertilizer was applied and then again at bloom in 1998. Yields at each location were measured when the sugar in the fruit indicated that particular vineyard would be harvested within one week. The fruit was returned to the Kearney Agricultural Center and subsequently dried. Leaves on the experimental vines were collected prior to the anticipated date they would have naturally fallen from the vine and taken to the Kearney Agricultural Center to be dried. All leaves remaining on the vines at each location were removed the second week of December both years. All leaves of each vine were dried and weighed. The dried leaves were subsampled and the remainder were taken back to each vineyard and placed beneath each respective vine replicate. Data vines were generally pruned in December or January both years, fresh weights taken and subsamples of each collected. The subsamples were taken to the Kearney Agricultural Center, dried and weighed.

RESULTS AND CONCLUSIONS

The values for both NO_3 and total N in petioles at bloom varied greatly from one location to another and somewhat less so for rootstocks at a particular location. Values in 1997 ranged from a low of approximately 60 ppm NO_3 at the Oakville site to a high of 4,000 to 10,000 ppm NO_3 at Paso Robles. Total N in the petioles appeared to be a function of cultivar and not related to petiole NO_3 levels. Petiole analyses in 1998 were either lower or higher than the previous year, depending upon location, and were very similar across rootstocks and location.

The amount of N found in the clusters at harvest, leaves as they fell from the vine and pruning canes was determined for all scion/rootstock combinations at each site. Total N per acre in those organs was greater in 1997 than in 1998, the exceptions being several of the rootstocks at the Paso Robles site. The decrease in total N per acre was due to the fact that yields were lower in 1997 than 1998, especially at the Gonzales site. Lower yields in 1998 were a general phenomenon in vineyards throughout California. The amount of N per tonne of fruit at harvest was lowest for vines at the Oakville site and highest at the Paso Robles site in 1997 (Table 1). Paso Robles still had the highest amount of N per tonne of fruit in 1998 but the amount of N in the fruit at Oakville was similar to those at Carneros and Gonzales.

The range in petiole K varied to a lesser degree from location to location and among rootstocks at a particular location than did petiole NO_3 concentrations. The concentration of K in clusters, leaves and pruning canes among locations and rootstocks varied even less than the K in the petioles. As bloom time petiole K increased the concentration of K in the clusters also increased.

Table 1. The total amount of N in the fruits, leaves and the prunings at the four vineyard locations.

Location	Total N (clusters, leaves & prunings) (lb per acre) 1997	1998	Total N (fruits) (lb per ton) 1997	1998
Carneros	52.2	37.9	2.68	2.50
Gonzales	42.0	23.6	2.48	2.56
Oakville	39.8	38.2	1.96	2.48
Paso Robles	38.9	41.0	3.16	3.02

Each value is the mean (averaged across rootstocks) at each location for each year.

Table 2. The relationship between the amount of ^{15}N labeled fertilizer found in each rootstock/scion combination and the amount of ^{15}N fertilizer applied.

Location	Cultivar	Rootstock	^{15}N in vine/^{15}N applied (%) 1997	1998	1997 & 1998
Carneros	Chardonnay	5C	9.7	1.1	10.5
		110R	11.1	1.2	12.3
Gonzales	Chardonnay	5C	4.0	0.6	4.4
		110R	4.3	0.5	4.8
		Freedom	4.0	0.4	4.4
Oakville	Cabernet	5C	10.4	1.5	11.9
		110R	11.2	2.1	13.3
		3309C	11.5	2.1	13.6
Paso Robles	Cabernet	5C	2.1	1.2	3.3
		110R	3.2	1.8	5.0
		Freedom	6.1	1.7	7.8
		140Ru	3.5	1.6	5.1
		1103P	4.8	2.2	6.0

There were little differences among rootstocks in fertilizer use efficiency (FUE) at a given location in 1997. This was anticipated as all rootstocks were culturally treated the same (i.e. vertical trellis system, shoot positioned, hedged at a certain height and drip irrigated according to best estimates of vine water requirements). There were somewhat larger differences in FUE among locations. Fertilizer use efficiency, when averaged across rootstocks, was 10.3, 3.81, 3.45 and 11.5 percent at the Carneros, Gonzales, Paso Robles and Oakville sites, respectively. The higher FUE at the Carneros and Oakville sites may have been due to the fact that neither vineyard had been fertilized since planting. In addition, the Oakville vineyard had very low petiole NO_3 levels when sampled at bloom (an average of 60 ppm). The amount of ^{15}N fertilizer found in the clusters, leaves and pruning canes in 1998 was also very low and differed little among rootstocks at a given location (Table 2). The greatest uptake of the labeled fertilizer over the two-year period occurred at the Carneros and Oakville locations.

The current recommendation for adequate levels of NO_3 in the petioles at bloom, for Thompson Seedless grapevines, is between 500 and 1200 ppm NO_3. Data from this study indicates that when bloom time petiole NO_3 levels were below 500 ppm, the concentrations of N in the clusters, leaves and stems (or canes) were lower than when the levels were greater than 500 ppm. However, the concentration of N in those same organs did not increase as bloom time petiole N increased from 500 to 10,000 ppm. This would indicate that the values of petiole NO_3-N established for Thompson Seedless might also be valid for other cultivars and rootstocks.

Linear relationships were observed between organ tissue N concentration at berry set and the same organ's N concentration at the end of the season, and the concentration of N in the leaves and the fruit at harvest using the 1997 data set. Similar correlations will be made on data collections of 1998 and 1999 growing seasons. These relationships would also indicate that any of the above organs, sampled either during the growing season or during dormancy (pruning canes) could also be useful in determining vine nutrient status when used in conjunction with petiole analysis.

The data collected to date indicate that the efficiency of N fertilizer utilization by the various rootstocks differs only slightly. It is often assumed by many in the grape industry that rootstocks with greater petiole nutrients (such as higher NO_3 levels) are more efficient than rootstocks that generally have lower values. However, the data collected in this study indicate that not to be the case. The small differences among the rootstocks at any one location may be the reason that rootstock affected vine growth, and the growth then drove the uptake of the N fertilizer.

Determining Nitrogen Best Management Practices for Broccoli Production in the San Joaquin Valley

Project Leaders:
Michelle Le Strange
UC Cooperative Extension Tulare & Kings Counties
Visalia, CA
(559) 733-6366

Jeffrey P. Mitchell
UC Cooperative Extension
Kearney Agricultural Center
Parlier, CA

Louise E. Jackson
Department of Vegetable Crops
University of California, Davis, CA

INTRODUCTION

Broccoli production in the San Joaquin Valley is primarily aimed at fall and spring markets. Fall harvested broccoli is planted in midsummer when high temperatures are above 95°F during establishment and vegetative growth stages followed by cold temperatures (30s at night) at the time of head formation and maturation. Different temperature conditions exist for spring harvested broccoli which is planted in mid fall. Young plants must tolerate cold, damp conditions that slow vegetative growth for several months, then during head formation and development the weather is extremely variable at a time when nitrogen demand is high.

Broccoli has a high potential for NO_3 leaching losses because it requires high N inputs, tends to be irrigated frequently, has a relatively shallow root system, and is a high value crop. There is also a tendency to add excess nitrogen since it is apparently not harmed by excessive N applications. Although several broccoli field research projects have been conducted over the years in California to investigate fertilizer timing and amounts, only a few have been grower directed, and none have investigated the movement of nitrate from nitrogen fertilizer application performed under San Joaquin Valley growing conditions.

OBJECTIVES

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

DESCRIPTION

Four broccoli nitrogen fertilizer field experiments were conducted from 1996 through 1998 at the UC West Side Research and Extension Center. Two of the experiments were harvested in spring and two were harvested in fall. Seven N rates (0, 60, 120, 150, 180, 240, and 300 lb N/acre) and three application timings (preplant -P, sidedress at thinning - S_1, sidedress at layby-S_2) for a total of thirteen N treatments focused on N needs and response by the crop and investigated NO_3 leaching. Five treatments used low N levels at preplant and first sidedress with double rates applied as a second sidedress application. Two treatments tested high rates of N that were applied all as a preplant or sidedress application.

Data measurements included sampling petioles and whole plants at key stages of broccoli growth: thinning, rapid vegetative growth, button formation, preharvest, and postharvest. Tissue NO_3 levels were determined at the UC DANR laboratory and with a Cardy meter quick test. Soils samples to a depth of 60 inches (150 cm) were collected before planting and at harvest and analyzed for nitrate analysis in the laboratory. Ion exchange resin bags were buried at two depths, 18 and 36-inches, (45 and 90 cm) prior to seeding and removed after harvest to investigate NO_3 movement through the soil profile. Yield and quality characteristics were also assessed.

RESULTS AND CONCLUSIONS

Of the four field trials conducted for this project, the 1997 fall study had the best visual separation of fertilizer treatments as it was growing. This was substantiated over all measured parameters: broccoli head development and maturity, yield components, petiole samples for NO_3 content by standard lab practices and with the in-field quick tests using fresh plant sap, postharvest soil samples, NO_3 accumulation in ion exchange resin bags and plant biomass and N content. The field site was extremely low in preplant N (only 23 lb in top 5 feet) which was undoubtedly responsible for the dramatic visual observations.

Overall, the effects of N stress were smaller head size, decreased weight per head, and decreased yield (approximately 80 percent tonnage loss when unfertilized plot is compared to highest yielding fertilizer treatment—Table 1).

In the fall 1997 field trial 240 to 300 lb N/acre was needed to obtain maximum broccoli tonnage with good individual head weight under the field situation of very low preplant soil sample results. This is a higher minimum than the previous field studies, which indicated 180 lb N/acre. The application of preplant N was extremely important for high yields. Best yields (tons per acre and weight per head) were obtained with a minimum of 60 lb preplant providing at least 240 lb were applied in total. High tonnage could be obtained with 180 lb N/acre; however, head size and weight per head were less. Close to maximum yields could be obtained with any application timing (all preplant, three split applications, two split applications, or all early sidedress application) of 180-240 lb N/acre.

A useful indicator for sufficient N application was dry petiole NO_3-N. Higher values were observed in treatments greater than 180 lb N/acre, as were values for harvest yield. Like yield, dry petiole N showed little response to the higher N application rates (except when a very large amount was applied sidedress). Readings of nitrate concentrations in the petiole fresh sap made with the handheld Cardy meter showed similar trends. In previous field tests fresh sap results were less indicative of treatment differences, but in this study they mirrored the dry petiole data.

While crop yield response to 180 and 240 lb N/acre was not dependent upon application timing, the amount of leached NO_3, as estimated by trapping NO_3-N in ion exchange resin bags was affected (Tables 2 and 3). At 18-inches (just at or below the main rooting zone of broccoli) and at 36-inches (below the rooting zone), there was a tendency toward greater leaching with higher N application, and the highest recovery was found when total seasonal N was applied preplant. At 18-inches more NO_3 was leached at the 240 lb rate when applied in a single application than when it was split into three applications; however, at 36-inches the treatment separation was not the same. Data from deep soil cores at preplant and harvest tended to corroborate greater accumulation of NO_3 deep in the profile in treatments with high N application.

Preplant and postharvest soil samples collected in the Fall 1997 field experiment differed from results obtained from the three previous trials. In the earlier tests, the preplant soil samples contained higher amounts of NO_3-N as a field average with a lesser amount recovered postharvest. In the fall 1997, study more NO_3-N was recovered in the soil after harvest (Table 4). However, the specific treatment results are like the three previous trials: the largest pools of N remaining in the soils were obtained in the 240 lb preplant and the 300 lb total applied fertilizer treatments.

By taking a systems approach to evaluate crop performance as well as soil N fates and losses, this study has shown that best management practices for fertilizer scheduling must consider the relative benefits of adding excess fertilizer as well as the relative costs of leaching large amounts of NO_3. The final report will combine and compare all four field studies and aim to clarify these relationships.

In the final report the biomass and total N data will be plotted to show amount of N per plant on a weight basis (e.g., pounds N/plant) and then converted to lb N/acre to try to determine how many pounds of N fertilizer can be accounted for by the crop. Also, a time course of biomass or nitrogen accumulation aboveground in broccoli plants will be plotted at several rates of fertilizer. Theoretically these curves should show that plants cannot take up much nitrogen early in the season even if nitrogen is present. From a resource conservation and environmental pollution viewpoint, it would be more efficient to time N application to plant growth.

Table 1. Broccoli x N-rate and timing (Yield results—tons/acre)

	Nitrogen lb/Acre									1996 Spring		1997 Spring		1996 Fall		1997 Fall	
	P	+	S_1	+	S_2	=	Total										
1	0	+	0	+	0	=	0			6.1	e	4.3	g	4.7	e	1.3	f
2	15	+	15	+	30	=	60					8.0	ef	5.7	d	3.8	e
3	30	+	30	+	60	=	120					9.5	de	6.1	cd	5.0	d
4	45	+	45	+	90	=	180					11.3	c	7.1	ab	5.9	ab
5	60	+	60	+	120	=	240					13.4	ab	7.0	ab	6.2	a
6	75	+	75	+	150	=	300					14.7	a	7.9	a	6.4	a
7	30	+	30	+	0	=	60			7.4	bcd	7.6	f	6.6	bcd	3.5	e
8	45	+	45	+	0	=	90			7.2	cde	8.9	ef	6.8	bc	4.5	d
9	60	+	60	+	0	=	120			7.1	cde	10.8	cd	6.9	bc	5.0	cd
10	75	+	75	+	0	=	150			7.7	abcd	11.2	cd	6.7	bc	5.6	bc
11	90	+	90	+	0	=	180			8.2	abc	11.3	c	7.2	ab	5.9	ab
12	240	+	0	+	0	=	240			8.9	a	12.3	bc	6.8	bc	6.1	ab
13	0	+	240	+	0	=	240			7.7	abcd	12.2	bc	6.9	bc	6.1	ab
								Average		**7.7**		**10.4**		**6.6**		**5.0**	
								LSD .05		1.3		1.8		0.9		0.6	
								CV%		11.4		11.7		9.7		11.9	

Table 2. Broccoli x N-rate and timing (Ion exchange resin bags, 18-inch depth): Estimate of nitrate leaching (NO_3-N content lb/acre)

	Nitrogen lb/Acre									1996 Spring		1997 Spring		1996 Fall		1997 Fall	
	P	+	S_1	+	S_2	=	Total										
1	0	+	0	+	0	=	0			3.2	b	8.2	d	3.7	e	1.8	c
2	15	+	15	+	30	=	60					12.8	d	11.1	de	3.3	bc
3	30	+	30	+	60	=	120					50.5	bcd	35.6	cde	8.4	bc
4	45	+	45	+	90	=	180					91.0	bc	56.3	bc	8.1	bc
5	60	+	60	+	120	=	240					81.6	bcd	58.8	bc	10.3	bc
6	75	+	75	+	150	=	300					111.0	b	88.0	b	24.7	a
7	30	+	30	+	0	=	60			60.0	b	12.8	d	29.8	cde	1.6	c
9	60	+	60	+	0	=	120			137.8	b	27.1	cd	62.8	bc	3.5	bc
11	90	+	90	+	0	=	180			168.1	b	105.9	b	53.6	bcd	7.8	bc
12	240	+	0	+	0	=	240			424.2	a	206.8	a	201.9	a	26.0	a
13	0	+	240	+	0	=	240			30.3	b	44.2	bcd	60.1	bc	14.6	ab
								Average		**142.2**		**68.4**		**60.1**		**10.0**	
								LSD .05		214.2		76.9		44.0		11.9	
								CV%		99.5		77.8		50.6		82.5	

Table 3. Broccoli x N-rate and timing (Ion exchange resin bags, 36-inch depth): Estimate of nitrate leaching (NO_3-N content lb/acre)

	Nitrogen lb/Acre								1996 Spring		1997 Spring		1996 Fall		1997 Fall	
	P	+	S_1	+	S_2	=	Total									
1	0	+	0	+	0	=	0		22.3	d	9.1	b	23.1	c	1.4	d
2	15	+	15	+	30	=	60				7.7	b	27.0	bc	3.9	d
3	30	+	30	+	60	=	120				21.5	ab	24.1	c	3.4	d
4	45	+	45	+	90	=	180				27.2	ab	35.2	bc	8.5	cd
5	60	+	60	+	120	=	240				28.9	ab	33.5	bc	22.6	abc
6	75	+	75	+	150	=	300				51.4	a	60.8	ab	26.4	ab
7	30	+	30	+	0	=	60		80.3	bcd	9.8	b	9.7	c	2.3	d
9	60	+	60	+	0	=	120		170.2	abc	20.5	ab	24.3	c	3.5	d
11	90	+	90	+	0	=	180		163.8	abcd	26.5	ab	23.6	c	13.3	bcd
12	240	+	0	+	0	=	240		263.8	a	45.6	a	95.5	a	34.7	a
13	0	+	240	+	0	=	240		41.5	cd	24.8	ab	40.2	bc	5.7	cd
			Average						**123.6**		**24.8**		**36.1**		**11.4**	
			LSD .05						144.6		33.3		34.9		17.7	
			CV%						66.6		92.8		67.0		107.3	

Table 4. Summary of NO_3-N content (lb/acre) from soil samples

Soil sampling depth cm (ft)		*Spring 1996*		*Fall 1996*		*Spring 1997*		*Fall 1997*	
		*Pre**	*Post***	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*
0-30	(1)	61.4	17.8	60.6	3.8	77.5	7.2	11.6	6.6
30-60	(2)	9.5	21.3	13.9	2.9	27.7	1.1	3.6	3.6
60-90	(3)	8.8	31.9	8.9	2.1	4.6	1.7	2.1	61.9
90-120	(4)	36.6	35.6	6.4	9.0	12.7	6.7	3.8	2.7
120-150	(5)	23.6	22.7	5.3	8.0	2.4	4.5	2.0	0.7
Total		**139.9**	**129.3**	**95.0**	**25.8**	**126.0**	**21.1**	**23.1**	**75.5**

* preplant   ** postharvest

Effects of Irrigation Non-Uniformity on Nitrogen and Water Use Efficiencies in Shallow-Rooted Vegetable Cropping Systems

Project Leaders:
Blake Sanden
UC Cooperative Extension Kern County
Bakersfield, CA
661-868-6218

Jeffrey Mitchell
University of California, Davis
Kearney Agricultural Center
Parlier, CA

Laosheng Wu
Department of Soils and Environmental Sciences
University of California
Riverside, CA

Cooperators:
Susanne Leung
University of California
Riverside, CA

Bolthouse Farms
Kern County

INTRODUCTION

Solid-set sprinkler irrigation and fertigation using hand-move pipe is the most common irrigation system for production of high value vegetable crops in California. The most common design uses 30-foot lengths of pipe with 2-foot sprinkler risers set up in laterals with 40 to 48 foot spacing. The average distribution uniformity (DU) of 65 Mobile Lab Irrigation evaluations in Kern County from 1988 to 1993 for a variety of spacings was found to be 65.5 percent. This level of uniformity, coupled with high N fertilizer applications, poses risks of NO_3 leaching to groundwater in these shallow rooted cropping systems.

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

OBJECTIVES

For standard and alternative sprinkler lateral spacing in solid-set sprinkler irrigation systems:

1. Characterize in-field irrigation distribution uniformities (DU) and their impact on soil N distribution/leaching, crop N distribution, yield, and quality.
2. Use computer modeling to simulate these alternative management strategies given the soil hydraulic properties.
3. Determine the impact of sprinkler age on DU. (Added for the 1998-99 season.)

DESCRIPTION

Seven different sprinkler lateral spacings of 33.3 to 48 feet over three different carrot plantings were tested. The same field was used for the spring 1996 and fall 1997 trials with subsampling from nearly identical locations for both years. The age of sprinklers used each season were new (spring 1996), two years old (spring 1997), and greater than three years old (fall 1997). The first trial was planted on 40-inch beds with the last two on 36-inch beds. Irrigation duration was scheduled in an attempt to apply the same depth of water (about 2 inches for established carrots) to all spacings.

One intensively sampled grid with each node consisting of 2 beds wide by 5 feet long was established between sprinklers in each of the spacings. Soil samples, irrigation catchcan evaluations, and hand-harvested yields were determined for these grids to better understand the pattern of precipitation and yield under the different spacings. This required 30 to 48 sample points depending on lateral spacing. In addition to these grids, four replicated sites measuring yield, soil water content, precipitation, and NO_3 leaching were established at 3 to 4 locations in each lateral spacing in an attempt to sample the spots of high (Middle), medium (Mid Sprink), and low (Lateral) precipitation (Figure 1). Anion exchange resin bags (25 sq.cm. with 5 dry grams of BIO-RAD AG 1-X8 resin) were installed at 3 feet and retrieved three times during

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

Lateral Spacing (ft)	Typical Irrigation Set Time (hrs)	Applied Water per Set (in)	[1] Total Irrigation for Season (in)	Mean Root Yield for Grided Plots (ton/ac)	[2] Mean Normalized Sprinkler DU (%)	Yield DU (%)	[3] R^2 for Normalized Sprinkler and Yield DU	[4] Mean Evaluation DU (%)
Spring 1996								
33.3	8.5	2.21	25.65	35.95	84.1	84.3	0.047	*80.6ab
40.04	10	2.16	25.63	37.35	81.6	81.5	0.114	78.1a
46.7	12	2.23	26.08	36.03	89.9	85.4	0.073	86.0 b
Spring 1997								
42.0	10	2.41	30.94	*38.80A	87.6	89.3	0.054	82.0
48.0	12	†2.64	34.32	32.48 B	84.2	85.2	0.042	76.2
Fall 1997								
36.0	9.5	†2.67	19.64	35.91	84.2	87.2	0.063	75.2
42.0	11	2.35	17.96	34.58	90.8	85.6	0.124	77.4
45.0	12	2.40	17.27	34.81	87.6	88.0	0.054	71.8

1Rainfall negligible for fall 1996 and spring 1997. Fall 1997 includes 5.19" rainfall.
2Normalized precipitation for each grid element was computed as a percent of the average for each evaluation. The mean normal value for each element of all sprinkler evaluations times total precipitation for the season is used to compute mean normalized sprinkler DU.
3R2 values are for a second order polynomial regression of yield and normlaized precipitation by grid element and spacing.
4Equals the mean of computed DU values from individual evaluations. Does not include rainfall events.
*Numbers with different letters are significantly different at the 0.05 level.
†Pressure excessive due to cooperator error when changing sets.

the season to monitor nitrate leaching. Soil solution access tubes (SSAT) were installed in the final two trials as a spot comparison with resin bags.

Soil samples were taken at planting and after harvest to a depth of 4 feet to correspond with the location of resin bags. Plant samples were also collected during the season.

Undisturbed soil cores were taken from the 100-acre field to determine soil hydraulic characteristics to be used as computer model inputs. Model components include: irrigation and fertilization , water and N cycling and uptake in the rootzone, crop yield, and N leaching.

In light of apparent differences in DU due to sprinkler age (found during the first part of this study), the final component of this project has been regional solid set sprinkler evaluations to compare the impact on DU of new nozzles versus new sprinklers versus in-field sprinklers of various ages.

RESULTS

Irrigation System Distribution Uniformity

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

A "mean normalized sprinkler DU" was calculated to estimate the uniformity of precipitation for the whole season. This value accounts for shifts in wind pattern from one sprinkler evaluation to another and provides a more "plant based" viewpoint of seasonal precipitation uniformity. The result is a general increase of 4 to 8 percent in seasonal DU over the straight mean DU. These DU's (from a low of 81.6 to a high of 90.8 percent) are more consistent with the uniformity of total root yield as discussed below. Natural rainfall greatly increased the seasonal uniformity of the fall 1997 trial (Table 1) despite the older sprinklers. (See CDFA/FREP 1998 Proceedings for surface charts of seasonal DU and yield DU.)

Total Carrot Root Yield and Quality

Total carrot root yield and quality was not statistically different for any of the spacings for sampling over the entire field,

Table 2. Precipitation, nitrate leaching, plant growth, yield and quality as a function of monitoring location between sprinkler laterals for the same field over two different seasons.

Location	Total Precipitation (inches)	Resin Bag NO_3-N (lb/ac)	Plant Growth Rate[1] (g plant/day)	Total Yield (ton/ac)	Marketable Yield (ton/ac)	Cello Pack Carrot Yield (ton/ac)	"Baby" Peeled Carrot Yield (ton/ac)	Cull (ton/ac)
Spring 1996								
Mid Sprink	22.8a2	19.6	0.072	42.0	41.1	14.2	26.4	1.0
Middle	23.2 a	21.1	0.065	40.8	39.0	16.3	22.7	1.8
Lateral	19.2 b	19.7	0.073	41.3	39.9	15.2	24.7	1.5
Fall 1997								
Mid Sprink	16.0 b	216.9	0.075	37.6	33.7	21.0	6.7	0.5
Middle	16.6 b	243.4	0.066	34.7	30.5	25.8	4.7	0.8
Lateral	14.2 c	255.4	0.075	32.4	30.3	25.4	5.0	0.6
Sprinkler	21.6a	186.3	0.076	31.4	31.4	25.7	5.8	1.1

1Average over the entire growing season.
2Values separated by different letters are significantly different at 0.05 confidence level.
NO_3-N concentrations in soil solution access tubes (SSAT) were also unrealistically high. Further confounding these results is the fact that intercepted resin bag nitrate was lowest for the Sprinkler location that had the greatest precipitation and should have realized the greatest flux of nitrate over the season. This is not supposed to happen. Appropriate lab procedures and necessary dilutions appear to have been executed and control bags showed zero nitrate contamination.

although a consistent trend of 2 to 6 percent increased yield for the closest spacing was observed for each trial. Total root yield for the 42-foot intensively monitored grid in the Spring 1997 trial was significantly greater than the grid from the 48' spacing by 6.2 ton/acre (Table 1), but this difference was reduced to 1.5 ton/acre for overall replicated field sampling. Total root yield DU ranged from 81.5 to 89.3 percent with no significant differences from lateral spacing. Total precipitation in monitored grids ranged from 75 to 160 percent of ET for the season depending on location relative to sprinklers. There was no correlation with yield and applied water at these levels (Figure 2) for any spacing, suggesting that carrots are capable of maximum yield even under some deficit irrigation. Table 2 confirms these results for the replicated monitoring sites. No significant differences were found in yield or quality even though cumulative precipitation was significantly different for these locations.

Estimation of Nitrate Leaching

Nitrate leaching as estimated by anion-exchange resin bags was found to be 7 to 12 percent (19.2 to 30.5 lb/acre) of applied N (250 lb/acre) in the Spring 1996 trial (Table 2). The 40.0-foot lateral spacing leached significantly less NO_3 than the 33.3 or 46.7-foot spacings even though the 46.7-foot spacing proved to have the highest mean DU. An 85 percent efficiency of NO_3 recovery was observed for these bags using soil columns prepared in the laboratory from soils used in these trials. Use of these resin bags to accumulate total leached NO_3 seemed highly promising after the first season. Intercepted NO_3 in the Spring 1997 trial jumped to 18 to 27 percent of applied N (Data reported in 1998 FREP Proceedings). Resin bag results from the Fall 1997 trials, however, showed impossibly high levels of NO_3 leaching from 66 to 132 percent (more than 300 lb/acre for the 36-foot lateral spacing) of applied N (data reported in the 1998 FREP Proceedings).

Examining the degree of leaching by 'Location Relative to Sprinklers' (Table 2) reveals a much greater differential than seen between different lateral spacings (shown in the 1998 Proceedings). Data reported in Table 2 excludes the Spring 1997 trial, concentrating instead on the two carrot plantings from the same field and nearly the same sampling locations over two different seasons.

After seeing elevated levels of nitrate leaching in the Spring 1997 trial we had some concerns about passive diffusion of soil nitrate into the resin bags that represents part of the

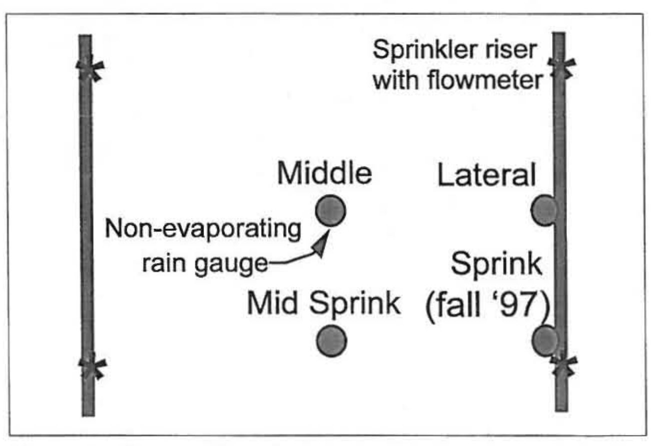


Figure 1. Key to replicated monitoring sites.

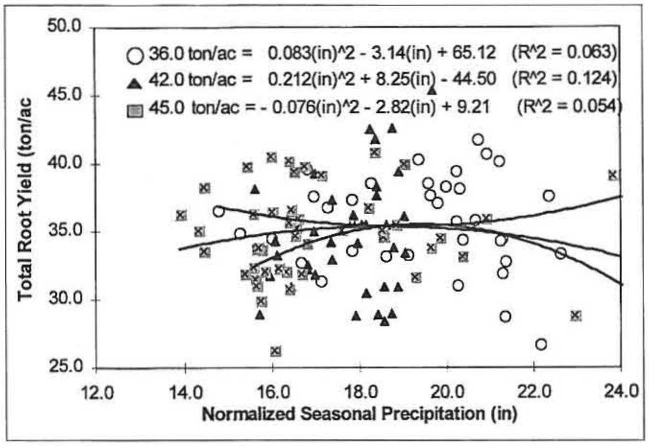


Figure 2. Second order polynomial regression of total root yield and normalized seasonal applied water for intensively monitored grids for all spacings for the fall 1997 trial. Same field and approximately same sites as spring 1996 trial.

background soil N pool that is not necessarily being leached out of the profile. A few bags were installed in the Fall 1997 trial that were exposed to the soil at the 3 feet depth, but protected from any leaching of water from above. These bags showed 30 to 50 ppm accumulated NO_3-N, which translates to 35 to 65 lb/acre NO_3-N that did not actually "leach" through these bags but was absorbed from nitrate resident at that depth. Values of leached NO_3 reported in Tables 2 has not been discounted by these amounts as the "diffusion bags" were placed at four locations only. An average "diffusion

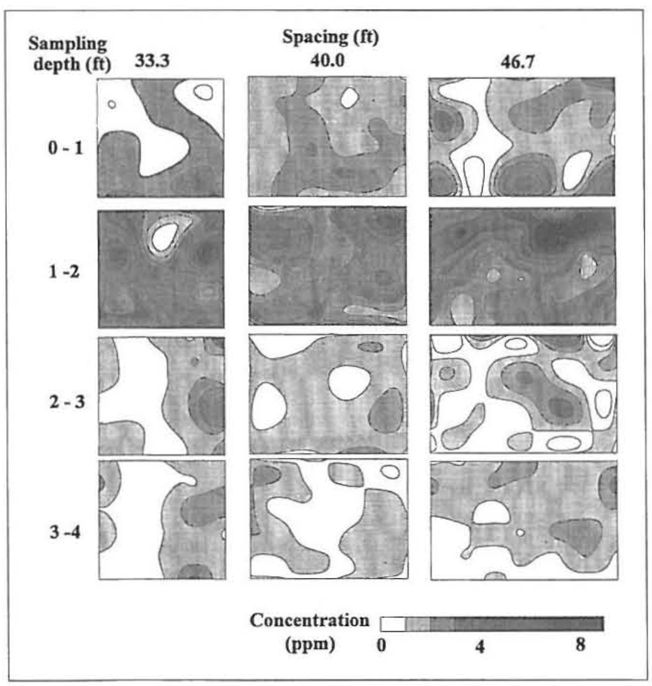


Figure 3. Seasonal (1996) average soil nitrate distribution at different depths and for different sprinkler spacings.

value discount" would have caused some monitoring sites to have negative nitrate leaching. More benchtop studies using these resin bags are needed to resolve this issue.

Nitrate leaching estimates from site-specific soil sampling is confounded by soil heterogeneity. Figure 3 illustrates the variability of the 1996 seasonal mean soil nitrate concentrations for all the spacings at the 1, 2, 3, and 4 foot depths.

The 1 to 2 foot depth (0.3 to 0.6 m) had the greatest concentration of clay relative to the other depths, and, therefore showed the highest concentration of NO_3. However, there was no correlation with soil NO_3 at this depth and NO_3 leaching as estimated by resin bags (Figure 4). Instead, cumu-

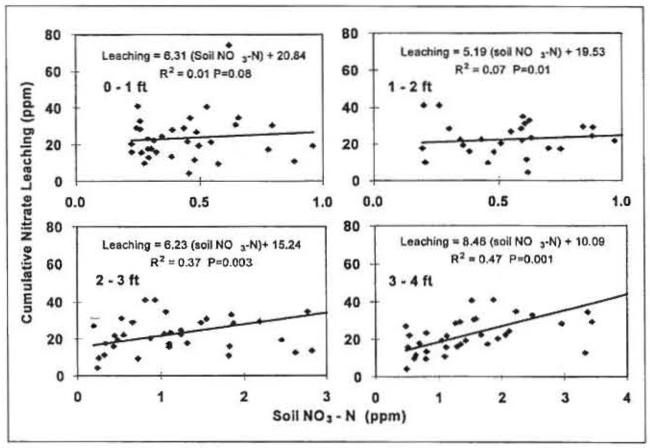


Figure 4. Relationship of cumulative nitrate leaching (as determined by resin bags) and soil nitrate at various depths for all sampling locations for the 1996 carrot crop.

lative leaching appeared significantly related to soil NO_3 at the 3 to 4 foot depth (0.9 to 1.2m). Even though this relationship is highly significant (a 99.9 percent confidence), the margin of error means that net NO_3 leaching could be anywhere from ten to twenty times the soil NO_3 concentration in these sandy soils.

On average, NO_3 content was 0.97 ppm in Spring 1996, which was significantly lower than 3.09 ppm in Fall 1997. The higher values in Fall 1997 were associated with high fertilizer input for potatoes planted in the spring prior to carrots. Figure 5 reveals that for the Fall 1997 crop, total soil nitrate load in the top four feet at 60 days after planting (about 11/1) was two to three times greater than 18 days after planting for the Spring 1996 crop. However, at the end of the season more soil NO_3 was present at the 4-foot depth for the 1996 crop than the 1997 crop. This is not surprising as more than twice the leaching occurred during the 1997 planting due to the late summer irrigations required for germination and winter El Nino rains. Figure 6 shows a signifi-

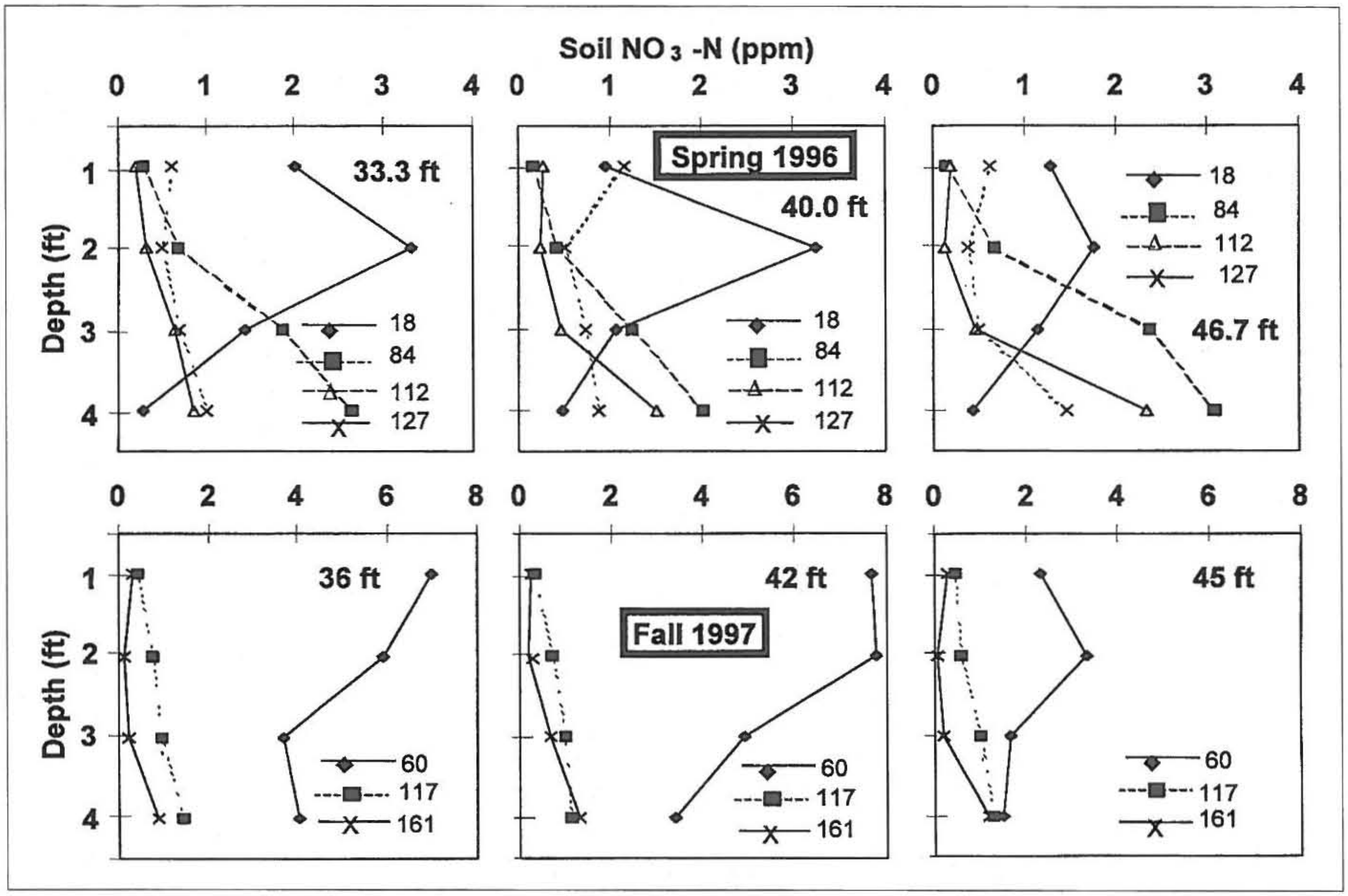


Figure 5. Change in soil nitrate with depth during the season. Legend indicates days after planting when sampling was done.

cant relationship between declining soil nitrate levels with increasing deep percolation for the 1 to 2 foot depth (the zone of slightly higher clay content). Leaching ran 0 to 6 inches depending on location for 1996 and 2 to 12 inches for 1997. Thus, cumulative NO_3 leaching for 1997 would have been substantially higher than 1996 with the end result being uniformly lower soil NO_3 levels.

Computer Simulations

Computer simulations conducted in this study used the ENVIRO-GRO model developed by Pang and Letey at UC Riverside. The adapted model simulates carrot growth in response to soil, water, salt and nutrient transport in three soils with different textures. Monte Carlo simulation of four DU's of 50, 75, 90, and 100 percent were used. The output from each run (100 runs for each of the three soil types) was then used to calculate the average ET, deep percolation, N uptake, nitrate leaching, and relative yield.

Typical soil hydraulic properties of a loamy sand, sandy loam and silty clay loam were used to drive the model. The simulation used the same amount of N fertilizer as was applied in the field for spring 1996. The N application methods were the same as for spring 1996 (Table 2). The ET rate in the simulation was adjusted to get the same seasonal total ET of 80 cm. The root growth (depth and shape) was adjusted to get the same N uptake, and it was within the normal growth range.

Not surprisingly, these simulations revealed that relative yield and seasonal ET was affected by DU on substantially course textured soils, but had little or no effect on carrots growth to a fine soil. In the sand and sandy loam, relative yield of carrots increases as irrigation uniformity increases. In the silty clay loam, however, the relative yield was not affected by irrigation uniformity. The simulation also showed that carrot yield is relatively lower in a fine-textured soil than in a coarse-textured soil, which is not necessarily true in Kern County production fields. The seasonal ET has the same trend as the relative yield, i.e., ET increases as the uniformity increases for the sand and the sandy loam; but ET was not affected by uniformity in the silty clay loam. Like the relative yield, total seasonal ET in the silty clay loam was much less than in the sand and sandy loam.

Nitrogen uptake in the sand and sandy loam increases as the irrigation uniformity increases; while N uptake was barely in-

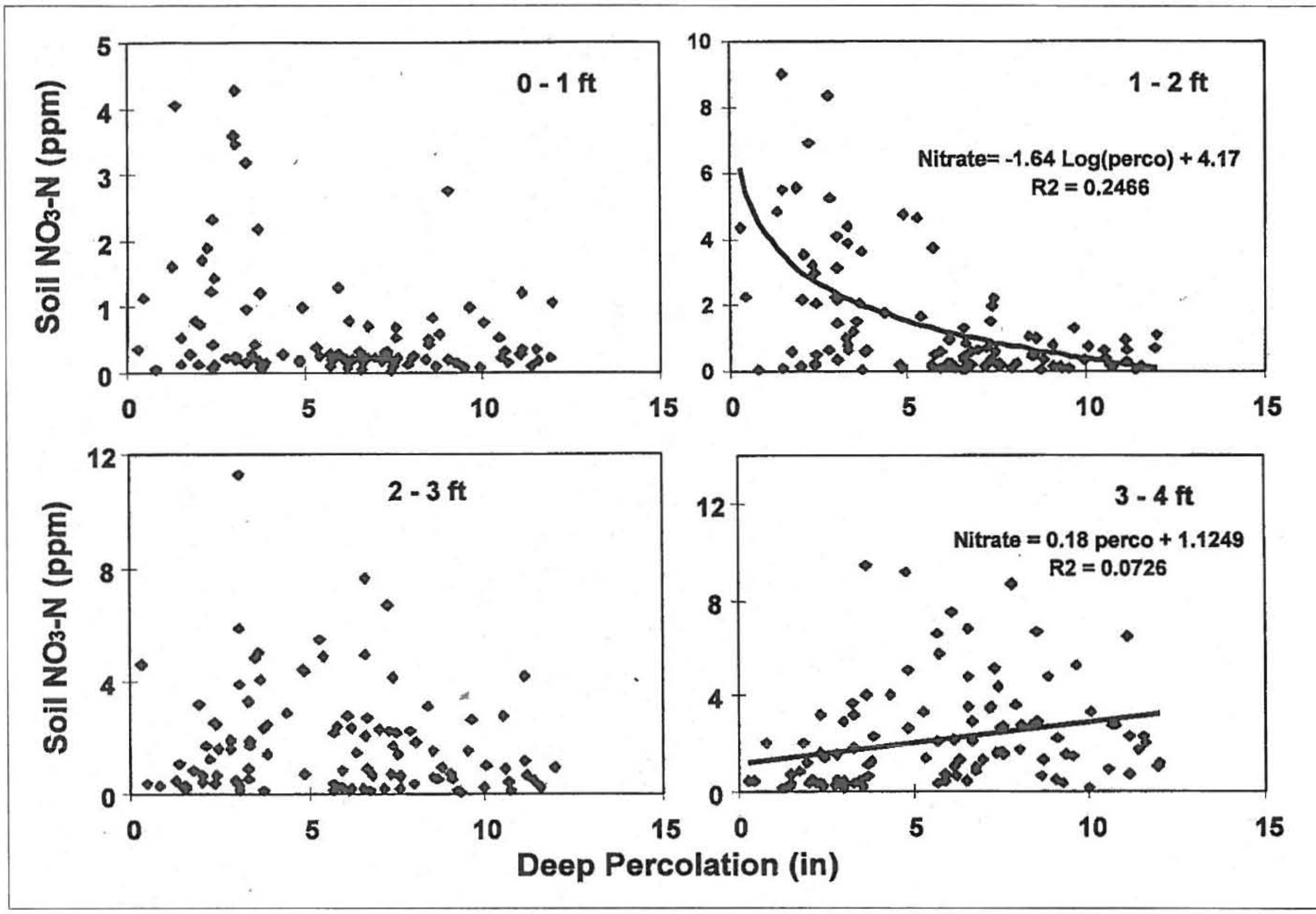


Figure 6. Soil NO_3-N concentrations as a function of cumulative deep percolation at that sampling location at the time of sampling. Deep percolation was estimated by subtracting crop ET as determined for the whole field from cumulative precipitation applied to that sampling location. Data for 1996 and 1997 crops are combined.

fluenced by irrigation uniformity in the silty clay loam. This is consistent with the simulated relative yields as the higher yield in the more responsive coarser soil, with increasing uniformity, requires more nitrogen to meet that yield.

Despite the field results of this study, model simulation showed nitrate leaching decreases dramatically as the irrigation uniformity increases in the sand and sandy loam. Two factors contribute to the decrease in NO_3 leaching in a field with high irrigation uniformity: (1) as the ET increases, the amount of deep percolation decreases; and (2) as ET and carrot yield increase, so does N uptake. In the silty clay loam, nitrate leaching was not affected by uniformity, but the leaching is lower than the coarse soils due to decreased deep-percolation loss.

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

Saturated hydraulic conductivity (K_S) values for the field used in the Spring 1996 and Fall 1997 trials ranged from a high of 3.35 in/hr in the top foot of soil to 0.94 in/hr for the four foot depth, with coefficients of variation (CV) for these values of 31 to 120 percent, respectively. Nitrate leaching proved to be significantly correlated only with K_S at the four foot depth ($R^2_{simulated}$ = 0.863 and R^2_{actual} = 0.712). Simulated values agreed very well with the actual data from this field. Our simulation model reveals that nonuniform leaching may be decreased as irrigation DU increases to some threshold, but can still be significant in a spatially variable soil even though the irrigation DU is 100 percent.

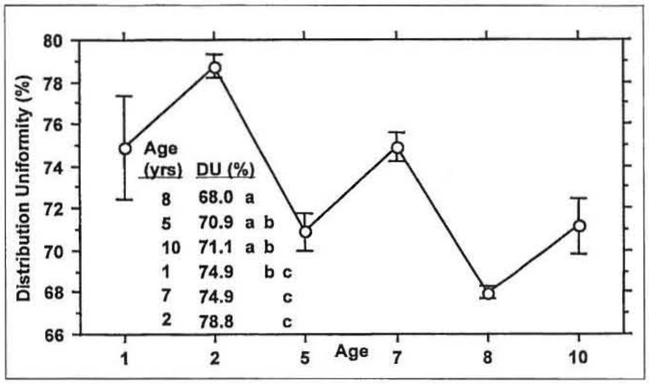


Figure 7. Impact of sprinkler system age on DU. Includes evaluations performed with new nozzles and sprinklers.

Irrigation System Evaluations

Regional irrigation system evaluations to examine the impact of sprinkler age revealed that this factor was not significant in improving DU. Forty-two evaluations of solid-set systems in ten different fields on irrigation systems ranging in age from 1 to 10 years were carried out between June 1998 and May 1999. Set duration ranged from 4 to 12 hours. The grower's existing system DU was evaluated in the same manner as for the carrot fields in the earlier part of this project. Using the same two laterals as those for the grower's system evaluation we installed a second set of catchcans four joints of pipe down the line (120 feet) and a third set another four joints down from that (240 feet away from the first catchcan set. For the 12 sprinkler heads surrounding the location of the second catchcan set we installed new nozzles (either 7/64 or 1/8 inch depending on the grower's system) into the grower's old sprinklers. For the third set, 12 new sprinkler heads were installed. The old sprinkler, new nozzle and new sprinklers were of course run simultaneously so that wind conditions and duration would be identical for all three evaluations.

Increasing system age showed a slight trend toward decreasing uniformity (Figure 7), but direct comparison of the original, new nozzles and new sprinklers showed no impact at all for age (Figure 8).

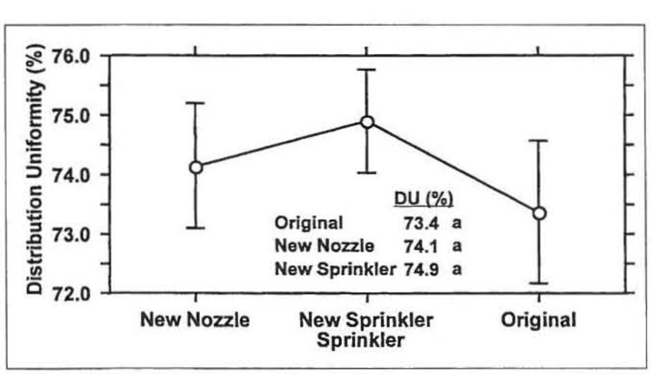


Figure 8. Impact of new nozzles and sprinkler heads on DU.

Figure 9 illustrates the depth of precipitation and corresponding DU for 5, 10, and 18 hour irrigation durations for the original grower sprinklers for 7-year old solid-set sprinkler pipe in potatoes with a 45-foot lateral spacing and 7/64 nozzles. Although not a significant enough area to substantially reduce DU, the one disadvantage of older sprinklers is increased misting from worn nozzles and spoons. Figure 9 shows the typical spike in the amount of precipitation within 3 to 5 feet of the sprinkler.

Set duration, or cumulative precipitation, made the most significant impact on DU (Figure 10). A very clear breakpoint at 10 hours was evident. Below this duration DU averaged around 72 percent. At or above this threshold the average was

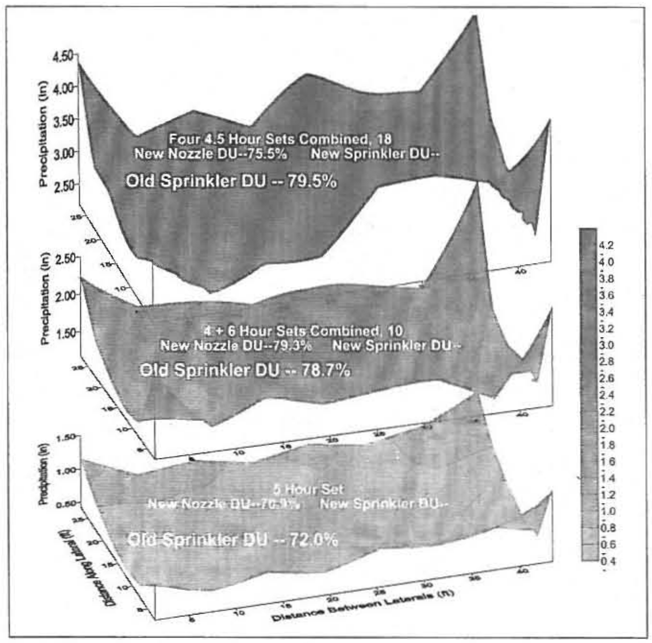


Figure 9. Surface contours of sprinkler precipitation over identical locations for irrigation durations of 5, 10 and 18 hours using seven-year-old Weather-Tec 10/20 sprinklers on two-foot risers with 7/64 nozzles running at 52 psi.

about 78 percent. This analysis includes three evaluations of an 18-hour duration that was actually the total precipitation from four, 4.5-hour irrigation sets in potatoes. As shown by the "seasonal normalized precipitation" DU from the carrot trials, the DU of the cumulative precipitation is significantly greater than the DU for any single short irrigation.

Finally, despite the results of 44 separate evaluations of the seven different lateral spacings examined during the carrot trials, narrower lateral spacing in these regional evaluations gave significantly higher DU then the 45 to 48 foot spacings (Figure 11). This also concurs with our computer modeling simulations in which DU improved with narrower spacing.

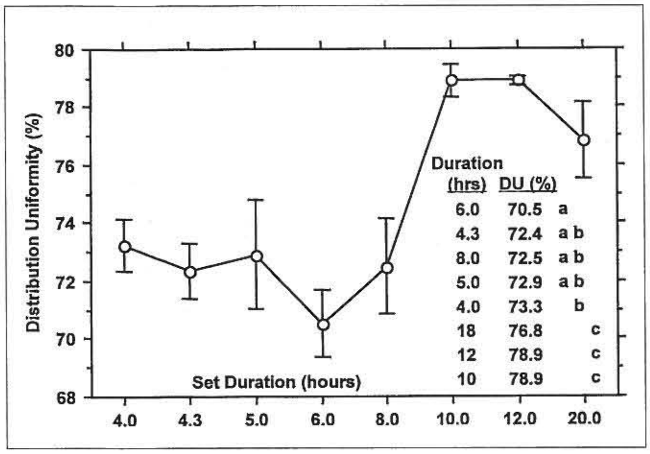


Figure 10. Impact of set duration and accumulated precipitation on DU for one-time regional evaluations.

Our earlier field work in this project, however, indicates that this benefit may disappear when considering precipitation uniformity over the whole season, and probably not translate into any yield benefit for carrots even though computer simulations on sandy soil say that yield should be improved.

CONCLUSIONS

Single event irrigation evaluations for distribution uniformity of sprinkler precipitation are insufficient indicators of season-long irrigation uniformity and impact on yield. Solid-set lateral spacings of 33.3 to 46.7 feet were found to have no significant impact on field yield or nitrate leaching. This may be in part because carrot yield was unaffected as long as applied water was between 75 to 160 percent ET. As applied water decreases, the impact of uniformity on yield should become more significant. Computer simulations showed that narrower lateral spacing should improve carrot yield and decrease NO_3 leaching on sandy ground. This was not corroborated in our field studies. Modeling further showed that as soil texture moved from sandy to silty clay loam then lateral spacing made no difference in simulated yield or leaching.

Nitrate leaching in Kern County carrot fields with sandy soils appears to range from 15 to perhaps more than 60 lb/acre N depending on previous crop rotation and time of planting. Current resin bag methodology proved undependable for verifying total NO_3 leaching in the second and third test fields. The reasons for this are unclear at this time but appear to be related to the adsorption of existing soil nitrates at the time of installation and perhaps the length of time bags remain in the soil. Resin bag estimates of NO_3 leaching were only weakly correlated to deep percolation, were not at all correlated to lateral spacing, but were significantly related to soil NO_3 concentrations at the three and four foot depths in 1996. Soil NO_3 levels were significantly related to deep percolation at the three-foot depth where clay content was slightly higher. Soil N reserve in the form of ammonium content and distribution for both years was not correlated to lateral spacing or irrigation uniformity. Our computer simulations and field data indicate that there is a threshold DU (possibly around 75 percent) and very minimal clay content above which yield and nitrate leaching will be unresponsive. At this point, assuming proper scheduling of irrigations and fertilizer application, the natural variability of soil characteristics determines the extent of deep percolation and nitrate leaching.

Regional sampling of 1 to 10-year old solid-set sprinkler systems across Kern County showed that DU was not significantly affected by the age of nozzles and sprinkler heads. Instead, irrigation set duration, or cumulative precipitation of 10 hours or more was found to significantly improve DU. For these evaluations, narrower lateral spacing was also found to significantly improve DU. However, in light of the intensive monitoring and development of a "seasonal uniformity" evaluation of the earlier carrot fields it is clear that a one-time catchcan DU estimate is an inadequate indicator of performance and yield impacts.

This study showed that sprinkler spacing has much less effect on NO_3 movement than suggested by earlier studies. These results indicate that under conditions similar to our study, during which irrigation uniformity was greater than 75 percent and the crop received sufficient water and fertilizer, any of the tested sprinkler spacings would lead to similar NO_3 distribution and movement. Therefore, as long as proper field pressure is maintained (52 to 56 psi), system leaks minimal and sprinklers turn properly, growers can choose the most cost efficient or the most convenient lateral spacing between 33 and 46 feet and maintain optimal efficiency and yield.

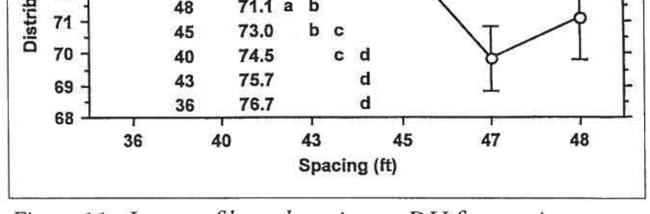


Figure 11. Impact of lateral spacing on DU for one-time regional tests.

DRIP IRRIGATION AND FERTIGATION SCHEDULING FOR CELERY PRODUCTION

Project Leader:
Timothy K. Hartz
Department of Vegetable Crops
University of California, Davis, CA
(530) 752-1738

Cooperators:
Warren Bendixen
UC Cooperative Extension Santa Barbara County

Gerald Czarnecki
Cachuma Resource Conservation District
Santa Maria, CA

Commercial growers in Monterey, Santa Barbara and Ventura Counties

OBJECTIVES

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

DESCRIPTION

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

An additional trial was conducted in Monterey County in 1999. A split plot experimental design was used, in which the main plot was early–season irrigation rate (the field system or 50 percent higher flow, delivered through the first 25 days of the drip irrigation season), and the split plot was irrigation rate for the final 37 days before the August 11 harvest (either the field rate, 30 percent less, or 50 percent more). Data collection was as described for the 1998 trials.

RESULTS AND CONCLUSIONS

There were vast differences among the 1998 growers in drip irrigation management strategies (Table 1). Seasonal water application through the field systems ranged from 120 percent to 290 percent of CIMIS reference evapotranspiration (ET_0). Drip irrigation was applied on average only 5-7 days in most trials; such widely spaced irrigations resulted in a relatively large amount of cumulative ET_0 between irrigations (up to 1.1 inches). Not surprisingly, when drip irrigation was applied individual applications were quite heavy averaging an inch or more in most trials. Unlike sprinkler irrigation, water applied through a drip system does not wet the entire soil

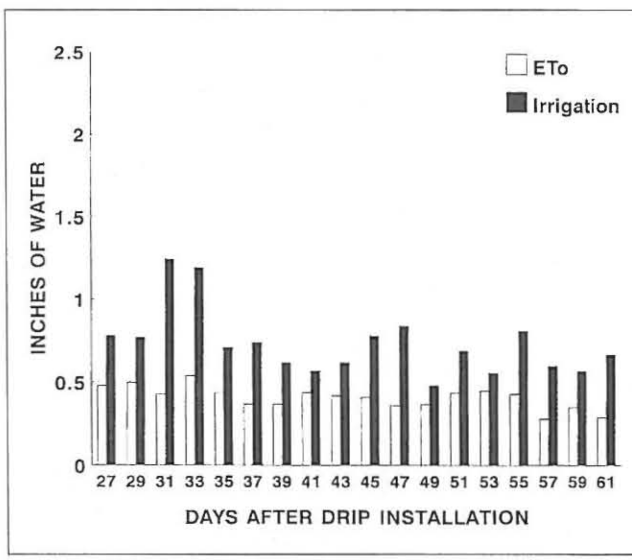


Figure 1. CIMIS evapotranspiration (ET_0) and drip irrigation in the 1999 Monterey County trial.

Table 1. *Drip irrigation management practices in the 1998 celery trials.*

Field trial		*Season*	*Seasonal ET_0 (inches)^z*	*Irrigation applied (inches)^z*	*Ave drip irrigation frequency (days)*	*Ave ET_0 per irrigation (inches)*	*Ave drip irrigation volume (inches)*
Ventura		fall	8.5	13.3^y	6	0.8	1.0
Santa Barbara	#1	summer	8.2	11.8^y	5	0.9	1.4
Santa Barbara	#2	fall	5.9	8.9^y	7	0.7	1.0
Santa Barbara	#3	fall	6.4	13.4	7	0.7	1.5
Monterey	#1	summer	10.2	29.6^x	4	0.9	2.7
Monterey	#2	summer	10.6	12.9	3	0.6	0.7

^{z}from drip installation to harvest
^{y}includes one furrow irrigation after drip installation
^{x}drip irrigation terminated about 3 weeks before harvest; crop finished with sprinklers

volume, but is concentrated in the bed center; even in relatively heavy soil significant leaching can occur when individual drip applications approach or exceed 1 inch. Such widely spaced irrigations resulted in tensiometers at some sites periodically exceeding 50 cb between irrigations, even in plots where irrigation volume significantly exceeded ET_0. None of the 1998 growers based irrigation directly on real-time ET_0, and only at the Monterey #2 site was irrigation delivered throughout the season in rough proportion to historical average ET_0. At the Santa Barbara #1 and #2 sites, and the Monterey #1 site reducing seasonal drip application by 20 percent or more did not affect crop yield or quality. Only one site (Monterey #2) had significant levels of pithiness. At that site the grower used relatively high frequency irrigation, generally keeping pace with historical average ET_0. However, since the grower was not specifically tying irrigation volume to current ET_0, there were two periods of abnormally hot weather when irrigation fell behind. Those transient water stresses, documented by tensiometer readings > 30 cb, resulted in 12 percent of the plants receiving the field rate of irrigation showing serious pithiness of petioles. By comparison, plots receiving more water were virtually free of pith development.

In the 1999 trial the grower irrigated every other day for the last five weeks of the season, applying 180 percent of ET_0 over that period (Figure 1). Despite that luxuriant level of irrigation there was still a significant level of pithiness in the field flow rate plots (Table 2); 19 percent of plants in those plots had objectionable levels of pith development. The plots receiving the higher irrigation rate (50 percent more than the field flow) had significantly lower levels of pithiness (only 5 percent of plants seriously affected). Although the low flow rate plots received more than 130 percent of ET_0, yields significantly declined and pithiness was severe. In this field the problem was not irrigation volume or frequency per se, but rather the unusual soil conditions. This sandy loam soil had low water holding capacity and very poor capillary water movement away from the drip tape. A substantial portion of applied water leached below the top foot of soil, the primary rooting zone for celery. Tensiometers set in the plant row at 10-inch depth routinely showed moisture stress (readings of 30-80 cb) in both the low flow and the field flow plots. The main benefit of the high flow tape was that it gave a broader wetting pattern, leaving enough water in the top foot of soil to carry the crop for over two days, even in periods when daily ET_0 exceeded 0.25 inches. Given these inherent soil limitations, a grower's options in producing summer celery would be to use daily irrigation, or to significantly overwater. In periods of lower daily ET_0, irrigation frequency could be reduced.

This project has shown that celery growers currently do not derive maximum benefit from drip irrigation. In some cases, significant amounts of water and fertigated N, are wasted; in others, crop quality is compromised. More attention to field specific factors such as soil water holding capacity, capillary water movement, and ET_0 are warranted. In general, more frequent watering, with lower volume per application, would dramatically improve both water and N use efficiency.

Table 2. *Effect of irrigation management on celery production, 1999 trial.*

		Inches			
*Early season irrigation**	*End of season irrigation***	*CIMIS ET_0*	*Irrigation volume*	*Ave trimmed wt (lb/plant)*	*Pith index****
Field		6.0	6.0	1.78	1.5
High		6.0	9.0	1.82	1.4
Low	7.3	9.7	1.47	2.4	
Field	7.3	13.3	1.97	1.1	
High	7.3	20.0	1.99	0.8	

*flow rate for first 25 days of the drip irrigation season; yields and pith ratings averaged over end of season flow rates
**flow rate for last 37 days before harvest; yields and pith ratings averaged over early season flow rates
***average pithiness of petioles, 0=none, 3=severe

Demonstration of Presidedress Soil Nitrate Testing as a Nitrogen Management Tool

Project Leader:
Timothy K. Hartz
Department of Vegetable Crops
University of California
Davis, CA
(530) 752-1738

Cooperators:
Richard Smith
UC Cooperative Extension
Salinas, CA

Commercial lettuce growers in the Salinas Valley

OBJECTIVE

Demonstrate the reliability of using presidedress soil NO_3-N concentration to guide sidedress application rates in lettuce production.

DESCRIPTION

Nitrate pollution of groundwater in the coastal valleys of California is widely recognized to be a serious environmental issue that threatens to disrupt the commercial vegetable industry. Vegetable cropping is intensive, with 2-3 crops produced annually; high levels of N fertilization are common. To date there has been no system available to growers that could reliably predict field-specific sidedress N requirement, thereby reducing unnecessary fertilizer application. Previous CDFA grants funded research into the adaptation of presidedress soil nitrate testing (PSNT), widely used in the Midwest to predict corn sidedress requirement, to irrigated coastal vegetable production. In the 1996 and 1997 production seasons trials were conducted in 11 commercial lettuce fields in the Salinas and Santa Maria Valleys. Fields were chosen in which residual soil NO_3-N in the top foot was greater than 20 ppm. Replicated plots were established in which the first sidedress N application was skipped; the production from these plots was compared with matching plots receiving the cooperating growers' full N program. In no field did the elimination of that first sidedress N application significantly reduce marketable yield. Clearly, sidedressing can be delayed in fields with this relatively high level of residual soil NO_3-N with no adverse consequences.

Additional trials were conducted in 1998 to determine whether the PSNT approach could be adapted for use in fields with lower residual soil NO_3-N levels. Four commercial fields in the Salinas Valley were identified in which soil NO_3-N was less than 20 ppm just prior to the initial sidedress N application. Replicated plots were established in which the amount of N applied at each sidedressing was determined by current soil NO_3-N concentration, as estimated by an on-farm "quick test" method; for each ppm soil NO_3-N below the 20 ppm threshold, 4 lb N/acre were applied. Using this technique seasonal sidedress rate were reduced an average of 70 lb/acre with no adverse effects on marketable yields or postharvest quality.

The current project was conducted to demonstrate the effectiveness of the PSNT technique under a wide variety of soil types and grower practices. Large plots (36 beds wide, the length of the field) were established in ten commercial lettuce fields in the Salinas Valley. Within these plots, soil NO_3-N in the top foot was evaluated by the quick test technique just prior to each sidedressing; sidedress N application was based on residual NO_3-N concentration, 4 lb N/acre for each ppm NO_3-N below 20 ppm. If soil NO_3-N was > 20 ppm, the sidedressing was skipped. These plots were compared to adjacent plots receiving the growers' full N regime. Yield data were collected from the commercial harvest crews. Postharvest quality (appearance, decay, russet spot development) was rated on 48 heads per N treatment per field, after 10-14 days of storage at 40°F.

RESULTS AND CONCLUSIONS

At the time of this report, only 5 of the fields have been harvested. In two of those fields, residual soil NO_3-N at the first sidedressing was greater than 20 ppm, the other fields ranging from 4-18 ppm. Overall, following the PSNT approach to fertilizer scheduling reduced average N application by 97 lb N/acre (see Table). Although, as paired comparisons, no statistical comparison of yield could be made within a particular field, average production across fields was virtually identical between the N treatments. Similarly, there was no apparent difference between N treatments in postharvest quality. The extra N applied in the grower standard N plots appeared to have no beneficial effect.

Effect of presidedress soil nitrate testing on N application rate and lettuce yield, 1999 trials.

			Boxes/acre harvested					% of all plants harvested			
Field	*N treatment*	*Seasonal sidedress N application* (lb/acre)*	*Total*	*Jumbo 24's*	*Regular 24's*	*30's*	*Export 38's*	*Total*	*24's*	*30's*	*38's*
1	PSNT	130	803	730			73	80	73		7
	Grower	250	835	760			81	81	75		6
2	PSNT	120	1106		1013	93		94	84	10	
	Grower	190	942		850	92		90	79	11	
3	PSNT	170	880		660	220		82	58	24	
	Grower	210	920		600	320		86	51	35	
4	PSNT	150	893		893			74	74		
	Grower	300	963		963			78	78		
5	PSNT	15	982	171	811			87	87		
	Grower	122	1013	101	912			84	84		
Average	PSNT	117	933	34	821	63	15	83	75	7	1
	Grower	214	934	20	817	82	15	84	73	9	1

*Sidedress N rate determined by presidedress soil nitrate testing (PSNT) or by growers' standard program

In summary, the PSNT approach to fertilizer decision making has been consistently successful (20 completed field trials over 4 years, representing a wide range of grower practices and soil conditions) in reducing unnecessary N applications; savings have averaged greater than 75 lb N/acre. This potential fertilizer cost savings more than offsets the cost associated with in-season soil NO_3-N monitoring. Widespread adoption of this practice would substantially reduce the potential for NO_3-N leaching from lettuce fields.

Water and Fertilizer Management for Garlic

Project Leaders:
Marita Cantwell/ Ron Voss
Department of Vegetable Crops
University of California
Davis, CA
(530) 752-7305

Blaine Hanson
Department of Land, Air and Water Resources
University of California
Davis, CA

Don May
UC Cooperative Extension Fresno County
Fresno, CA

Bob Rice
Rogers Foods
Turlock, CA

OBJECTIVES

The objectives of the research are to:

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

DESCRIPTION

Garlic is one of the important crops in annual cropping systems of the San Joaquin Valley and most of California's garlic is produced in this area. California produces more than 80 percent of the US garlic, thus any information on determining the most efficient and effective water and nutrient management of garlic must be developed in this area. Because of its rooting structure, garlic is a relatively inefficient user of both water and soil nutrients. Fertilization application rates of N are usually in excess of those generally recommended. Grower's fertilization and irrigation practices vary considerably and clear guidelines are not available. Timing and amount of irrigation, and the relationships among fertility-water management and yield are the areas with very little information. This is especially true for 'virus-free' garlic, which has a much higher yield potential. The purpose of the project is two-fold. One is to develop relationships between nutrient-water management and postharvest quality of garlic, and the other is to determine the relationships between nutrient-water management and nitrate movement, potential NO_3 pollution and garlic production.

A three-year research project was initiated at West Side Research and Extension Center in September 1996, with industry funding to assess the relationships among fertilizer management, water management, and garlic yield. The project was expanded in 1997 with CDFA/FREP funding for evaluations of leaf tissue analyses, soil N movement, and postharvest quality.

RESULTS AND CONCLUSIONS

Establishment and Management of Field Plots

Irrigation treatments for 1998 consisted of water applications equal to 85 percent (T1), 100 percent (T2), 115 percent (T3), and 130 percent (T4) of the potential evapotranspiration. Measurements of soil moisture content of T2 were to be the basis for estimating the amount of water to be applied. Weekly irrigations were to occur based on the 1997 results.

However, because of rainfall during the winter and spring, the irrigation treatments could not be applied. Instead, the effect of the timing of the irrigation cutoff was investigated with a cutoff date of May 12 for T1, a cutoff of May 19 for T2, a cutoff of May 25 for T3, and a cutoff of June 1 for T4 (Table 1). The N fertilization rates applied in 1998 are also summarized in Table 1. The total N actually applied is compared to treatment goals. The PK fertilization trial treatments actually applied in fall 1997 are described in Table 2. All plots received same N fertilization.

Soil and Tissue Analyses

Leaf tissue samples were collected only on one date (April 2 for fertilizer/irrigation trial and April 7 for PK trial). Samples were submitted to the UC-DANR laboratory for analyses. Data for PK trial are summarized in Table 3. At the time of leaf sampling, differences among PK fertility treatments were minimal.

Table 1. Irrigation and fertilization treatments applied in 1998.

Irrigation Trt.	Date last irrigation	N Fertilization Treatment	Preplant	Side-dress	Water-run	Total # N Applied	# N Goal
T1	May 12	F1	70	30	0	100	100
T2	May 19	F2	70	65	20	155	175
T3	May 25	F3	70	140	20	230	250
T4	June 4	F4	70	175	40	285	325
		F5	70	250	40	360	400

Quality Evaluations at Harvest

The last irrigation was June 4. Harvest for yield and quality was accomplished in late June. Bulbs were cured, undercut, and mechanically dug. For the quality/postharvest evaluations, all garlic was manually dug in early June (June 3 and 12). After digging, bulbs were covered with dry plant residue for one week of field curing. For the fertilization trial, bulbs were manually dug on June 8 and cured for about one week in the field. Quality/postharvest samples were transferred to an outdoor shed for additional two weeks of curing/drying.

Yield, grade, plant maturity characteristics were recorded. Observations were made during the last stages of development. Bulbs from each plot were graded into four size categories. Yields were determined on three subplots within each treatment plot.

Laboratory analyses were done after harvest. Garlic cloves were evaluated for soluble solids contents and percent dry weight. Selected samples were also analyzed for pungency by the pyruvate assay and by a more specific thiosulfinate assay. Results for the pyruvate assay are presented on a dry weight basis.

Table 2. Phosphorus and potassium fertilization treatments applied in fall 1997.

PK Treatment No.	P	Preplant K	Sidedress K
1	0	0	0
2	0	100	0
3	0	0	100
4	0	100	100
5	60	0	0
6	60	100	0
7	60	0	100
8	60	100	100
9	120	0	0
10	120	100	0
11	120	0	100
12	120	100	100

1998 Fertilization-Irrigation Trial

Results of the irrigation treatments showed decreasing bulb count and bulb weight with time of the last irrigation, while the piece weight yields increased with time. Irrigation treatments had no effect on the percent soluble solids. Shattering of the bulbs caused the decrease in bulb weight with time. Results of the 1998 N fertilizer treatments also showed a decreasing bulb count and bulb weight with increasing N applications. At the same time, the piece weight yield increased with increasing N applications. Soluble solids percentage decreased with increasing N applications.

Based on the 1998 results, late irrigations beyond the first part of May can reduce bulb count and bulb yields. Piece weight yields increased for the latter irrigation. The N fertilizer treatments showed decreasing bulb count and total weight with increasing N applications. Little yield difference occurred between the middle three N fertilizer applications with the smallest total yields for the smallest and largest N applications. These results are not entirely consistent with the 1997 results.

Table 3. Garlic petiole and leave analyses from samples of the PK Trial taken on April 7, 1998.

PK Treatment No.	% Total N	% Total P	% Total K
1	3.19	0.37	3.01
2	3.28	0.36	2.90
3	3.33	0.36	3.06
4	3.38	0.36	3.02
5	3.29	0.39	3.07
6	3.44	0.40	2.95
7	3.38	0.36	3.08
8	3.28	0.38	3.08
9	3.32	0.41	3.00
10	3.32	0.38	3.11
11	3.31	0.38	3.00
12	3.44	0.37	3.06
Average	3.31	0.37	3.02
LSD.05	0.06	0.03	0.05

Table 4. Composition and other quality aspects of peeled garlic cloves from 1998 Irrigation and fertilization trial. Analyses were done after field and laboratory curing (about 3 weeks). Data are averages from 60 outer cloves from 10 bulbs per replication x 6 field replications per treatment.

Field Treatment	Date Last Irrigation	Total lb N	Weight per bulb g	% Dry Weight	% Soluble Solids	Pungency[1] (µm/g dw)	Sprout[2] Develop.	Greentip[3]	Firmness[4] (lb)	Chroma[5]	Hue[5]
Dry F1	(T1) 5/12	100	27.8	39.6	39.6	49.3	0.13	1.16	4.07	8.9	115.8
Dry F3		250	33.9	36.7	37.4	45.5	0.07	1.06	4.07	8.8	110.7
Dry F5		400	32.4	36.8	37.8	49.6	0.07	1.04	4.21	9.4	109.8
Average			**31.4**	**37.7**	**38.3**	**48.1**	**0.09**	**1.09**	**4.16**	**8.9**	**112.1**
Wet F1	(T4) 6/1	100	34.7	36.8	38.7	64.1	0.08	1.21	4.39	9.3	105.9
Wet F3		250	38.2	35.0	35.9	60.7	0.09	1.00	4.15	8.8	104.6
Wet F5		400	35.5	33.4	35.0	60.7	0.07	1.00	3.94	8.5	112.4
Average			**36.1**	**35.0**	**36.5**	**61.8**	**0.08**	**1.07**	**4.12**	**9.0**	**107.6**
LSD.05			2.4	0.5	0.5	5.4	0.03	0.12	0.13	ns	ns

1 Pungency estimated as µmole pyruvate/g dry weight; data is average of 3 composite samples per treatment.
2 Cloves were sectioned longitudinally and the length of the sprout was estimated as a fraction of full clove length; data from 30 cloves per treatment. A score of 1.00 indicates that sprout equals clove length.
3 Greentip scored on 1 to 5 scale, where 1=none, 2=slight, 3=moderate, 4=mod.severe and 5=severe (>25% of clove green).
4 Firmness estimated as lbs-force to penetrate with a 0.3 mm probe.
5 Chroma calculated from a* and b* color values; chroma = $((a^*)^2+(b^*)^2)^{1/2}$. Hue calculated as arctan of b*/a*. L is measure of lightness

Garlic bulbs from the 1998 dry treatments (T1) had an average 14 percent lower weight than bulbs from the wet (T4) treatments. With higher irrigation level, N fertilization did not significantly affect bulb weight; however with low irrigation level, higher fertilization levels reduced bulb size. Because of the wet spring, there were notable levels of decay and waxy breakdown on the bulbs at harvest after field curing, with an average of 12 percent of the bulbs affected. Dry weight percent was significantly higher under dry irrigation regimes; higher N fertilization reduced percent dry weight. Both data from mechanically harvested and manually harvested bulbs show the same trends in dry weight (Table 4).

The percent soluble solids followed a similar trend to the percent dry weight analyses in relation to the field treatments, and are closely correlated (see Figure 1). The percent soluble solids and percent dry weight of the cloves from the 1998 harvest were substantially lower than values for the 1997 garlic. There were minor differences in whiteness of the cloves (L* color value) and no significant differences in coloration (chroma value) at harvest after curing (Table 4).

In 1998 an assay was used for pungency which is more specific to garlic. The bulbs from the dry irrigation treatment were less pungent than those from the wet irrigation treatments (Table 4). Pungency was lower for the lowest fertilization level. It was observed that pungency may be correlated to percent dry weight.

1998 PK Fertilization Trial

Data for yield from mechanically harvested plots will be presented later in subsequent reports. The highest fertilization regime (PK#12) resulted in the lowest weight per bulb (Table 5). The highest percent dry matter, percent soluble solids, firmness and white color was obtained with fertilization regime #6 (60 lb P and 100 lb K). Phosphorus fertilization without potassium (fert regime #9) resulted in cloves with the poorest color and the highest pungency. The relationship between pungency and dry matter was not as clear in PK experiment as in the N fertilization-irrigation trial (see Figure 1).

SUMMARY

The report describes two field trials were conducted in 1998. Due to the wet spring weather, the irrigation trial was converted into a "date of last irrigation" trial. Leaf tissue analyses conducted on one set of samples only are also mentioned. Total plot yields were higher with earlier cutoff irrigation dates, but piece weights were less under these conditions. Soluble solids contents were only slightly affected (but significantly) by irrigation regimes. High N fertilization notably decreased percent soluble solids and percent dry weight. Low N fertilization resulted in a higher incidence of cloves with green tips. Pungency was lowest with the earliest cutoff date, and highest when garlic was irrigated near harvest. Percent soluble solids, dry weight and pungency were higher in all treatments than in control samples (no PK application).

Table 5. Composition and other quality aspects of peeled garlic cloves from 1998 PK fertilization trial. Analyses were done after field and laboratory curing (about 3 weeks). Data are averages from 60 outer cloves from 10 bulbs per replication x 6 field replications per treatment.

Field Treatment	Total lb P	Total lb K	Weight per bulb g	% Dry Weight	% Soluble Solids	Pungency[1] (µm/g dw)	Sprout[2] Develop.	Greentip[3]	Firmness[4] (lb)	Chroma[5]	Hue[5]
PK # 1	0	0	33.5	33.0	34.2	28.9	.08	1.16	3.94	8.6	105.8
PK # 4	0	200	35.4	33.1	35.0	31.5	.07	1.19	4.01	9.1	105.3
PK # 6	60	100	33.9	34.6	36.8	28.6	.08	1.11	4.05	9.0	108.0
PK # 9	120	0	33.5	33.3	34.9	33.8	.08	1.04	3.94	12.2	102.1
PK# 12	120	200	30.8	32.9	34.9	30.4	.09	1.06	3.97	8.3	106.0
Average			**33.4**	**33.4**	**35.2**	**30.6**	**.08**	**1.11**	**3.98**	**9.4**	**105.4**
LSD.05			2.0	0.8	0.6	1.3	ns	ns	ns	0.5	3.1

1 Pungency estimated as µmole thiosulfinate/g dry weight; data is average of 3 composite samples per treatment.
2 Cloves were sectioned longitudinally and the length of the sprout was estimated as a fraction of full clove length; data from 30 cloves per treatment. A score of 1.00 indicates that sprout equals clove length.
3 Greentip scored on 1 to 5 scale, where 1=none, 2=slight, 3=moderate, 4=mod.severe and 5=severe (>25% of clove green).
4 Firmness estimated as lbs-force to penetrate with a 0.3 mm probe.
5 Chroma calculated from a* and b* color values; chroma = $((a^*)^2+(b^*)^2)^{1/2}$. Hue calculated as arctan of b*/a*. L is measure of lightness.

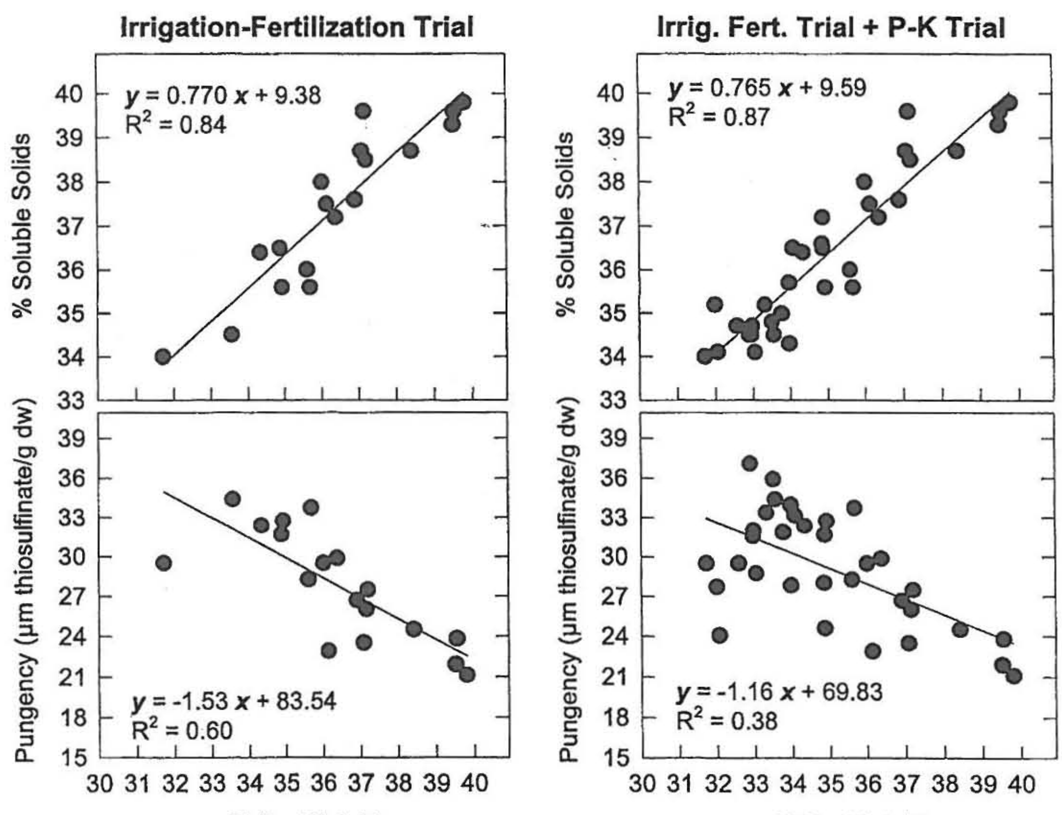


Figure 1. Correlations between soluble solids and pungency and % dry weight. Graphs on left are from data from 1998 Irrigation-fertilization Plots only and graphs on right also include data from PK plots.

SOIL TESTING TO OPTIMIZE NITROGEN MANAGEMENT FOR PROCESSING TOMATOES

Project Leaders:
Jeffrey Mitchell
University of California, Davis
Kearney Agricultural Center
Parlier, CA
(209) 646-6565

Don May
UC Cooperative Extension Fresno County
Fresno, CA

Cooperators:
Timothy K. Hartz
Department of Vegetable Crops
University of California
Davis, CA

Gene Miyao
UC Cooperative Extension Yolo & Solano Counties
Woodland, CA

Michael Cahn
UC Cooperative Extension Yuba & Sutter Counties
Yuba City, CA

Henry Krusekopf
Department of Vegetable Crops
University of California
Davis, CA

OBJECTIVES

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

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

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

RESULTS AND CONCLUSIONS

During the 1998 and 1999 growing seasons, the project was carried out on a total of fourteen on-farm sites in the Sacramento Valley and the West Side region of the San Joaquin Valley. Two trials were also conducted at the UC West Side Research and Extension Center (WSREC). Common processing tomato varieties were grown at each experimental site in standard crop rotations for the regions. All fields received N fertilizer sidedress applications of between 0 to 250 lb/acre of urea in increments of 50 lb/acre, with six treatment replications per site. Soil samples were collected at various depths from each plot prior to N sidedress applications. The soil samples were tested for total N, potentially mineralizable nitrogen (PMN), NO_3-N and NH_4-N. Each strip plot was machine harvested, followed by measurements for total yield and fruit quality.

Data from the six on-farm sites used during the 1998 growing season did not show a correlation between amount of urea added at sidedress application and total yield from harvest (Figure 1). In almost all cases, yields were essentially the same regardless of the amount of fertilizer N added at sidedress. These on-farm sites were characterized by a relatively large amount (57 lb/acre) of non-sidedress N fertilizer applied through water runs, foliar sprays, and pre-plant treatments, and high initial soil residual N content. Maximum yield response to applied sidedress N was observed in 1998 at

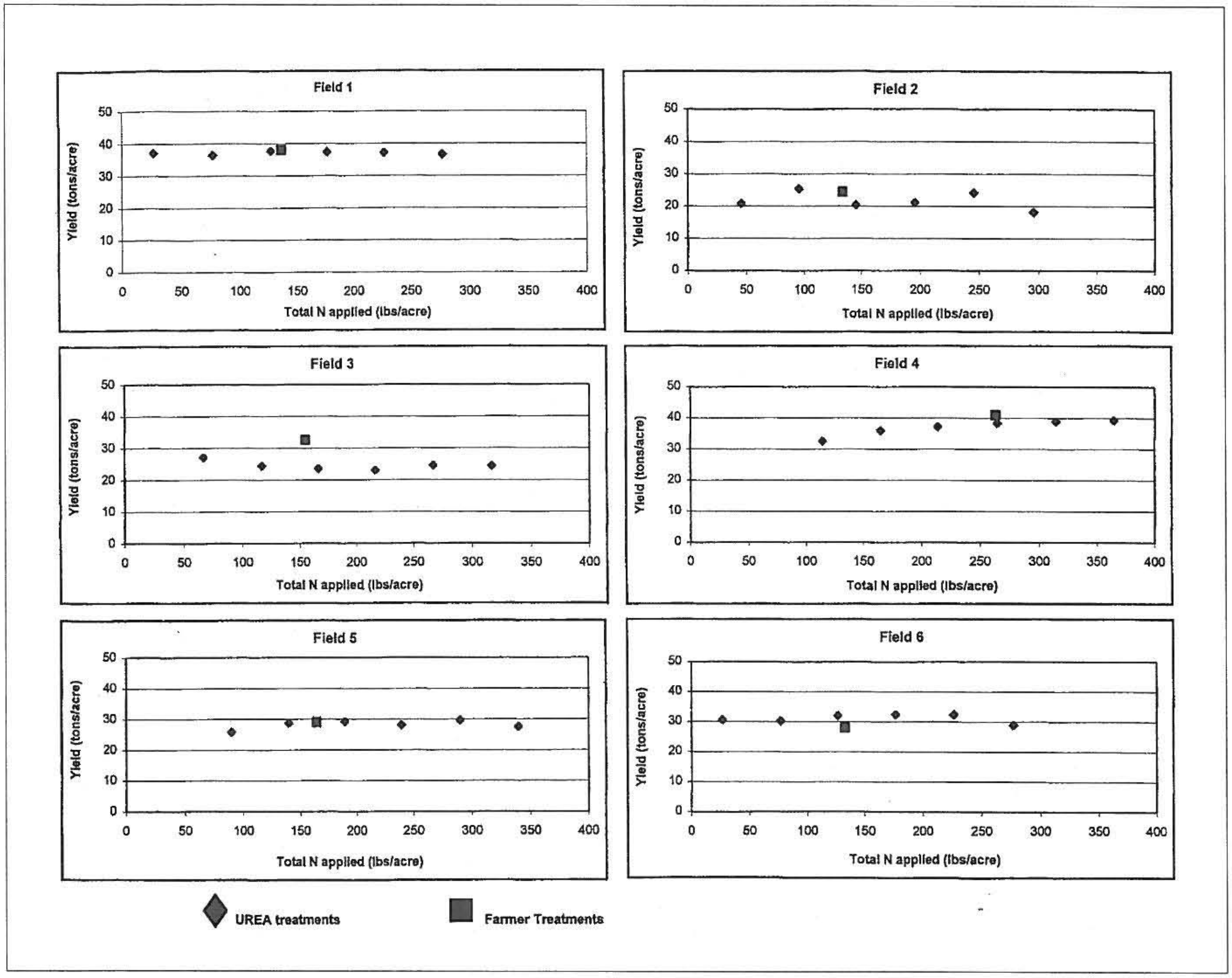


Figure 1. Effects of different N fertilizer application rates on yields of red processing tomatoes. Results from six on-farm trials in West Side region of Fresno Co., 1998.

WSREC, where initial soil N levels were generally lower at 0-1 ft depth and significantly lower at 1-2 ft. depth than those of the on-farm sites (Figure 2). Furthermore, the WSREC field did not receive additional, non-sidedress N applications. For the 1999 growing season, efforts were made to secure on-farm sites with low (<10 ppm) residual soil NO_3-N levels and less intensive use of non-sidedress N. Preliminary results from the completed trials, however, again showed little, if any, correlation between residual soil nitrate levels measured at pre-sidedress (layby) stage and yield response to different rates of sidedress N applications. On average, yields of processing tomatoes were lower in plots receiving the highest rate (250 lb) of sidedressed N and those getting no fertilizer at sidedressing., than plots that received between 50-200 lb N/acre. Likewise, a breakdown of the fields into those with low (<10 ppm) and high (>10 ppm) levels of residual soil NO_3-N in the top foot of soil did not show a clear relationship between amount of sidedress N applied and fruit yield. Average yields from fields with both low and high residual soil NO_3-N levels tended to increase with larger applications

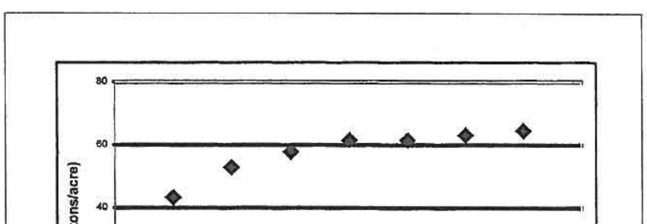


Figure 2. 1998 Tomato fruit yields at WSREC site.

of fertilizer, although the trend is somewhat more pronounced in the low residual soil nitrate fields. Fruit quality determinants—percent red fruit, individual fruit weight, soluble solids and color—were also apparently not affected by amount of fertilizer N applied nor initial soil NO_3-N content.

Preliminary results from the 1999 growing season, combined with the data from 1998, indicate that measurement of residual NO_3 levels in the top 1 ft of soil may not be an accurate indicator of processing tomato yield response in California to fertilizer N applied at sidedress. It should be noted, however, that these results and conclusions are only preliminary, and numerous more repetitions of the experiment need to be conducted before any conclusive statements can be made regarding the validity of the PSNT as a fertilizer management tool. Furthermore, additional field trials and data analysis are required to determine possible correlation between residual soil NO_3-N levels, yield response to fertilizer inputs, and factors such as date and depth of soil sampling, crop rotation patterns, and timing of fertilizer applications.

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

Project Leaders:
Gene Miyao
UC Cooperative Extension Yolo & Solano Counties
Woodland, CA
(530) 666-8143

Paul Robin
Yolo County Resource Conservation District
Woodland, CA

Cooperators:
Blake Harlan
Harlan & Dumars, Inc.
Woodland, CA

Jeffrey Mitchell
UC Kearney Agriculture Center
Parlier, CA

Louise Jackson
Department of Vegetable Crops
University of California
Davis, CA

OBJECTIVES

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

DESCRIPTION

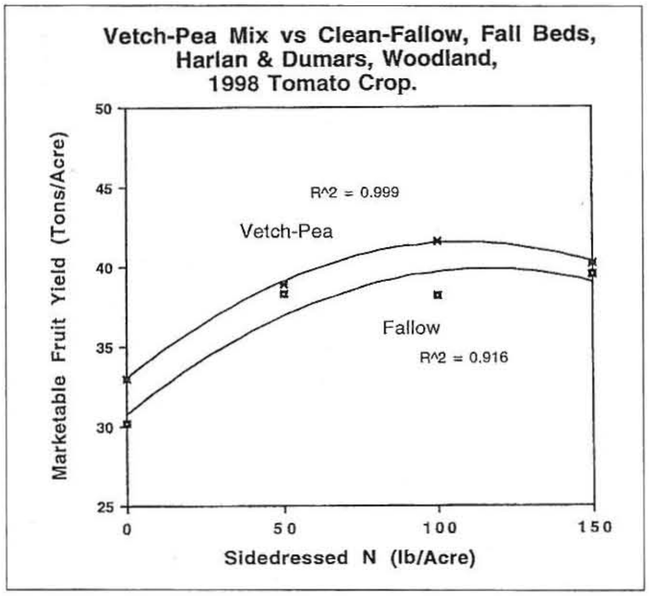
Planting fall cover crops in fields that will later be planted to processing tomatoes is a departure from the conventional cultural practice among tomato growers of minimizing weed vegetation prior to seedbed preparation. Vetch cover cropping may help reduce winter weed competition, increase soil organic matter, fix atmospheric N and reduce winter runoff. Incorporating the green manure crop can be a challenge for tomato growers as planting schedules are driven by pre-contracted harvest delivery dates.

RESULTS AND CONCLUSIONS

Field tests in 1998 and 1999 in the southern Sacramento Valley near Woodland established with a fall planting of a common vetch-pea mix found that there may be some benefits to this practice. Both trials were 3-acre plantings in commercial fields with cooperator Blake Harlan of Harlan and Dumars. The cover crop was drilled into dry beds in the fallow period between two consecutive rotations of tomatoes, and germinated with late fall rains. As expected, in both trials growth was slow during the winter and early spring. The peas were able to grow and develop during the cooler temperatures, compared to vetch, which grew more rapidly during late February and March. Ideally, vetch should be allowed to reach its maximum growth, normally by early April in the Sacramento Valley, before chopping and incorporating the plant biomass to maximize the benefit.

In the 1998 trial, the cover crop was terminated earlier to meet a planting schedule adjustment. After mid-March, an herbicide desiccant was sprayed and the vetch-pea cover was mowed prior to incorporation. The vetch-pea mix was over 2 feet tall at that time and it was calculated that it fixed over 100 lbs N/ acre from the top growth. It should be noted that bed preparation was more difficult because the plant debris caught on and wrapped around cultivator tools. Once the vetch was mowed and incorporated, and the beds prepared, greenhouse-grown tomato plants were transplanted into the beds, one line per bed, in late March between rain episodes.

The experiment was conducted in a randomized complete block design with each treatment replicated six times and each plot measured 3 beds wide by 100 feet long. The two factors evaluated were: 1) fallow vs. cover cropping with a vetch-pea mix and 2) spring-applied sidedress nitrogen rates of either 0, 50, 100, or 150 lb N/acre. Sidedressed N, as urea, was applied soon after transplants were well established. All other cultural practices were the same as commonly used by



growers in local area. Furrow irrigation combined with spring rain accounted for all the irrigation the crop received in 1998. Sprinklers were used to establish the transplants in 1999.

Growth of the tomato plants was monitored throughout the season. Plant tissue samples, petiole as well as whole leaf, were collected at 3 separate growth stages and sent to UC DANR lab. In the 1998 trial, tomato vine size and canopy cover each were reduced over 14 percent when no side-dressed N was applied, regardless of the presence of the cover crop. However, tomato yields suffered when grown solely on the N fixed by the vetch-peas and without benefit of supplemental applied N. Neither large N differences from lab-analysis of tissue samples from the 1998 cover crop could be detected nor substantial fertilizer N benefit could be seen.

In the 1998 trial we were encouraged by a 5 percent yield increase and a soluble solids improvement with the cover crop over the fallow-bed treatment. Yields were increased, on average, from 36.5 tons/acre in the fallow beds compared to 38.4 tons in the cover cropped beds. (see Figure) Applied N alone did not explain the yield enhancement. It seems that incorporation of a leguminous biomass may have been important in changing underground factors such as soil microbial activity. Soluble solids were also increased from 4.7 to 4.9 percent. Fruit color was reduced from 23.7 to 24.3 as measured by the Processing Tomato Advisory Board.

In the 1999 trial in a different field, the cover crop established well and grew vigorously during March despite a very dry and cold December. Analysis of the cover crop estimated a nitrogen contribution of approximately 200 lb/acre, twice the previous year's level. The relative growth of the cover crop species was also different between test years. In 1998, the cover crop biomass composition was roughly 50 percent peas and 50 percent vetch. In 1999, vetch dominated the cover crop biomass at a ratio of nearly 5:1. No major disease or pest problems were noted in the cover crop, although some large weeds grew through the dense cover in spots. The rest of the field, including the "fallow" trial plots, were treated with Roundup® herbicide. Gopher activity was greater in the cover cropped area.

In February and March 1999, runoff was compared from grouped sets of field-length (1000 feet) rows of cover crop and fallow beds. Seasonal runoff from the cover crop furrows was 60 percent or less compared to the fallow furrows. Three techniques were employed over a multiple storm period to assess tail water runoff from fallow versus cover crop beds: 1) a flow meter attached to a sump-type pump; 2) a stage recorder measuring water levels behind a v-notch weir; 3) a 1 x 5 feet cylinder set in a furrow to measure total water captured.

In 1999, a Wilcox Performer® bed mulcher was used to incorporate the cover crop. The bed mulcher chopped and incorporated the cover crop in two passes and repeated a week later in a single pass for final incorporation and bed shaping. Prior to incorporation of the cover crop, soil was sampled in cooperation with and consultation from Professor Louise Jackson of the UC Davis Vegetable Crops Department. About two weeks after cover crop incorporation, Mr. Harlan transplanted his tomatoes on April 18, 1999.

The evaluation of plant tissue nutrient levels and the analysis of irrigation measurement taken during the growing season are in progress. Harvest of the second year's trial was completed in late August. Yield and fruit quality data are also being analyzed. A summary report will be completed in the late fall of 1999.

It is anticipated that winter grown cover cropping may be attractive to tomato growers transplanting after late April. This planting period will maximize vegetative growth of the vetch cover crop and leave sufficient time to incorporate the green manure crop.

At the time of preparation of this report, data analysis is still in progress. These experiments will be repeated during 1999-2000 with a greater emphasis on solute transport and salt balance.

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

Project Leaders:
Charles. A. Sanchez
Yuma Agricultural Center
The University of Arizona
Yuma, AZ
(520) 782-3836

Dawit Zerrihun
Yuma Agricultural Center
The University of Arizona
Yuma, AZ

Khaled. M. Bali
UC Desert Research and Extension
Holtville, CA

Cooperators:
Mark Nibleck
U.S. Bureau of Reclamation
Low Colorado River Region
Yuma, AZ

Grower cooperators will be located in the second phase of the experiments.

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. In fact, the impact of salt-afflicted drainage water on farmland in Mexico was a key factor that prompted the Colorado Basin Salinity Control Act of 1974. 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. For example, while consumptive use of water for lettuce is estimated to be approximately 0.6 foot (0.2 m), amounts applied frequently exceed one foot (0.9 m). 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 believed 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. These technologies should be made available to the growers through education and training.

The first phase of this project will experimentally evaluate irrigation scheduling technologies and management practices as well as the influence of irrigation and N fertilization on crop response, N-leaching, and salt balance. This first phase is primarily aimed at testing weather based irrigation scheduling. However, neutron probe readings will also be collected in all plots so that alternative methods of scheduling irrigation are developed and compared. The second phase of this project will include training in the use of these technologies and their demonstration in commercial production operations.

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, N leaching, and salt balance.
2. Conduct an outreach program aimed at promoting and implementing efficient irrigation practices.

DESCRIPTION

Over 99 percent of all lettuce produced in the desert is furrow irrigated and experiments conducted during 1999 focused on developing efficient furrow irrigation practices. The first experiments with lettuce were aimed at verifying or modifying "management allowable depletion" (MAD) values. The second experiments with lettuce were aimed at evaluating system variables and system parameters for furrow irrigated lettuce with the intention of identifying those criteria associated with higher irrigation efficiency.

Because a significant portion of the melon acreage has been converted from furrow to buried drip, studies with melons conducted during 1999 primarily focused on developing irrigation scheduling criteria for drip irrigated melons. Nevertheless, some melon acreage is furrow irrigated, so one furrow irrigated melon experiment was conducted during 1999 in the Imperial Valley.

RESULTS AND CONCLUSIONS

Evaluation of Management Allowable Depletion (MAD) Values for Furrow Irrigated Lettuce

Two experiments were conducted during the winter-spring of 1999 to evaluate "management allowable depletion" (MAD) values for furrow irrigated head lettuce. One experiment was conducted on a silty clay loam and one was conducted on a loamy sand. The treatments were selected such that irrigations were applied at approximately 20, 40, 60, and 80 percent soil water depletion (SWD) in the surface 2 foot (0.6 m). Neutron probe access tubes were installed to a depth of 5 foot (1.5 m) in all plots. Tensiometers were also installed at one and two foot (0.3 and 0.6 m) in all plots. Soil moisture measurements were made at least three times weekly. Soil water depletions, as measured by neutron probe, will be used to calculate crop coefficients needed to convert ET_0 values to actual crop ET values. Irrigations were 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.

Bromide tracers were also applied to all plots to evaluate the influence of irrigation practices on anion leaching. Ceramic suction cups were used to collect soil solution samples after each irrigation or rainfall event. Additionally soil samples were collected to a depth of 5 foot (1.5 m) immediately after crop harvest.

Optimization of System Variables for Furrow Irrigated Desert Vegetables

Five field experiments were conducted during the winter-spring period of 1999 in the Lower Colorado River Valley (LCRV) of southwestern Arizona and southeastern California. Two experiments were initiated during the spring of 1999 in the Imperial Valley (IV) of southern California. The purpose of these experiments was to evaluate furrow irrigation performance as influenced by soil texture and temporal and spatial variability. Experiments in the LCRV were conducted on fields with 600 foot (183 m) runs and zero slope while experiments in the IV were conducted on fields with 1200 foot (365 m) runs and 0.1 percent slope. The sites were selected to produce variation in soil texture. In each experiment, neutron probe access tubes were installed to a depth of 5 foot (1.5 m) at four locations spaced equally along the irrigation run. Soil moisture distribution was monitored before and after each irrigation. During each irrigation flow hydrograph was determined using small plastic flumes. Water advance and recession as well as water depth along the furrow length was measured continuously during each irrigation. The data will help to determine infiltration parameters using a volume balance approach. A zero-inertia model will be validated using field data. The model will be used to identify flow and cutoff time combinations which optimize water application efficiency for furrow irrigated desert vegetables. It is also intended to develop user friendly methodology (such as design curves) for achieving efficient irrigation.

Plant growth was measured during the entire season to relate growth stage to ET_0, crop ET, and crop coefficients. Bromide tracers were applied to selected plots along the irrigation run to monitor anion transport.

Crop Coefficients for Drip Irrigated 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 irrigation regimes of 0.4, 0.6, 0.8, and 1.0 Penman ET_0 values. These treatments were in factorial combination with three nitrogen fertilizer treatments. Daily irrigations were computed from average ET_0 values calculated from the previous week weather data. The influence of irrigation regimes on melon growth and yield were determined from weekly measurements of plant growth and dry matter accumulation as well as marketable yields at maturity.

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

Project Leaders:
Jose L. Aguiar
UC Cooperative Extension Riverside County
Indio, CA
760-863-7949

Charles A. Sanchez
Yuma Agricultural Center
University of Arizona
Yuma, AZ

Keith S. Mayberry
UC Cooperative Extension Imperial County,
Holtville, CA

Marita Cantwell
Department of Vegetable Crops
University of California
Davis, CA

Cooperators:
Jeff Percy
Ocean Mist Farms
Coachella, CA

Eric McGee
Western Farm Service
Madera, CA

Joe Manion
JBR Farms
Coachella, CA

OBJECTIVES

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

DESCRIPTION

California ranks second in the United States in sweet corn production with approximately 28,800 acres of production during 1998. Sweet corn acreage in the US is at 235,760 acres with Florida being the major production area. Sweet corn is an important crop produced during the fall and spring in the low desert. Large amounts of N fertilizer per acre are typically used to produce high quality sweet corn. Rates of N applied to sweet corn in the desert often exceed 270 lb N/ acre (300 kg N/ha). Public health concerns about NO_3 contamination of ground and surface water from N fertilizer has prompted improved N management strategies for crop production in the desert.

RESULTS AND CONCLUSIONS

Several experiment-demonstration sites were established in March 1999 in the Coachella Valley at commercial sweet corn farms in Indio and Thermal. Experiments have been conducted to evaluate variables of N rate and N timing. Experiment sites are being established at two fields in Thermal for the fall 1999 season. At the time of submitting this report the compilation and analysis from the spring trials are ongoing.

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

Project Leaders:
Larry D. Godfrey
Department of Entomology
University of California
Davis, CA
(530) 752-0473

Robert Hutmacher
Department of Agronomy and Range Science
University of California-Davis
Shafter, CA

Cooperators:
Pete Goodell
UC IPM Project, Kearney Agricultural Center

Brian Marsh
UC Cooperative Extension, Kern County

Bruce Roberts
UC Cooperative Extension, Kings County

Steve Wright
UC Cooperative Extension, Tulare County

Dan Munk
UC Cooperative Extension, Fresno County

Ron Vargas
UC Cooperative Extension, Madera County

Bill Weir
UC Cooperative Extension, Merced County

INTRODUCTION

During the last 10 years, the cotton aphid (*Aphis gossypii*) has developed from a non-pest to one of the most significant insect pests of California cotton. For instance, in 1997, cotton aphid outbreaks were severe and an estimated 3.5 percent yield loss occurred and approximately $40/acre control costs were incurred. Cotton aphid infestations during the mid-season (July to mid-August) reduce cotton lint yields since the aphids act as a significant sink, competing with the bolls, for energy. The late-season infestations (mid-August to September) are problematic because the aphids deposit honeydew on the exposed cotton lint, which reduces the lint value. Reasons for this change in pest status of cotton aphid are unclear; however, one of the most noticeable changes in cotton production over the last 10 years is the use of a plant growth regulator instead of irrigation and nitrogen deficits to limit early-season cotton vegetative growth. This has allowed cotton production practices in the San Joaquin Valley to evolve to higher nitrogen fertilization and irrigation inputs. Host plant conditions including high nitrogen and adequate moisture are generally optimal for aphid population growth and development. An earlier small plot research by the project leader verified that there were more cotton aphids on cotton in a 200 lb N/acre compared with 50 lb N/acre treatment. The goal of the project is balancing the amount of N needed for optimal cotton yield with the level required to mitigate cotton aphid population build-up. Utilizing cultural control measures such as nitrogen management could play an important role in cotton aphid management. Biological control, predators and parasites, of mid- and late-season aphid outbreaks is only moderately effective. Relying on insecticides for aphid control adds undesirable production costs and also promotes the development of insecticide resistance in this aphid pest. Therefore, additional non-chemical control measures would fill an important void.

OBJECTIVES

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

DESCRIPTION

Naturally-occurring cotton aphid populations were monitored weekly from June to September at 8 field sites set up for this project and, in part, for the ongoing work of Dr.

Hutmacher on the influence of nitrogen fertilization on cotton growth, development, and yield. Six of these plots were located in grower fields in the San Joaquin Valley and the other two were on University of California Research and Extension Centers. These plots contained treatments of 50, 100, 150, and 200 lb N/acre. For the detailed studies on population dynamics, cotton aphids from a laboratory colony were used and infested into cotton plots. Ten aphid adults were confined on to a 4th main stem node leaf and allow them to deposit aphid nymphs for one day before removing adults. Data were collected such that the effects of the nitrogen regime could be examined on percentage aphid survival, length of survival, length of reproduction period, number of offspring produced, etc. This will allow to determine and separate the exact effects of N on cotton aphid biology. These studies were conducted in small plots (4 rows x 20 feet) with differing N rates (ammonium sulfate) of 0, 50, 100, 150, 200, and 250 lb N/acre, 200 lb N/acre split into 4 applications of 50 lb each, 200 lb N/acre + 100 lb K /acre, and 200 lb N/acre (urea form).

RESULTS AND CONCLUSIONS

Naturally-occurring cotton aphid populations were generally low in San Joaquin Valley cotton during the 1999 growing season. A low number of cotton aphids (<10 per leaf) were found in many fields (including our study sites) but outbreak populations have occurred in only a few isolated areas in the San Joaquin Valley. At the end of August, populations appeared to be increasing in some areas, but at that time the season was moving out of the "mid-season" period for cotton (which was the target for this study) and into the late-season. Cotton aphids can also be a pest during the "late-season" for cotton, but the nitrogen regimes that were set-up have likely largely equilibrated at that time. Data are still being collected and summaries have not yet been prepared.

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

Project Leaders:
Chris van Kessel
Department of Agronomy and Range Science
University of California
Davis, CA
(530) 752-4377

William Horwath
Land, Air, and Water Resources
University of California
Davis, CA

Cooperators:
John Williams
UC Cooperative Extension Sutter &Yuba Counties
Yuba City, CA

Marlin Brandon
Rice Experiment Station
Biggs, CA

OBJECTIVES

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

DESCRIPTION

California legislation (AB 1378) leads to a phase down of rice straw burning over a ten year period which will change the way farmers manage rice straw. Although various options are available, it is likely that the incorporation of rice straw; i.e., on-site disposal, will remain a major option for rice straw disposal. The average concentration of K in rice straw is around 1.4 percent but its range can be as low as 0.6 percent or as high as 1.8 percent. The amount of straw removed by baling for off-site use is approximately 6 tones/acre and hence the amount of K removed in the straw in Californian rice fields can exceed 100 lb/acre, which is in addition to the K removed by grain. When straw is removed on a continued basis, this management practice would show a pronounced effect on the available K levels in the soil. Some preliminary data gathered from the long term straw rotation studies at the Rice Experiment Station showed that the extractable K levels in the soil in the top 6 inches (15 cm) declined significantly to less than 60 ppm when straw was baled for 3 years. The current fertility guideline for rice is that 30-60 ppm of extractable K should be present at time of seeding; otherwise K fertilization is recommended.

Preliminary studies in the Sacramento Valley also showed that the use efficiency of available N can be greatly increased when the crop has access to sufficient amounts of K. When a comparison was made between the amount of N required to produce a ton of grain, the N requirement (UNR) was reduced by 50 percent at the site with sufficient K. The Unit N Requirement (UNR) is defined as the amount of N in lb/acre that needs to be available to the crop to produce a ton of grain.

RESULTS AND CONCLUSIONS

As part of the first field season activities of a three-year field study, a field at Mathew Farm near Marysville, California that would likely show a K deficiency was selected. From half of the selected area, the rice straw was removed whereas for the other half of the field, the rice straw was incorporated in the fall of 1998. The same location will be used for the next three years and straw will be removed or incorporated for the duration of the experiment.

In the spring of 1999, 10 soil samples were collected from the site where straw was removed or where straw was incorporated. After one year of straw removal, a significant difference in soil available K concentration: 59 mg K/kg soil when the straw was removed versus 88 mg K/kg soil when the straw incorporated plot was detected.

In the spring of 1999, an N by K rate trial was established on both straw management treatments. A split plot factorial design replicated 4 times with 5 rates of N 0, 44, 89, 134 and 178 lb/acre (0, 50, 100, 150, 200 kg /hectare) as ammonium sulfate and 6 rates of K 0, 22, 44, 67, 89 and 112 lb/ acre (0, 25, 50, 75, 100, 125 kg/ hectare) as potassium chloride for each straw management treatment (total of 240 plots) was used. In addition of using unlabelled fertilizer in the N by K trial, ^{15}N –labeled fertilizer was used for selected treatments. By using ^{15}N-labeled fertilizers, a second method to calculate fertilizer-N use efficiency as affected by K fertilization can be made.

Plant tissue samples were collected before panicle initiation and are currently being analyzed for N and K content. Visual observations at panicle initiation showed a strong N response, independent whether straw was removed or incorporated. There was also a visible, positive N response when straw was incorporated compared to straw removal. The crop response to K was less dramatic than for N but remained detectable after panicle initiation. It remains to be determined whether K fertilization will lead to a significant yield response.

A key to improve K fertilization in rice will be our ability to predict the amount of K that will be available at time of seeding and what becomes available during the growing season. Soil samples with soil organic matter and clay content have been collected from various locations throughout the rice growing areas. Various extractants will be used to determine the K availability in the soil. Yield samples will be collected from the sites where the soil samples were taken in the spring and the total amount of K related to the availability of K in the spring and total K accumulation.

Management of Nitrogen Fertilization in Sudangrass

Project Leader:
Dan Putnam
Department of Agronomy and Range Science
University of California
Davis, CA
(530) 752-8982

Cooperators:
Roland D. Meyer
Department of Land, Air and Water Resources
University of California
Davis, CA

R. Kallenbach
Previously with UC Cooperative Extension,
Riverside County

OBJECTIVES

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

INTRODUCTION

Sudangrass hay (*Sorghum sudanense* (Piper) Stapf.) was grown on over 100,000 acres in 1997 and contributed 53 million dollars to the agricultural economy of California. Most of California's sudangrass is grown in the Imperial and Palo Verde Valleys of southern part of the state. In addition, small acreage of sudangrass has been used as summer-grown forage in California in dairy regions. Statewide average yields are 5.5 tons/acre. Acreage in the desert has grown significantly due to the rise in exports to Japan, as well as overall increased domestic forage demand. Although sudangrass export markets declined significantly in 1998 and early 1999, there is continued interest in sudangrass for exports, as well as for California's rapidly expanding cattle population (dairy and beef). Sudangrass is often double- or triple-cropped with small grain forage or corn in California's Central Valley.

Large quantities of N fertilizers are commonly used in the production of sudangrass hay, at rates varying from 150 to over 800 lb N/acre. Typical system in the desert is a 3 to 4 cut system when the crop is planted in early summer (April). However, there has been very little research data to guide growers in the determination of optimum N fertility management for sudangrass in California. Insufficient N has been identified as a common yield-limiting factor. In addition, excessive application rates applied to sudangrass may exacerbate groundwater nitrate problems or nitrate toxicity in cattle feed.

This research was conducted to determine the yield and forage quality (particularly nitrate concentration) response of sudangrass to N fertilizers in the low desert environment, quantify the effects of N application rates on the potential for NO_3 accumulation. Efforts were also made to develop rapid diagnostic tests (using Cardy meters and near infrared spectrophotometry- NIRS) to monitor N content in the forage. Nitrogen rate studies were conducted in Blythe and El Centro, California. This is a preliminary report of the yield and forage quality results of this study to date, with other aspects of the study to be reported later.

DESCRIPTION

Sudangrass responds remarkably to N fertilizers, but there is little data to guide nitrogen recommendations for California growers, especially in desert regions. An informal survey of growers in the low desert region indicates that nitrogen rates vary from 150 to over 800 lb N/acre annually. These rates seem excessive in comparison with recommended rates in other regions, but our growing season is longer, we have warmer temperatures, we harvest 4 times compared with 1-2, and yields are often double those of other regions.

Researchers in Oklahoma, Alabama, and Australia found that sudangrass yields are maximized when fertilized with about 250-350 lb N/acre In these studies, fertilizer rates greater than 350 lb N/acre either reduced yields, increased N losses through leaching, or both. It is not likely that these results are highly relevant to our conditions, given the tremendous differences in seasonal yield. It is probable that larger N applications are appropriate for the warmer conditions and longer growing season of the low desert, but there is little scientific basis for this assumption.

One method for calculating N recommendations is to estimate crop removal, adjusted for fertilizer N-use efficiency (50-80 percent). Sudangrass yields in the low desert averaged 7.1 tons per acre in 1993 and 1994. Based on an N concentration of 1.75 percent of dry weight, annual crop removal for an average crop would be about 249 lb N/acre. Adjusting for fertilizer efficiency, this might be equal to over 350 lb N/acre applied fertilizer/ year.

However, many producers and crop consultants are uncomfortable basing N rates based solely on uptake. Several factors are unaccounted for by this method including: contributions of residual N from previous crops, timing of application, N lost to denitrification, N contributions from organic matter, leached N and application inefficiencies. Methods should reflect more closely plant requirements and ability of the soil to provide N. At present, low desert producers and crop consultants rely on anecdotal or trial-and-error protocols to fertilize Sudangrass.

RESULTS AND CONCLUSIONS

Field plots of sudangrass were established in 1997 and again in 1998 at the UC Desert Research and Extension Center in El Centro and on a grower's field in Blythe, California. Seven N rate treatments (applied as ammonium nitrate) were established in a randomized block design at these two locations. Nitrogen was applied at 35, 70, 105, 140 and 210 lb N/acre at each growth period, while non-fertilized plot served as control.

Fertilizers at rates above 35 lb N/acre were applied in split applications during each growth period. One application was initially after harvest, just before irrigation, and the other at the time of a second irrigation. These treatments were meant to correspond to water-applications of N fertilizers, which are

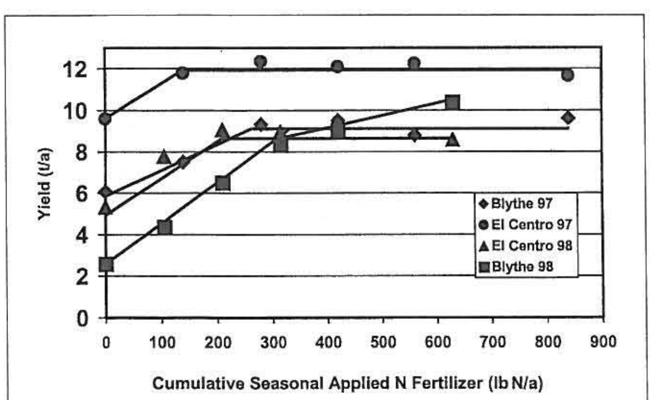


Figure 1. Seasonal total sudangrass forage yields as affected by N at Blythe and El Centro, 1997-1998.

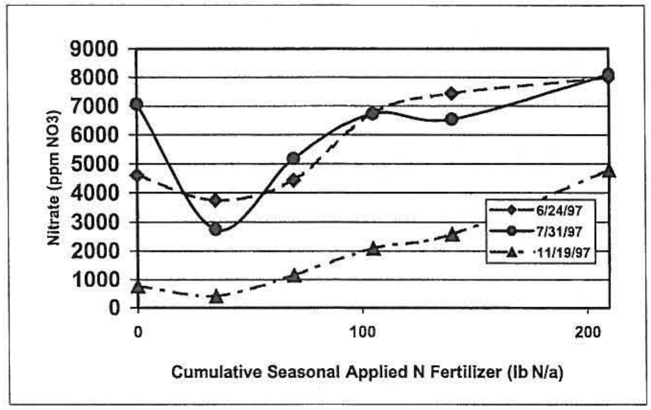


Figure 2. Nitrate concentration of sudangrass forage as affected by N at Blythe, 1997.

very common in desert regions. Data from these trials were collected for forage yield, dry matter, and forage quality. Chlorophyll-meter readings (for total chlorophyll concentration) and Cardy meter readings (which measure NO_3 in the stems) were taken at each harvest. Cardy meter readings were taken on the stem material, and chlorophyll readings were taken at mid-leaf, avoiding the midrib.

Four harvests were measured on these plots in 1997 and three harvests were measured in 1998 from both Blythe and El Centro. The Blythe data from 1997 indicated a significant ($P<0.05$) effect of N at all harvests. The first cutting showed increased yields only in the treatment supplied with 35 lb N/acre. At the time of the second and subsequent cuttings, yields responded significantly at the 70 lb N/acre rate, and seasonal yields showed little response past 70 lb N/acre applied at each cutting. The El Centro site in 1997 exhibited higher field variation due to unknown factors, and the response of sudangrass yield to the N treatments was non-significant at each harvest and in the seasonal total. Highest yields were observed at the El Centro site in 1997 (Figure 1). The cutting-by cutting data from Blythe, 1997 were typical of the pattern of yield response in 1998 at both sites (data not shown), with little response at the first cutting, and more intense yield response in subsequent cuttings. The seasonal 1998 totals indicated a yield response up to 70 lb/acre at El Centro, and up to 210 lb/acre in Blythe.

Nitrogen application increased NO_3 concentration in all the samples of sudangrass that have been analyzed to date (Figures 2 - 4). A wide range of NO_3 levels was measured at the different cuttings and environments, ranging from 100s of ppm to more than 20,000 ppm (lab values). For example, the last cutting of 1997 at Blythe was 1,000 to 4000 ppm, and the first two cuttings were 3,000 to 8,000 ppm. The first cutting at El Centro was increased from about 6,000 ppm NO_3 to over 20,000, and the first cutting at Blythe ranged from 100 to 2500 ppm. Similarly, previous observations of NO_3 as affected by N have show dramatic affects, causing sudangrass nitrates to range from 2,000 to 25,000 ppm NO_3.

Many experts describe hay with less than 1,000 ppm of NO_3 as generally safe, and hay with less than 2,000 ppm of NO_3 as mostly safe except for some particular classes of livestock (pregnant animals, very young animals). It is possible to feed forage with NO_3 ranging from 2,000 - 4,000 ppm, but the quantity should be limited and the ration fortified with energy, minerals and vitamin A. Concentrations of NO_3 more than 4,000 ppm is often considered toxic and unsafe to feed. It should be noted that these 'threshold' levels are not universal, and opinions may vary widely as to acceptable levels of NO_3 in forage. The acceptability of NO_3 in diets is a complex trait with type of animal, acclimatization, health, water source, and total ration ingredients all important considerations.

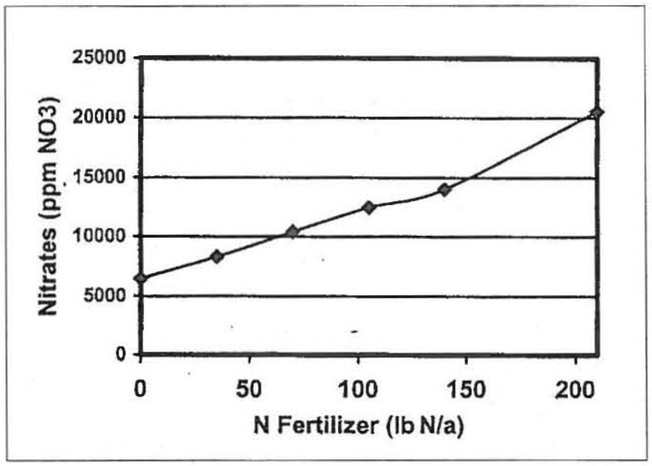


Figure 3. First cut sudangrass nitrates as affected by N at El Centro, 1998.

However, many samples from this study showed NO_3 concentration more than 4,000 ppm. Since many of the exporters demand NO_3 less than 1,000 ppm (and would prefer less than 750 ppm), this may be of concern, since even at 0 N fertilizers, some of the plots exhibited high nitrate contents. However, several points should be considered to reach some conclusion. The first is that transformation of nitrate may occur considerably during the curing process. These samples were taken directly from the field and were oven dried. It is likely that the process prevented substantial enzymatic transformation of plant cell NO_3 to amino acids which would occur during an extended curing time. Secondly, absolute levels may differ according to method, making comparisons among hay lots more difficult. These two issues need further study.

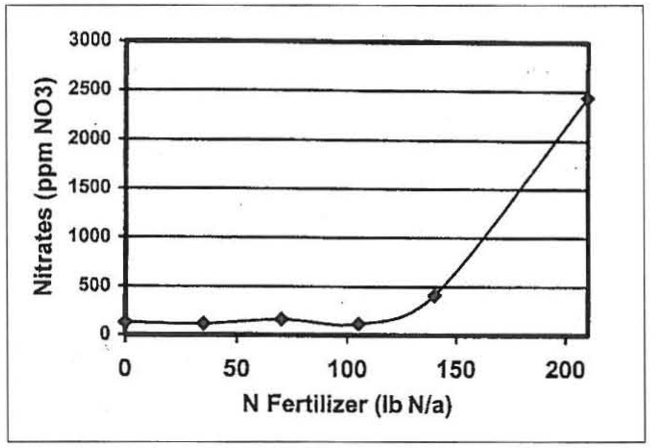


Figure 4. First cut sudangrass nitrates as affected by N at Blythe, 1998.

Cardy meter readings for NO_3 of the standing crop did respond to applications of N fertilizers (Figure 5). Cardy meter readings were somewhat successful at predicting relative changes in plant nitrate. Figure 6 represents the relationship between the Cardy readings (X) for all values which are currently available (more sample results are pending at this writing). However, it is questionable as to whether the absolute values of Cardy meter readings or the relative readings will be helpful in the management of N fertilizers by growers. In this sample set, a negative bias (under-predicting the lab values) was seen, explaining 67 percent of the variation in lab NO_3 values.

High NO_3 values are clearly a hazard of sudangrass production, but not always clearly related to soil N values. Plant nitrate accumulation is also a function of temperature, stage of sample, drought stress, cold stress, and other factors. It is apparent from these studies that avoidance of high N applications is an important (but not the only) strategy for

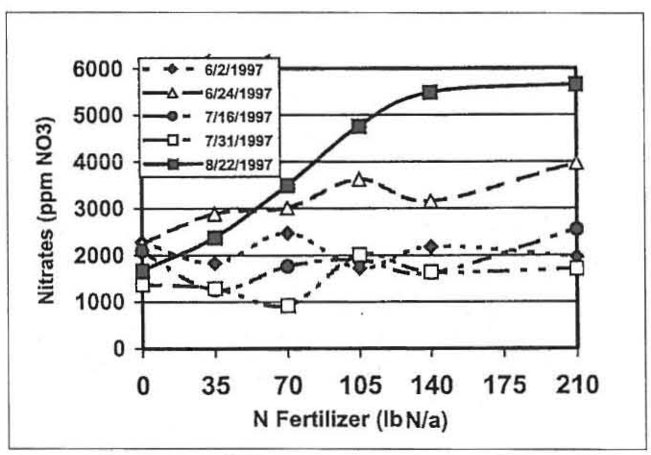


Figure 5. Average sudangrass nitrates as measured by Cardy meter, Blythe, 1997.

Value of Additional yield from each increment of N Fertilizer in Blythe and El Centro, 1997 and 1998 (seasonal totals). Assumptions: $80/ton hay, $30/lb N applied.

Rate/Cutting (lb/acre)	Blythe 97	El Centro 97	Blythe 98 $/acre	El Centro 98
35	73	31	110	164
70	103	3	142	72
105	-27	-61	116	-39
140	-97	-29	23	-19
210	-19	-132	45	-109

minimizing NO_3 in forage. From the standpoint of fertilizer management, however, there is a clear incentive to minimize applications to the greatest extent possible.

However, economics will likely cause growers to minimize fertilizer applications. The estimate of the economic return of each increment of fertilizer applied shown in the above table. With the exception of Blythe, 1998, there was little indication that rates greater than 70 lb N/acre at each cutting would result in improved economic returns. At El Centro, although no significant effect of N on yield was found, some small benefit from the lower rates was seen. The Blythe 98 site was the most responsive of all sites, showing incremental economic returns all the way to the highest N rate

SUMMARY

Sites varied in their N response, from no significant response at any N rate, to yield response to the highest rate per cutting (210 lb N/cut or 630 lb N/acre annually). Most evidence indicates little chance of yield response at N applications greater than 70 lb/acre per growth period (280 lb N/year). Most sites indicated lower response in the first harvest, with a greater response in later cuttings, indicating that applications at the first growth period should be minimized to account for residual soil N. Nitrate concentrations in sudangrass forage were increased significantly in most cases by N applications, but fertilizers were not the only cause of high NO_3. Cardy meter (nitrate-specific electrode) readings explained 67 percent of the variation in plant NO_3 in the samples analyzed to date, but the levels show a distinct negative bias, and some data sets showed a poor relationship between Cardy meter readings and plant nitrates. Future work should address issues of the causes of NO_3 concentrations in sudangrass forage, and standardize nitrate methods.

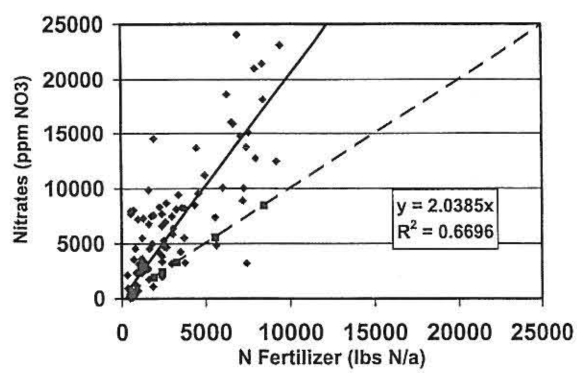


Figure 6. Sudangrass nitrates as measured by Cardy meter (X axis), as a predicter of lab nitrates (Y axis). Includes data from Blythe, 1997 all cuts, and 1st cut 1998, Blythe and El Centro.

Nitrogen Budget in California Cotton Cropping Systems

Project Leaders:
D. William Rains/R.L. Travis/Robert Hutmacher
Department of Agronomy and Range Science
University of California
Davis, CA
(530) 752-1711

OBJECTIVES

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

INTRODUCTION

Cotton has been an important crop in the San Joaquin Valley for many years. Approximately one million acres of cotton are grown in California every year. While this indicates that cotton production has been successful in California, producers have been and are continuously facing new challenges such us a volatile market as well as changing production conditions. Modern cotton varieties, for example, are more determinant, earlier maturing, set and fill bolls over a shorter period of time, and respond more strongly to nitrogen applications than obsolete varieties. Many of the production guidelines for cotton, including those for nitrogen (N) fertilization, were developed in the 1960's based on different cultivars and management practices than those employed today. Cotton cultivars currently grown in California produce lint yields approaching three bales/acre—among the highest in the world. To obtain these yields, nutrient, water and other inputs need to be managed with great care.

Nitrogen nutrition is known to affect the development of cotton plants, particularly the balance between vegetative and reproductive growth. Thus, N fertilization represents a valuable management tool for producers to control cotton development. The critical role of N in cotton management warrants a reevaluation of its application guidelines tailoring its management to new cultivation practices and recognizing widespread environmental concerns. Nitrogen fertilization in cotton may be in one application, or in split applications and depending on soil type and previous cropping history generally varies between 150 and 200 lb N/acre but may exceed 200 lb N/ acre in some cases. Hence, assuming an average annual cotton production of one million acres, cotton accounts for nearly 20 percent of all agricultural N use in California. Nitrate concentrations in well water from the Central Valley of California increased over the past ten years mostly due to non-point sources, indicating possible involvement of agricultural production. This is critical for cotton producers since management of nitrate contamination in groundwater is increasingly regulated in California. In addition, it has been reported that high N application rates increase the likelihood of aphid infestations and decrease the efficiency of defoliation.

Reevaluation of the N fertilization guidelines is needed in light of the above noted changes in the production system and to optimize management practices for environmental concerns, insect control, and defoliation efficiency. Based on ongoing studies very small or no yield responses to N were observed at several locations throughout the San Joaquin Valley. In order to understand this occurrence better and since cotton varieties and management practices are likely to keep changing in the future, the focus of the project discussed here is to understand the N dynamics in the cotton production system over the course of a growing season as well as cropping cycle. Better understanding of the underlying mechanisms controlling N dynamics in a cotton field will facilitate adaptations of fertilization practices to new production requirements.

DESCRIPTION

A field study was initiated in spring 1998 at two sites in the San Joaquin Valley. The first site was at a farmer's field (Wisecarver farms) in Kings County and second was on the West Side Research and Extension Center (WSREC) in Fresno County. Four treatments (four replications), 50, 100, 150, and 200 lb N/acre were established at each location. In the 50 and 150 lb N/acre treatments microplots were established using ^{15}N enriched urea. Over the course of the season, observations were made on the dry weight of leaves, stems, and fruiting structures. All treatments were analyzed for yield. Subsamples of plant materials collected throughout the season were analyzed for total N and for atom % ^{15}N.

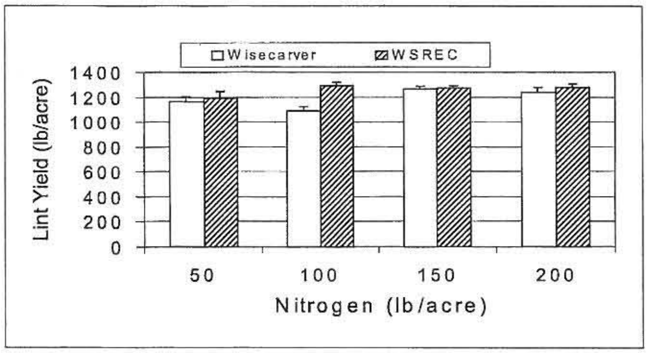


Figure 1. Effect of N fertilization on cotton lint yield at the Kings County site and the West Side Research and Extension Center in 1998.

Soil samples were collected at the beginning, in the middle and at the end of the season and analyzed for total N and ^{15}N atom percent. In addition, end-of-season soil samples were taken from the 50 and 150 lb N/acre treatments in order to analyze mineralization rates for cotton residues under controlled conditions. Soil samples were sieved through a 5 mm screen and subsamples of 100 g were incubated either directly or with 0.4 g ground cotton residue at 10°C or 25°C. Evolution of CO_2 and the appearance of NO_3- and NH_4^+ was measured in intervals.

RESULTS

Lint yields were not different between the treatments at WS-REC. At the Kings County site the difference was significant only between the 100 and 150 lb N/ acre treatments (Figure 1). Only small differences in lint yield between the two locations were observed. In contrast to lint yield, a positive response to additional N fertilizer was found for above ground biomass present at defoliation (Figure 2). The amount of biomass accumulated at defoliation was higher at WSREC than at Wisecarver farms. Similar to data from other sites,

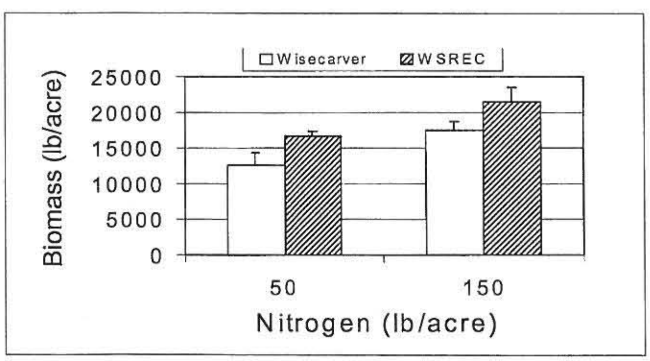


Figure 2. Effect of N fertilization on above ground biomass at the time of defoliation at the Kings County site and the West Site Research and Extension Center in 1998.

these results suggest that N fertilization rates could potentially be lowered without significant reduction in lint yield. This may be particularly true for cotton grown in rotation with other crops after which high residual soil NO_3 levels can be found. Evaluation of the ^{15}N data will aid in the interpretation of these results. Tissue analyses from early season plant samplings indicate high amounts fertilizer N being taken up in the 150 lb N/ acre treatment and low amounts in the 50 lb N/ acre treatment (data not shown). Evaluation of ^{15}N analyses from plant samplings conducted later in the season is in progress and will allow calculations of the fertilizer-N uptake efficiencies for the first year and the different treatments.

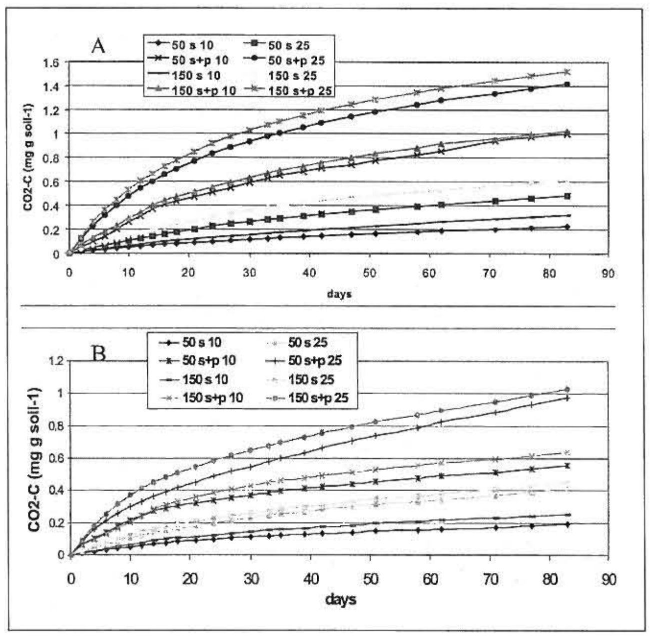


Figure 3. Effect of soil type, temperature and cotton residue addition on CO_2 evolution. Soil was incubated at 10°C (10) or 25°C (25) without additional plant material (s) or with 0.4 g cotton residue per 100 g soil (s + p). Soil was collected from the 50 and 150 lb N/acre fertilization treatments, respectively. A) West Side Research and Extension Center, B) Kings County site.

Figures 3a and b show the rate of CO_2 evolution from the two soil types indicating the amount of organic matter being decomposed. At both locations soils incubated at 10°C (50°F) evolved roughly 50% less CO_2 than those incubated at 25°C (77°F). The addition of plant material (0.4 g per 100 g of soil) at least doubled the amount of CO_2 evolved over time. While all treatments were the same relative to each other for the two soil types, the absolute amounts of CO_2 evolution were higher in the lighter soil than in the heavier one. The rate of CO_2 evolution as a function of time gave expected results. Treatments without the addition of plant material exhibited only small changes in the rate of CO_2 evolution over the first 120 days of the experiment. Treatments with added plant material had about two to three fold higher CO_2 evolution rates during the first 14 days than over the next 100 days. This suggests a readily decomposed fraction of soil organic matter (added plant material) which is broken down initially followed by a soil organic fraction that is more difficult to decompose.

In order to construct a N budget for California cotton production and to understand the N dynamics in the current production system more data are being collected and those obtained need to be analyzed further. Collectively these data will serve as source of information based on which researchers, extension agents, and producers can make sound decisions.

Site-Specific Farming Information Systems in a Tomato-based Rotation in the Sacramento Valley

Project Leaders:
Stuart Pettygrove
Department of Land, Air and Water Resources
University of California
Davis, CA
530-752-2533

Richard E. Plant
Department of Agronomy and Range Science
University of California
Davis, CA

Robert O. Miller
Department of Soil and Crop Sciences
Colorado State University
Fort Collins, CO

Shrini K. Upadhyaya
Department of Biological and
Agricultural Engineering
University of California
Davis, CA

R. Ford Denison
Department of Agronomy and Range Science
University of California
Davis, CA

Lee F. Jackson
Department of Agronomy and Range Science
University of California
Davis, CA

Thomas E. Kearney
UC Cooperative Extension
Yolo County

Michael D. Cahn
UC Cooperative Extension
Sutter and Yuba Counties

Cooperators:
Button & Turkovich, Winters, CA, Gene Miyao, UC Cooperative Extension, Yolo Co., Tim Hartz, Dept. of Vegetable Crops, UC Davis; Susan Ustin, Dept. of LAWR, UC Davis

OBJECTIVES

1. Measure variability of yield within fields in a processing tomato-based rotation.
2. Determine relationship of crop yield to soil and plant characteristics and color infrared aerial imagery
3. Assess the potential for site-specific farming in irrigated row crop rotation and communicate with growers and allied businesses

DESCRIPTION

For the past four years, a cooperating farmer and UC researchers have monitored crop yield and plant and soil characteristics in two approximately 80-acre fields in Yolo County. During the first two years of the project, a third field was monitored. Rotations followed in the two fields were wheat-tomato-dry beans-sunflower, wheat-tomato-sunflower-corn, and wheat-tomato. Each of the three fields has areas of Class I and Class II soils. Yields on this farm are often limited by slow permeability of the subsoil of the Class II Capay silty clay, an important agricultural soil in Yolo County and the rest of the Sacramento Valley. In addition to the challenge presented by the Capay soil itself, there is the difficulty of optimizing irrigation, tillage, and nutrients in fields that contain both the Capay soil and medium-textured, well drained soils like the Yolo silt loam. In this project, all crops were grown on 60-inch beds with conventional farming practices for the area. No site-specific practices (such as variable rate fertilization) were used. However, in 1999, starter P fertilizer strip trials were conducted by the grower in sunflower and corn crops. Data from the 1999 crop have not been analyzed yet.

Color infrared aerial photographs were collected several times during each of the four growing seasons and during the winter or early spring when there was no plant cover. Photographs were scanned at a density that provided a 3 x 3 ft pixel size. A vegetation index was calculated from the digitized images. Researchers collected plant samples for nutrient analysis each season. Soil samples were collected to provide a detailed soil texture map as well as monitor nutrients. All sampling was carried out on a 200 ft x 200 ft grid. At each grid point, multiple soil cores were collected from a 15 x 15 ft area from bed tops. Likewise, plant samples were collected over a three-bed x 15 ft area and composited into a single sample representing that grid point. Aerial images and plant and soil data and the latitude/longitude (determined in the field by differential GPS) were entered into ArcView GIS/mapping software.

Crop yield monitor data were collected by the grower using an Ag Leader®/GPS yield mapping system (Ag Leader Technology, Ames, IA). During the 1997 season when tomatoes were grown on all three fields, yield mapping was done with a prototype yield monitor developed at University of California, Davis and mounted on one of the grower's harvesters. Crop yield data files were entered into the project ArcView GIS file.

RESULTS AND CONCLUSIONS

Results from the wheat and tomato crops were shown in the 1998 FREP Conference proceedings. In only one of the three fields, designated as Field 5, was there an obvious relationship of the tomato yield to the wheat yield the preceding year. Yields of both crops tended to be lower in the area highest clay content, corresponding to areas of Capay silty clay soil with slow subsurface permeability. However, in a small area of the field with a loam soil texture and good subsurface permeability, the highest wheat yields were produced, but tomato yield was low. The grower's irrigation, optimized for the greater area of the field with clay loam soil, most likely was not frequent enough for the faster-draining area.

Because the grower reported that P fertilizer was applied, we assumed nutrient deficiencies would not be a factor in any of the fields. However, plant and soil samples from Field 5 showed that low phosphate probably limited tomato yield. Thus, low yields were related to both low soil P and to soil texture (see Table). It is uncertain whether the direct cause of low yield was (1) low soil P, or (2) inadequate P uptake due to poor root development in areas with fine-textured soil where the crop was subjected to prolonged saturation. Apparently, the grower's knifed application of 100 lb P_2O_5/acre in the fall seven months prior to the April transplanting of the tomatoes was not effective. It is uncertain whether P was present in the transplant water. The average soil test P was low—7.7 ppm Olsen's P the previous year. Combined with acidic pH (5.8, some areas as low as 5.56), it is likely that even if P were applied with the transplant water, an additional starter or side-dress P would have been helpful, especially in the lower-yielding areas of the field.

Relationship between tomato fruit yield and soil and plant characteristics in Field 5. Data collected from 79 grid points on a 200 x 200-ft spacing.

	Yield	*Midbloom petiole PO_4*
	r	
Midbloom petiole PO_4	0.66	—
Late bloom petiole PO_4	NS	NS
Mid-bloom petiole NO_3	NS	0.53
Sand content	0.43	0.56
Clay content	-0.55	-0.65
Soil P, Na bicarb. extractable	0.49	0.41
Soil organic matter	NS	NS
Soil pH	NS	NS

r = coefficient of correlation. All significant at 1% level except where NS appears.

Several other findings of the project are listed here.

1. Wheat yield in one field was most affected by the presence of grassy weeds and was not influenced by soil texture or nutrient deficiencies. An economic analysis of this variable weed impact was presented at the 1997 California Alfalfa Symposium.
2. Grain protein content within the same field was correlated with leaf greenness measured by the Minolta SPAD chlorophyll meter and N analysis on the flag leaf at anthesis and showed some spatial variability in the field.
3. Wheat yield in field 5 (described above) most closely correlated with clay content, i.e. low yield where clay content was highest. Secondarily, grassy weeds reduced wheat yield. This analysis was clearly shown with a statistical method, CART (Correlation and Regression Tree analysis) that has rarely been used in site-specific farming yield analysis. The low yield observed in high clay areas was due to heavy winter rains that kept the soil saturated.
4. In field 5, a wheat yield pattern of stripes perpendicular to beds was shown to exist and (based on interview with the grower and the aerial applicator) is believed to be a result of non-uniform N topdressing during the winter.
5. Tomato yield variation did not match variation in the vegetation index computed from the color infrared aerial photographs. This was in agreement with data collected in other fields by Tim Hartz. However, the aerial photos have proven very useful for detecting large-scale patterns, such as weed patches, plant size differences, and non-uniform fertilizer N applications.
6. The low soil P level in field 5 offered an opportunity for a fertilizer field experiment. A strip trial was conducted in

the 1999 sunflower crop – data to be analyzed. A similar strip trial in the second field (planted to corn) did not show any impact of P starter fertilizer, in agreement with high soil test P value in that field. Because the grower has a yield monitor, he has been able to conduct these trials without assistance from the researchers.

7. Dry edible bean yield in Field 5 followed a similar pattern to the wheat and tomato yield the two previous years, i.e., it was lower in areas of the field with Capay soil. As the Yolo silty loam area of the field was planted to onion seed and managed separately, there was not an opportunity to determine if the low tomato yield in that part of the field would be repeated on the beans.

8. Gypsum blocks placed at 20 locations in Field 5 during the 1998 bean crop were useless for detecting differences in irrigation effectiveness. The blocks were not sensitive in the right portion of the moisture release curve for the fine-textured soil. However, we note that in areas with slowest drainage, readings on the blocks barely changed between irrigations, and this by itself, may be an important finding. A second type of moisture block was more sensitive in the range of interest, but lack of agreement between individual blocks was a problem. In 1999, neutron probe access tubes were installed at 12 locations in the same field, now planted to sunflower. We observed standing water in many of the tubes at a depth of 4-5 ft even just prior to the grower's irrigations. Data analysis is yet to be completed.

Researchers and the grower agree that irrigation management and related tillage management (i.e., subsurface tillage) are key cultural practices and need to be monitored along with nutrient, pest, and soil variables.

Development and Testing of Application Systems for Precision Variable Rate Fertilization

Project Leader:
Ken Giles
Department of Biological and Agricultural Engineering
University of California
Davis, CA
(530) 752-0687

Cooperators:
Tony Turkovich
Button & Turkovich
Winters, CA

Graeme W. Henderson
Capstan Ag Systems, Inc.
Pasadena, CA

INTRODUCTION

Precision or "site-specific" management of agricultural production involves the application of fertilizer, pesticides, water and other inputs on land areas much smaller than previously used when entire fields are managed uniformly. The concept is simple; by utilizing accurate navigation and positioning, the crop yield, soil properties and other characteristics can be used to produce maps or databases of soil, climate, crop response or pest variation. From the collected information and by understanding crop development, the crop inputs and production management can be refined and adjusted to small, unique areas in the field. This improves overall profitability while possibly reducing undesired environmental effects. Research is underway to understand how the concept can be applied to California agriculture. Crop responses to fertilization practices, variability in soil properties, potential for reduced adverse environmental effects and improved economic returns are being investigated.

This project is working with a key mechanical component in precision farming, namely, a fast system for varying the application rate of liquid and gaseous fertilizers. If a grower wants to change fertilizer rates on a small scale, the applicator must be able to respond quickly since the ground speeds are often high. Most application equipment, even those with electronic rate control, cannot respond quickly enough. Moreover, the range and resolution of rate control are often limited when liquid pressure is changed to adjust the flow rate.

A new liquid control system has been developed at University of California, Davis that can control liquid spray or release rates over an 8:1 range and respond within 0.3 seconds and often within 0.1 seconds. The system uses electronically controlled pulsing valves at each fertilizer outlet to meter the desired flowrate without disrupting the distribution pattern. This project is investigating using the system for liquid fertilizer and anhydrous ammonia application for variable rate fertilizing.

OBJECTIVES

One goal of this project is to determine if desired rate changes can actually be achieved with existing application equipment and improved metering systems. Another goal is to address the question, "Can uniformity and accuracy of fertilizer application rates be improved with the pulsing valve flow rate control approach?" The specific objectives are:

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

DESCRIPTION

For the first objective, a test tank was built and a recirculating system was used to pump two common liquid fertilizers (UN 32 and UN 20) through a test boom of liquid pulse valves and liquid spray nozzles. The liquid pressure was varied over a practical range of 10-30 psi (75-225 kPa) and three common ag spray nozzles were tested (8008 and 11015 flat fans and TF-10 flood tip). The valve pulse frequency and duration was varied over a wide range and the resulting liq-

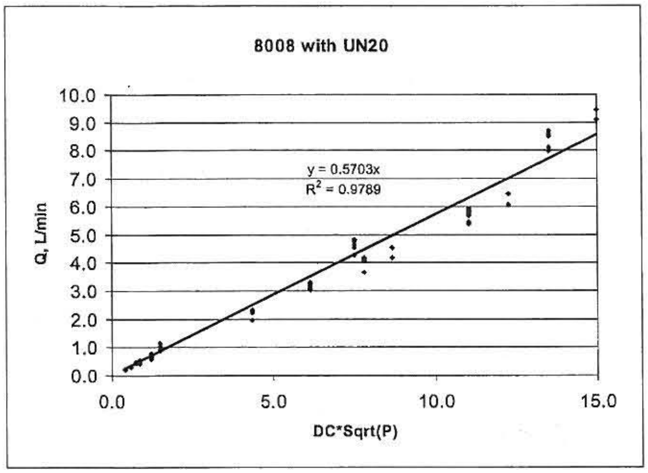


Figure 1. The flowrate of UN 20 fertilizer solution through an 8008 (80° angle, 0.8 gpm at 40 psi) standard flat fan spray nozzle over a range of pressures and pulsing duty cycles (% on time) of the control valve. Observed data and fitted line are shown.

uid flow rate was measured. From the results, the possible range of fertilizer rate control was estimated.

For the second objectives, the pulse valves were installed on two liquid applicator vehicles. One vehicle was a 500 gal (2000 L) trailer sprayer with a 30 ft (9 m) boom. On that test vehicle, a research system was installed to allow monitoring and recording of the liquid application rates and liquid pressures. The desired pressures and rates could be programmed into the system for testing how fast the system could respond. The second vehicle was a commercial system— a Case Tyler Patriot® WT self-propelled liquid applicator with a 700 gal (2,600 L) tank and a 75 ft (23 m) boom. The Case machine was equipped with an AIM® control system consisting of a Mid-tech TASC® rate controller and a Springhill Navigator® GPS system. The trailer sprayer was used to investigate the speed of response of the pulsed valve system when integrated into a complete rate controller system. The Case vehicle was used to demonstrate and investigate using the pulsed valves with a true GPS-directed application map in a test field.

The third objective is underway in cooperation with an equipment manufacturer, Kansas State University and a California application company. Preliminary data have shown that the pulsed valve system can improve uniformity of anhydrous ammonia distribution across a manifold, reduce the formation of vapor and allow a wider range of application control. A test system will be placed in the field in California during the fall of 1999.

RESULTS AND CONCLUSIONS

The recirculating test results were conclusive. Generally, the flow rate of liquid through a fertilizer nozzle is proportional to the square root of the liquid pressure at the nozzle. This is generally how liquid applicators are calibrated and how rates are changed, either in response to changing ground speeds or variable rate applications. However the problem with this is that large changes in pressure must be made in order to achieve small changes in flow rate. For example, if an applicator wishes to double the flow rate, the pressure must be increased by 4 times. This can cause delays in changes and also affect the distribution pattern of the fertilizer. Even with the pulsing valve controller, the liquid pressure still affects the flow rate. Therefore, if the system is to be useful, the flow rate of fertilizer from a nozzle should be proportional to the square root of the liquid pressure and the percent open time (duty cycle) of the pulsing valve. The collected data were analyzed by looking at each nozzle and fertilizer combination and seeing if any relationship held. Example results for selected fertilizer and nozzle combinations are shown in Figures 1 and 2. In each case, the relationship was proven with a high degree of statistical confidence. These results indicate that the flow control concept should work well for precision fertilizer application.

The installed system on the trailer sprayer was used to test the performance of the pulsed valves when integrated into a complete rate control system. Results are shown in Figure 3.

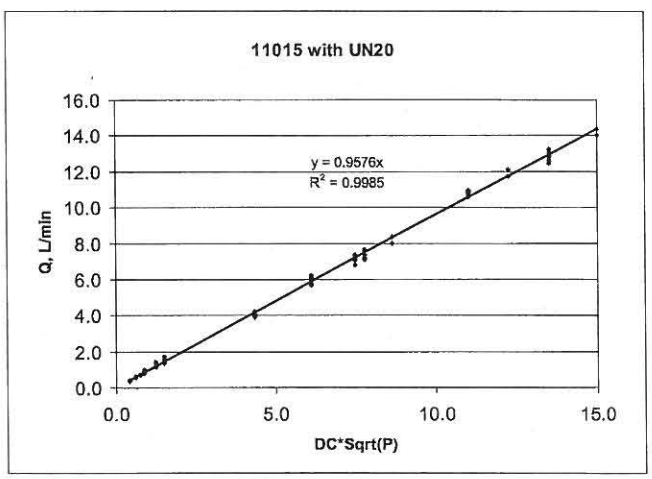


Figure 2. The flowrate of UN 20 fertilizer solution through a 11015 (110° angle, 1.5 gpm at 40 psi) standard flat fan spray nozzle over a range of pressures and pulsing duty cycles (% on time) of the control valve. Observed data and fitted line are shown.

In that test run, the liquid pressure was kept fixed at 60 psi (410 kPa), and the liquid application rate was varied over a 3:1 range of 10 to 30 gal/acre (90 to 270 L/ha) with instantaneous changes every 100 seconds. Each time the application rate was changed, it disturbed the pressure system which then responded by restoring the pressure setpoint. The spray trailer had 30 foot boom of 11005 fan nozzles and a test ground speed of 5 mph. The data showed that the system was both stable and could respond quickly. A 3:1 rate change with a conventional system would require a 9:1 pressure change—well beyond the range of most nozzles and systems. These results indicate that the pulsing technique can provide fast response over a useful range of application rates.

The installed system on the self-propelled sprayer was used to generally evaluate the integration of the pulsed flow system into a commercial system including a GPS navigation and variable rate system, a commercial rate controller with conventional electronics and commercial software for creating a variable rate application map. The pulsing nozzles were interfaced to the existing rate controller using a commercial control module. Otherwise, the GPS system and variable rate map creation software was used without any modification. A series of application tests, at different ground speeds and application rates, was conducted. The system generally performed well and the pulsed spray technique worked well with the commercial equipment. These results indicate that the technique is compatible with existing commercial equipment.

Work on the final objective is still underway but the general approach has been to install the pulsing valves downstream

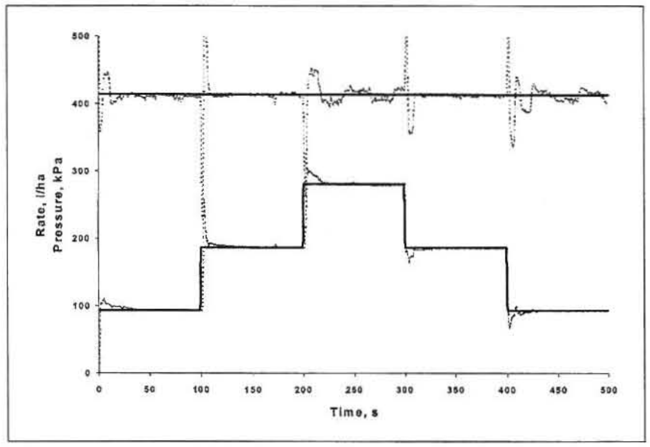


Figure 3. Response performance of fertilizer applicator with a 30 foot boom of 11005 fan nozzles and a test ground speed of 5 mph. The pressure was maintained at 60 psi and the application rate changed instantly from 10 to 20 to 30 gal/acre and back down. The solid lines are the desired pressure and rate; the dotted lines are the actual response.

of the ammonia distribution manifold. This allows the manifold to be kept at a sufficiently high pressure to prevent vapor formation in the lines and to keep a uniform distribution of flow through the manifold. The pulsing valves are then used to modulate flow using the same technique as with the liquid controller. Some problems have been seen with freezing of valves since the expansion of the ammonia from liquid to gas absorbs heat from the valve. Work is underway to prevent such freezing and to use chilling capacity to cool the incoming ammonia.

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

Project Leader:
Jack W. King, Jr.
Research for Hire
Portville, CA
(209) 784-5787

Cooperators:
Nat Dellavalle
Dellavalle Laboratories
Fresno, CA

Steve Beckley
California Fertilizer Association
Sacramento, CA

Dan Munk
UC Copperative Extension Fresno County
Fresno, CA

Steve Spangler
UNOCAL
Fresno, CA

David Holden
AG RX
Oxnard, CA

Robert Fry
USDA/NRCS
Hanford, CA

G. Stuart Pettygrove
Department of Land, Air and Water Resources
University of California
Davis, CA

OBJECTIVES

1. Compile a monthly calendar of agricultural practices including method, amount and form of nitrogen fertilizer applied to major crops in California's San Joaquin Valley.
2. Develop precise time fertilizer application information for San Joaquin Valley

DESCRIPTION

Nitrogen contained in fertilizers applied to agricultural lands can be lost to the atmosphere in the form of ammonia and nitrogen oxide. Nitrogenous gases released to the atmosphere can lead to the production of ozone and cause air pollution problems in the San Joaquin Valley. Ozone concentrations in the San Joaquin Valley often exceed state and federal ambient air quality standards especially during the winter months. An improved understanding of the causes of these excesses will require the development of the inventories of nitrogen oxide and ammonia emissions from all potentially significant sources in the San Joaquin Valley, including fertilizer application.

This project will generate a calendar of N fertilizer applications for the major crops in San Joaquin Valley. The report will describe factors that will account for differences in the timing of N fertilizer use between farms, crop years, and timing of N fertilizer application among regions of the San Joaquin Valley. This project will also identify and describe circumstances that make it feasible to predict and inventory, within a comparatively precise time frame, instances of strongly expressed pulses of N fertilizer application to agricultural lands.

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

Project Leaders:
Thomas Harter/Jan Hopmans/William Horwath
Department of Land, Air and Water Resources
University of California
Davis, CA
(559) 646-6569

OBJECTIVES

Nitrate-nitrogen is the most widespread contaminant in groundwater, causing as much as ten times as many well closures in California as all other industrial contamination combined. While a large amount of research has focused on nitrogen cycling in the root zone of California tree fruit orchards (0-6 ft depth), little is known about the fate of nitrogen between the root zone and the groundwater table. Unlike other agricultural regions of the United States, groundwater levels in many areas of Central and Southern California are from 30 ft to over 100 ft deep. Therefore, the deep vadose zone is a critical link between agricultural sources and groundwater. Few studies have surveyed nitrogen levels or denitrification rates at such depths or monitored leaching of nitrogen to a deep water table. Field-scale spatial variability of nitrate levels due to natural variability of soils and vadose zone sediments also remains unaccounted for in most work on groundwater quality impacts of agricultural nitrogen management. The objectives of the proposed research are:

1. Investigate the fate of nitrogen throughout the entire deep vadose zone at a well-controlled, long-term research orchard with a stratigraphy typical of many areas on the east side of the San Joaquin Valley and Southern California, and with management practices representative of orchards and vineyards.
2. Develop and validate an appropriate modeling tool to assess the fate of nitrogen in deep, heterogeneous vadose zones.

DESCRIPTION

During 1998, approximately 3000-ft of geologic material was drilled and characterized from 60 cores drilled to groundwater at a 52-ft depth. Eighteen cores were sampled at each of three subplots in the orchard, The subplots had been subject to a twelve-year fertilization trial with different rates of fertilization: The annual fertilization rates had been less than 5 lb/acre in the first subplot (0 lb/acre treatment), 100 lb/acre in the second subplot, and 325 lb/acre in the third subplot.

Drilling and field analysis during the initial months of the project provided a detailed characterization of the geologic architecture that makes up the vadose zone underneath the orchard. It was also possible to map several ancient soil horizons throughout the orchard. The ancient soil horizons are typically much less permeable than the remaining sediment and impede the downward movement of percolating water. The hypothesis is that these so-called paleosoils may potentially be conducive to denitrification of NH_4-N. Former river channels of the Kings River that meandered through the orchard during, or prior to, the last ice age were also mapped out. These channels are composed primarily of clean sands that readily percolate soil water and any nitrate dissolved in the water.

During the past year, laboratory analysis was implemented to determine the distribution of nitrate and other chemical parameters in the vadose zone and to determine the hydraulic properties of the various geologic units that were encountered underneath the orchard. During the coming year, the geochemical and hydraulic characterization of the core samples will be completed. Ultimately, this work should provide the geologic framework, the hydraulic framework associated with the geologic framework, and the geochemical process framework, all of which affect the fate of nitrate in the vadose zone. The "snapshot" of the NO_3 distribution that were obtained from the cores is the result of the geologic-hydraulic-geochemical architecture.

RESULTS AND CONCLUSIONS

This year's focus has been to determine, whether significant differences can be observed in average vadose zone nitrate concentrations underneath the three subplots, even 2 years after completion of the long-term fertilization research project and a one-time 100 lb/acre application throughout the orchard during that interim period.

The average nitrate concentration in deep soil water of the first (0 lb/acre) and second subplot (100 lb/acre) were not significantly different (5 mg/L and 7 mg/L, respectively). Variabiliy of nitrate concentrations in both subplots was very large, ranging from less than 1 mg/L in many samples to over 100 mg/L in some soil samples. Underneath the 325 lb/acre N treatment, however, average NO_3-N concentrations in soil water were almost three times higher (17 mg/L) than in the two other subplots. Almost a third of the NO_3-N samples exceeded concentrations of 10 mg/L (the maximum allowable groundwater quality limit). The high soil water NO_3 concentration levels are similar to groundwater NO_3 concentrations found in many areas with elevated NO_3-N contamination levels.

Due to the large localized variability of the NO_3 concentrations throughout the 50' profile, no significant NO_3 trends were observed with depth indicating that denitrification is not a dominating factor in this research orchard. Isotope analysis and computer modeling will help to further identify any denitrification processes, while assessing the impact of geologic heterogeneity, lateral flow mixing (between different subplots), and vertical mixing due to the changes in N management during the year before drilling on nitrate concentrations throughout the deep vadose zone.

The amount of water stored under unsaturated conditions in the vadose zone is equivalent to 12 acft per acre or more than 5 years worth of irrigation recharge (estimated to be 2 acft/ac per year or less). The total N storage in the vadose zone below the root zone is 190 lb (0 lb/acre treatment), 240 lb (100 lb/acre treatment) and 620 lb/acre (325 lb/acre treatment). This corresponds to annual N losses of 30-40 lb/acre in the first and second subplot, and over 100 lb/acre in the third (325 lb/acre) subplot.

The NH_4-N found underneath the zero lb/acre subplot is attributed to lateral movement of soil water (the subplots are only 10' wide, while the vadose zone is 50' deep), to background NO_3 concentration in irrigation water, and to significant influx of N during the one-time 100 lb/acre application 9 months prior to drilling. For the same reasons, the total nitrogen found underneath the high fertilization subplot is thought to be a diluted mixture with net annual nitrogen losses potentially being as high as 250-300 lb/acre. If the high N treatment had been applied to the entire orchard, our preliminary estimates indicate that NH_4-N concentrations in the percolating water recharging the aquifer would have been as much as three to fives times higher, on average. Such concentrations would exceed the groundwater quality standard five- to tenfold. The detailed nitrate "snapshot" is therefore direct evidence for the importance of proper nutrient management in tree orchards with respect to protecting groundwater quality.

Improving the Fertilization Practices of Southeast Asians in Fresno and Tulare Counties

Project Leader:
Richard Molinar
UC Cooperative Extension
Fresno, CA
(559) 456-7555

Cooperator:
Manuel Jimenez
UC Cooperative Extension
Visalia, CA

INTRODUCTION

Fresno and Tulare Counties are first and third in the state for total value agricultural production, respectively. These two counties also have many small farms and numerous Southeast Asians than all other counties. A small farm is one, which is 'family run' and grosses less than $250,000 in sales. Immigrants from Laos comprise the majority of Southeast Asian small farmers and estimates are in the range of 800-1,000 immigrant farmers. The Hmong, Lao, and Mien sub groups from Laos first started coming to the United States in 1978. Hmong make up about 62 percent of all the Asian farmers, and 30 percent are Lao. New groups of immigrants from Laos continued to come over until 1998 when the refugee camps in Thailand were closed. The majority settled in the Southern San Joaquin Valley.

Each of the three subgroups have their own distinct language and have very limited education. These farmers are not familiar with modern technology-based and mechanized farming system of the Western World. The type of farming in Laos is generally "slash and burn" with little mechanization. The majority of strawberries in Fresno and Tulare are now raised by the Hmong and Mien populations. They also grow many other Asian specialty crops such bittermelon, opo, sinqua, daikon, bok choy and lemongrass. It is estimated that between 25,000 to 35,000 acres are farmed intensively by these groups.

OBJECTIVES

1. Obtain background and demographic information of Hmong, Mien, and Lao farmers through a survey, and ascertain current fertilizer practices, as well as knowledge of plant nutrition and fertilizer use through a "pre-test".
2. Provide seven training classes, demonstrations, and/or workshops in the areas of plant nutrition, fertilizer analysis, integrated pest management, and chemical safety.
3. Statistically measure the effect of gained knowledge in plant nutrition through a post-test at the conclusion of the training sessions.

DESCRIPTION

In the first phase of the project 20 farmers were identified and given the initial survey and pre-test. The plan was to conduct the entire project in field groups at their sites. Each of the 20 surveys required about 2 hours to complete because of the translation and questions from the growers. It was quickly realized that growers may have a very difficult time to meet at specific times for their training. The growers would either not show or be unable to meet at the predetermined times due to unknown or variable schedule.

A plan was devised to recruit growers and bring them together in one group for one day a week. The sessions would continue for seven weeks in the Cooperative Extension office in Fresno. Each session lasted for 3 hours in the evening. Several incentives were added consisting of complimentary personal protective equipment (PPE), door prizes, and continuing education Units (CEU) for their restricted permit renewal (required by the Department of Pesticide Regulation). All seven sessions were consistently attended by 15 to17 people. At the completion of the training a post test was given to measure and differences in learning as a result of the training sessions.

RESULTS AND CONCLUSIONS

Farmers Background

Surveys from the first and second groups were combined for the demographic and background information (32 respondents). Most of the people in the class were Hmong farmers from Laos, all males (the principal member of the family),

Table 1. Respondent Characteristics.

Respondent Characteristics	*Number*
ETHNICITY	
Hmong	29
Laotian	2
Cambodian	1
COUNTRY OF ORIGIN	
Laos	30
Thailand	1
Cambodia	1
NUMBER OF YEARS IN THE U.S.	
4 to 8 years	3
9 to 12 years	2
13 to 16 years	7
17 to 19 years	14
20 to 25 years	6
AGE	
31 years to 35 years	6
36 years to 40 years	6
41 years to 45 years	5
46 years to 50 years	7
51 years to 55 years	5
Over 55 years *(two missing cases)*	1
SEX OF RESPONDENT	
Male	32
Female	0
EDUCATION	
Less than 3 years	6
3 to 4 years	9
5 to 6 years	7
7 to 8 years	3
9 to 10 years	3
11 years or more	4

and most were between 30 to 50 years of age (Table 1). Almost 19 percent of the class had less than 3 years of any type of schooling and 78 percent did not continue their education beyond 8th grade.

Farm Characteristics

When asked how many years they had been farming in the U.S., 60 percent reported 4 years or less (Table 2). This is important from the issue of the amount of exposure they have had to Western technology. Also interesting is the fact that 97 percent farm less than 20 acres. Only one person had more than 20 acres, and almost everyone rented their land. The main crops raised were green beans and strawberries, and the most often used place to sell their produce was the local packing house (41percent), even though a 10 percent commission is taken from their sales. Only 25 percent of the farmers sold at a farmers market.

Pests and Chemicals

A variety of insects, pests and weeds were mentioned as problems (Table 3). However most of them have difficulty identifying the various pests by name as evidenced in the pre-test. Use of a variety of insecticides was mentioned to control the pests. However, only two herbicides were used by this group—Roundup® and Gramoxone®. None of the group uses preemergent herbicides.

Table 2. Farm Characteristics.

Farm Characteristics	*Number*
YEARS IN FARMING IN U.S.	
None	2
1 to 2 years	6
3 to 4 years	10
5 to 6 years	6
7 to 8 years	2
9 years or more *(two missing cases)*	4
TOTAL NUMBER OF ACRES	
1 acre or less	7
2 acres	11
3 to 4 acres	2
5 to 9 acres	2
10 to 12 acres	4
13 to 15 acres	1
16 to 20 acres	4
More than 20 acres	1
RENT OR OWN ACRES	
Rent	30
Own	2
MAIN CROP	
Beans	13
Strawberries	7
Tomato	2
Moqua	2
Eggplant	2
Lemon grass	2
Other	3
None grown	1
MARKET OUTLET	
Farmer's Market	8
Packing House	13
Farm/Packing House	5
Roadside Stand	0

Table 3. Most Frequently Mentioned Pest Problems (Open-ended response).

Pest Problems	*Number*
INSECT OR DISEASE	
Spider mites/Mites	9
Aphids	7
Worms	7
Whitefly	3
Other	8
WEEDS	
Johnson grass	5
General grasses	8
Pigweed	4
Lambsquarter	4
Nutsedge	4
Bindweed	2
Other	2
General weeds	9
Chemicals Used	*Number*
INSECTICIDES	
Dipel	11
Lannate	8
Asana	5
Diazinon	2
Malathion	2
Other	2
HERBICIDES	
Roundup	18
Gramoxone	2
Other	4

Technical Assistance

The most often used resources for information are nurseries (referring to strawberry and strawberry processor nurseries), UC Cooperative Extension, and the county agricultural commissioners office (Table 4).

Training, Pre-Tests and Post-Tests

The results of the training sessions, and their effects on learning, are being analyzed and will be included in the forthcoming final report.

Table 4. Farm Practices.

Farm Practice	*Number*
APPLY CHEMICALS	
Insect pests	18
Weeds	18
Hoeing/Hand Labor for Weeds	6
SOURCE OF INFORMATION	
Nursery	8
UCCE Farm Advisor	7
Ag. Commission	5
UC Small Farm Center	1
Friend	1
No source reported	7

Development of Irrigation and Nitrogen-Fertilization Programs for Turfgrass

Project Leaders:
Robert L. Green/Victor A. Gibeault
Department of Botany and Plant Sciences
University of California
Riverside, CA
(909) 787-2107

Cooperator:
Janet S. Hartin
UC Cooperative Extension
San Bernardino/Los Angeles Counties
San Bernardino, CA

OBJECTIVES

1. Test irrigating tall fescue at a defined annual amount (80 percent historical ET_0 plus rain) with increased irrigation during the warm season to improve grass performance, and then proportionally adjusting the cool-season irrigation amount downward to make up for the additional warm-season irrigation. These treatments are compared to irrigating tall fescue at a constant rate of 1) 80 percent historical ET_0 plus rain and 2) 80 percent ET_0 (real-time) plus rain.
2. In conjunction with irrigation treatments, test the influence of the annual N-fertility rate on tall fescue performance.
3. Quantify the effects of irrigation and N-fertility treatments on tall fescue visual appearance and drought stress tolerance, growth (clipping yield) and N uptake, along with treatment effects on soil water content and soil N status.
4. Develop BMPs for tall fescue relating to turfgrass water conservation and N-fertilizer use efficiency, which provide optimal performance in terms of visual quality and drought stress tolerance, growth (clipping yields), and N uptake.
5. Conduct outreach activities, including trade journal publications and oral presentations, emphasizing the importance of turfgrass BMPs, and how to properly carry out these practices for turfgrass irrigation and N fertilization.

DESCRIPTION

This project involves the study and development of best management practices (BMPs) for landscape water conservation and N-fertility efficiency on tall fescue, currently the most widely-planted turfgrass species in California. This 3-year field study, initiated January 1, 1998, investigates irrigation treatments that are designed to test irrigating tall fescue at a defined annual amount (80 percent historical ET_0 plus rain), with increased irrigation during the warm season to improve grass performance, and then proportionally adjusting the cool-season irrigation amount downward to make up for the additional warm-season irrigation. These treatments are being compared to irrigating tall fescue at a constant rate of 1) 80 percent historical ET_0 plus rain and 2) 80 percent ET_0 (real time) plus rain (see Figure). Treatments B and C are considered "water banking" treatments because of the increased irrigation amount during the warm season to improve tall fescue performance, followed by proportionally adjusting the cool-season irrigation amount downward to makeup for the additional warm-season irrigation. It should be noted that 80 percent historical ET_0 plus rain and 80 percent ET_0 plus rain irrigation treatments would be comparable to 100 percent historical ET_0 plus rain and 100 percent ET_0 plus rain, respectively, for most landscape sites because the distribution of uniformity (DU) of the irrigation system of the research plots is probably 20 percent higher than the DU of the irrigation system of most landscapes. Also, it should be noted that considerable care was taken to ensure accurate irrigation treatments and well-managed turfgrass.

In conjunction with the irrigation treatments, this study investigates N-fertilizer treatments designed to test optimal annual N rates for tall fescue performance in terms of visual quality and drought stress tolerance, growth (clipping yields), and N uptake. The influence of irrigation and N-fertilizer treatments on soil water content and soil N status is also being determined.

In the course of the study, outreach activities were also conducted. This included trade journal publications and oral presentations, reflecting both the ongoing research and the

Table 1. 1998 protocol for irrigation treatments based on a percentage of historical (hist.) ET_0 (three treatments) and ET_0 (one treatment) for four, quarterly (3-month) periods, and three N-fertility treatments based on the annual N-fertility rate.

Month	Monthly historical ET (inch)[z]	Quarter	Quarterly historical ET (inch)[z]	Irrigation treatment[y] A	B	C	D	N-fertility treatment[x] Date of application	Source of N	Rate (lb N/1000 ft^2) a	b	c
January	2.07	1										
February	2.87	1	8.97	80% hist. ET_0 (7.18")	58% hist. ET_0 (5.20")	58% hist. ET_0 (5.20")	80% ET_0	March 1	$Ca(NO_3)_2$	0.75	1.125	1.50
March	4.03	1										
April	4.13	2										
May	6.10	2	17.32	80% hist. ET_0 (13.86")	90% hist. ET_0 (15.59")	96% hist. ET_0 (16.63")	80% ET_0	May 15	NH_4NO_3	0.75	1.125	1.50
June	7.09	2										
July	7.93	3										
August	7.57	3	21.64	80% hist. ET_0 (17.31")	90% hist. ET_0 (19.48")	85% hist. ET_0 (18.39")	80% ET_0	August 15	NH_4NO_3	0.75	1.125	1.50
September	6.14	3										
October	4.15	4										
November	2.60	4	8.70	80% hist. ET_0 (6.96")	58% hist. ET_0 (5.05")	58% hist. ET_0 (5.05")	80% ET_0	October 15	$Ca(NO_3)_2$	0.75	1.125	1.50
December	1.75	4										
Total	**56.63**		**56.63**	**45.3"**	**45.32"**	**45.27"**	**TBD**[w]			**3.0**	**4.5**	**6.0**

[z]Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of California, Division of Agricultural and Natural Resources. Publication 21454 (see page 62). Data is for Riverside, CA.

[y]Anonymous. 1981. California rainfall summary, monthly total precipitation, 1949-1980. SDWR. 54 pp. plus microfiche. Data is for Riverside, CA.

[x]The CDFA study is a split-plot design, with irrigation treatments assigned to 20.0- x 20.0-ft main plots that are arranged in three randomized complete blocks. Treatments A, B, and C reflect reported monthly turfgrass crop coefficients and are applied in two irrigation events per week–Saturday and Wednesday morning before sunrise. These treatments are based on the 3-month irrigation treatment quantity and scheduled utilizing the application rates of each main plot and the total number of irrigation events per quarter (irrigation run times are set the first day of each 3-month period). Treatment D is based on the previous 7-day cumulative ET_0 (from an on-site CIMIS station 169 ft from the center of the research plot) and are applied in two irrigation events per week–Saturday and Wednesday morning before sunrise. This treatment is scheduled utilizing the application rates of each main plot and the two irrigation events per week (irrigation run times are set on Tuesdays). Irrigation events for all treatments are cycled to prevent runoff. Rain is not subtracted from either the 3-month or weekly irrigation treatment quantity but may result in cancellation of an irrigation event.

[w]N-fertility treatments applied uniformly to subplots by hand application. P_2O_5 applied as needed, according to annual soil test in December. K_2O applied in April, May, June, November and December at a rate of 1.2 lb $K_2O/1000\ ft^2$ per application (for a total of 6.0 lb K_2O applied during the year). Note: irrigation used to water in fertilizer will be subtracted from irrigation treatments.

[v]TBD = to be determined.

importance of turfgrass BMPs in general. Further presentations will evolve with the ongoing research and from audience evaluations, which will include an assessment of the current turfgrass management practices of the target audience, so suggestions can be made as to how such practices can be modified in order to meet the requirements of generally accepted BMPs for turfgrass irrigation and N fertilization. Upon completion of this project, necessary information will be generated for maintaining acceptable tall fescue, complying with landscape water-use budgets, and efficiently applying N fertilizers. Considering that water use is the top environmental issue in California, and that tall fescue is currently the most widely planted turfgrass species in the state, there is a high potential that BMPs developed from this project will have immediate and widespread adoption by professional turfgrass managers, personnel involved in the fertilizer industries, educators, consultants, as well as home-lawn owners.

RESULTS AND CONCLUSIONS

Results from the 1998 Field Study

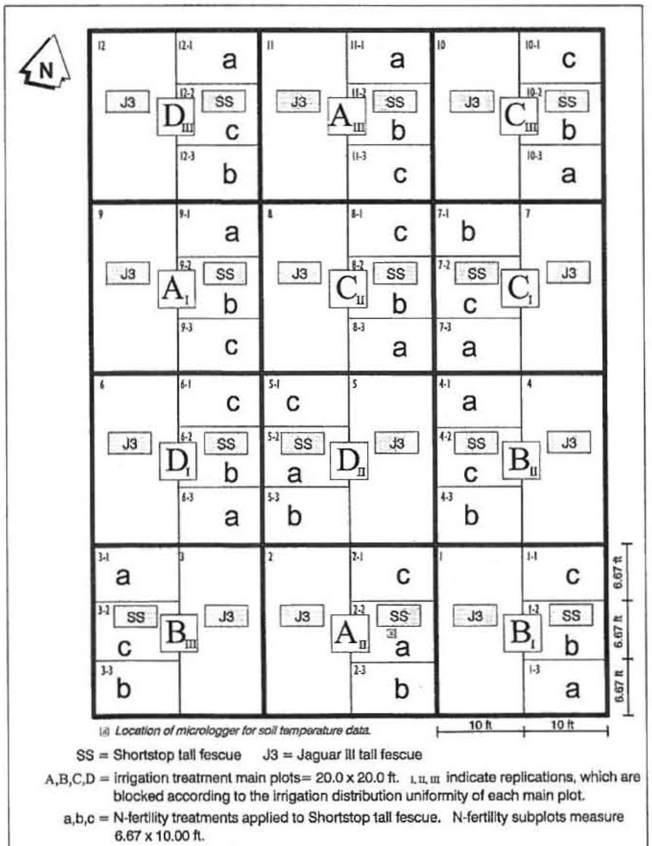
Selected results from the first year show several trends.

During the critical 3-month quarter of July to September, the water banking treatments (irrigation treatments B and C, Tables 1 and 2) performed as well as the 80 percent ET_0 (real-time) plus rain irrigation treatment. Performance was based on the number of rating dates that visual turfgrass quality and color was ≥ 5.5 on a 1 to 9 scale (Table 3). A rating of 1 is the poorest quality and a rating of 9 is the best quality, while a rating of 5 is minimum acceptable quality. Also, a rating of 1 is brown color and a rating of 9 is best dark green color, while a rating of 5 is minimum acceptable color.

Table 2. Protocol for research plot management and associated information for the tall fescue irrigation and N-fertility study.

Activity	*Comment*
1. Mowing	Each Friday, using a walk-behind, rotary mower set at a 1.5-inch mowing height. Clippings collected. Note that the Jaguar III tall fescue is mowed the same as the Shortstop tall fescue.
2. Irrigation	Two irrigation events/week, according to irrigation treatment protocol (Table 1). Irrigations are on Wednesday and Saturday morning, before sunrise. Irrigation water quality is excellent because it is the Riverside potable water supply.
3. Irrigation-system check	The vertical of all heads, checked with a level and adjusted once every 2 weeks. Clock operation, irrigation run times via hour meters wired parallel with solenoid valves, and pressure of the irrigation system routinely monitored to ensure accurate irrigation treatments. Catch-can tests conducted on each irrigation cell in January and June. Most recent application rates of each irrigation cell are then used in calculating irrigation run times.
4. Fertility	P_2O_5 and K_2O applied as needed based on annual soil tests beginning December 1997. The native soil of the research plot normally possesses sufficient levels of these elements. Native soil = Hanford fine sand loam; pH = 7.0 to 7.3; P-bicarbonate[z] > 20 ppm; extractable K[y] > 80 ppm; CEC = 13 meq/100 g; SAR = 2; ESP (%) = 2.0; soluble Ca[x] > 6.0 meq/L; soluble Na[w] > 5.0 meq/L; 12% clay; 51% sand; and 37% silt.
5. Pesticide application	To ensure representative tall fescue, pesticides will be applied if needed.

[z]Extractable phosphate based on alkaline extraction by 0.5 Normal $NaHCO_3$. Plant available phosphate for soils with pH greater than 6.5 by ascorbic acid reduction of phosphomolybdate complex and measurement by spectrophotometry. (As cited in DANR Analytical Lab Soil Citations.)
[y]Equilibrium extraction of soil for plant available exchangeable potassium performed using 1.0 Normal ammonium acetate (pH 7.0) with subsequent determination by atomic absorption/emission spectrometry. (As cited in DANR Analytical Lab Soil Citations.)
[x]Amounts of soluble calcium in the saturated paste extracted by inductively coupled plasmic atomic emission spectrometry. (As cited in DANR Analytical Lab Soil Citations.)
[w]Amount of soluble sodium in the saturated paste extracted by emission spectrometry. (As cited in DANR Analytical Lab Soil Citations.)



Plot plan for the tall fescue irrigation and N-fertility study.

The water banking treatments had one irrigation clock change on July 1, while the 80 percent ET_0 (real time) plus rain irrigation treatment had weekly irrigation clock changes (Table 1). The former treatments may be more realistic to the needs of the industry.

Treatment A, the constant 80 percent historical ET_0 plus rain, had the poorest performance among all irrigation treatments during the 3-month quarter of July to September. Performance was based on the number of rating dates that visual turfgrass quality and color was ≥ 5.5 on a 1 to 9 scale. During this time, the soil water content at the 9- to 24-inch depth for treatment A was lowest (dry) among all irrigation treatments.

During the October to December 3-month quarter, the water banking treatments had the poorest performance among the irrigation treatments. Performance was based on the number of rating dates that visual turfgrass color was ≥ 5.5, on a 1 to 9 scale. The poor performance was due to insufficient irrigation during the October to December 3-month quarter (Table 4).

Considering the historical rainfall patterns shown in Table 4, more irrigation should be allotted to the water banking irrigation treatments during the October to December 3-month quarter. It should also be noted that the rainfall amount during October to December 1998 was 71percent lower than the historical average.

Table 3. Protocol for measurements collected during the tall fescue irrigation and N-fertility study.

Measurement	*Frequency*	*Method and other comments*
1. Visual turfgrass quality	Once every 2 weeks on Friday, which is the day of mowing.	Ratings follow mowing. 1 to 9 scale, with 1 = worst, 5 = minimally acceptable, and 9 = best quality for tall fescue
2. Visual turfgrass color	Same time as quality	1 to 9 scale, with 1 = worst (brown), 5 = minimally acceptable, and 9 = best (dark green) color for tall fescue
3. Visual estimate of percent leaves that are wilted and rolled	As needed	1 to 100 percent of entire canopy of each subplot
4. Visual estimate of percent leaves that are fired and yellow to brown	As needed	1 to 100 percent of entire canopy of each subplot
5. Clipping yield, TKN, and N uptake	Four growth periods, with each period spanning four consecutive weekly clipping yields. All periods start 5 weeks following each of the four N-fertility treatment application dates (Table 1). Generally, periods are from April 1 to 30, June 15 to July 15, September 15 to October 15, and November 15 to December 15.	Weekly clipping yield, representing 7-days' growth, collected with the same mower used for the routine, Friday mowing, except a specially constructed collection box is attached to the mower. A subsample, 28.9 ft^2, is harvested from each subplot. Weekly clipping yields are dried and weighed via standard procedures. The four weekly yields within each growth period are pooled by the 36 subplots 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 along with the statistical effect of N fertility and irrigation treatments.
6. Volumetric soil-water content; soil-water tension	Once every month (volumetric soil-water content) and once every week (soil-water tension) on Tuesdays. Note that soil-water measurements are collected from Jaguar III tall fescue (Figure 1).	Volumetric soil-water content at 9-, 12-, 18-, 24-, 36-, and 48-inch depths via the neutron-scattering method (Campbell Pacific Nuclear, Model 503 Hydroprobe). Two neutron probe access tubes/irrigation cell, at the same center locations of each Jaguar III plot (Figure 1). Soil-water tension at the 6- and 12-inch depths using Watermark granular matrix sensors connected to a Watermark soil-moisture meter. Two locations/irrigation cell, at the same center locations of each Jaguar III plot (Figure 1).
7. Soil NO_3-N, NH_4-N and TKN	October 1	Soil samples collected from each subplot and prepared according to standard procedures. Analyses conducted at the DANR laboratory, located at UC Davis.
8. Weather data	Continuous	Data obtained from a CIMIS station located 169 ft from the center of the research plot. A soil-temperature data logger also is installed on the research plot at a depth of 4 inches.

All measured variables, except weather data and soil-water data, are statistically analyzed according to a split-plot design, with main-plots arranged in a RCB design. Soil-water data are analyzed for the irrigation treatments as a RCB design. A repeated-measures design also is used within and between years when appropriate. Weather data is summarized by week.

The 6 lb N/1000 ft^2 per year N-fertility treatment had significantly higher visual turfgrass quality and color ratings than the 3 and 4.5 lb N/1000 ft^2 per year treatments. Actually, both the visual turfgrass quality and color of the latter treatments were poor.

RECOMMENDATIONS

Based on the findings from the first year, revised water banking irrigation treatments are being implemented for 1999 and 2000 (please see irrigation treatments B and C, Table 5). These treatments are designed for the most water banking during the January to March 3-month quarter when the historical average rainfall is 5.55 inches (Table 5). Also, more irrigation has been allotted to the October to December 3-month quarter because the historical average rainfall during this quarter (3.22 inches) is lower than the January to March quarter.

Though these water banking treatments are customized for Riverside weather, the same process of irrigation allotment based on historical ET_0 and historical rainfall amounts could be developed for most locations in California.

The maintenance of shoot growth and plant vigor by providing a good N-fertility program is especially important for the potential drought stress conditions that may occur during reduced irrigation. It is concluded that the annual N rates, ranging from 3.0 to 6.0 lb N/1000 ft2, were too low, and

Table 4. Summary of ET_0, historical ET_0 and rainfall, applied irrigation water, and other irrigation information for four, 3-month quarters in 1998.

Variable	*Quarter*																*Annual*			
	January to March *Irrigation treatment*				*April to June* *Irrigation treatment*				*July to September* *Irrigation treatment*				*October to December* *Irrigation treatment*				*January to December* *Irrigation treatment*			
	A (80% hist. ET_0)[z]	B (58% hist. ET_0)	C (58% hist. ET_0)	D (80% ET_0)[y]	A (80% hist. ET_0)[z]	B (90% hist. ET_0)	C (96% hist. ET_0)	D (80% ET_0)[y]	A (80% hist. ET_0)[z]	B (90% hist. ET_0)	C (85% hist. ET_0)	D (80% ET_0)[y]	A (80% hist. ET_0)[z]	B (58% hist. ET_0)	C (58% hist. ET_0)	D (80% ET_0)[y]	A (80,80, 80, 80% hist. ET_0)[z]	B (58,90, 90, 58% hist. ET_0)	C (58,96, 85, 58% hist. ET_0)	D (80,80, 80, 80% ET_0)[y]
ET_0 (mm)	195.2	195.2	195.2	195.2	418.0	418.0	418.0	418.0	512.7	512.7	512.7	512.7	244.7	244.7	244.7	244.7	1371	1371	1371	1371
Historical ET_0 (mm)	227.8	227.8	227.8	227.8	439.9	439.9	439.9	439.9	549.6	549.6	549.6	549.6	221.0	221.0	221.0	221.0	1438	1438	1438	1438
ET_{crop} (ET_0 x K_c month) (mm)	133.9	133.9	133.9	133.9	398.5	398.5	398.5	398.5	440.7	440.7	440.7	440.7	169.0	169.0	169.0	169.0	1142	1142	1142	1142
Rainfall (mm)	366	366	366	366	43	43	43	43	14	14	14	14	24	24	24	24	447	447	447	447
Historical rainfall (mm)[x]	141	141	141	141	34	34	34	34	8	8	8	8	82	82	82	82	265	265	265	265
Applied water (mm)[w]	53	60	60	66	296	336	358	219	444	497	466	433	178	128	131	201	971	1021	1015	919
Total water (rainfall plus applied) (mm)	419	426	426	432	339	379	401	262	458	511	480	447	202	152	155	225	1418	1468	1462	1366
(Applied water/ET_{crop}) x 100	39.6	44.8	44.8	49.3	74.3	84.3	89.8	55.0	100.7	112.8	105.7	98.3	105.3	75.7	77.5	119.1	85.0	89.4	88.9	80.5
(Applied water/ET_0) x 100	27.2	30.7	30.7	33.8	70.8	80.4	85.6	52.4	86.6	96.9	90.9	84.5	72.7	52.3	53.5	82.2	70.8	74.5	74.0	67.0
(Applied water/historical ET_0) x 100	23.3	26.3	26.3	29.0	67.3	76.4	81.4	49.8	80.8	90.4	84.8	81.0	80.5	57.9	59.3	93.2	67.5	71.0	70.6	63.9
No. irrigation events	10	10	10	10	22	22	22	19	27	27	27	27	26	26	26	26	85	85	85	82
No. irrigation events canceled	16	16	16	16	4	4	4	7	0	0	0	0	0	0	0	0	20	20	20	23

[z]Historical ET_0. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of California, Division of Agricultural and Natural Resources. Publication 21454 (see p.62). Data is for Riverside, CA.
[y]Real-time ET_0 based on 7-day cumulative ET_0 from an on-site CIMIS station 169 ft from the center of the research plot.
[x]Anonymous. 1981. California summary, monthly total precipitation, 1949-1980. SDWR. 54 pp. plus microfiche. Data is for Riverside, CA.
[w]Applied water is calculated as (actual water time per day / system precipitation rate) x no. irrigation events. Numbers for each irrigation treatment are calculated as the average of three replicate plots.

Note: Within each column, underlined percentages can be compared to the percentages that are listed directly below the letters (A, B, C, D) that designate irrigation treatments.

Table 5. Protocol for 1999 and 2000 irrigation treatments based on a percentage of historical (hist.) ET_0 (three treatments) and for ET_0 (one treatment) for four, quarterly (3-month) periods and three N-fertility treatments based on the annual N-fertility rate.

Month Quarter	Monthly historical ET_0 (inch)[z]	Monthly historical rainfall (inch)[y]	Quarterly historical ET_0 (inch)[z]	Quarterly historical rainfall (inch)[y]	Irrigation treatment[x] A	B	C	D	N-fertility treatment[x] Date of application	Source of N $N\text{-}P_2O_5\text{-}K_2O$	Rate (lb N/1000 ft^2) a	b	c
January (1)	2.07	1.85											
February (1)	2.87	2.05	8.97	5.55	80% hist. ET_0 (7.18")	40% hist. ET_0 (3.59")	40% hist. ET_0 (3.59")	80% ET_0 43-0-0	March 1	Polyon	1.0	1.5	2.0
March (1)	4.03	1.65											
April (2)	4.13	1.02											
May (2)	6.10	0.28	17.32	1.34	80% hist. ET_0 (13.86")	92% hist. ET_0 (15.93")	85% hist. ETo (14.72")	80% ET_0 42-0-0	May 15	Polyon	1.0	1.5	2.0
June (2)	7.09	0.04											
July (3)	7.93	0.00											
August (3)	7.57	0.12	21.64	0.32	80% hist. ET_0 (17.31")	91% hist. ET_0 (19.69")	97% hist. ET_0 (20.99")	80% ET_0 42-0-0	August 15	Polyon	1.0	1.5	2.0
September (3)		6.14	0.20										
October (4)	4.15	0.39											
November (4)	2.60	1.02	8.70	3.22	80% hist. ET_0 (6.96")	70% hist. ET_0 (6.09")	70% hist. ET_0 (6.09")	80% ET_0 43-0-0	October 15	Polyon	1.0	1.5	2.0
December (4)	1.75	1.81											
Total	56.63	10.43	56.63	10.43	45.31"	45.30"	45.39"	TBD[v]			4.0	6.0	8.0

[z]Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of California, Division of Agricultural and Natural Resources. Publication 21454 (see page 62). Data for Riverside, CA.

[y]Anonymous. 1981. California rainfall summary, monthly total precipitation, 1949-1980. SDWR. 54 pp. plus microfiche. Data is for Riverside, CA.

[x]The CDFA study is a split-plot design, with irrigation treatments assigned to 20.0- x 20.0-ft main plots that are arranged in three randomized complete blocks. Treatments A, B, and C reflect reported monthly
turfgrass crop coefficients and are applied in two irrigation events per week–Saturday and Wednesday morning before sunrise. These treatments are based on the 3-month irrigation treatment quantity and scheduled utilizing the application rates of each main plot and the total number of irrigation events per quarter (irrigation run times are set the first day of each 3-month period). Treatment D is based on the previous 7-day cumulative ET_0 (from an on-site CIMIS station 169 ft from the center of the research plot) and are applied in two irrigation events per week—Saturday and Wednesday morning before sunrise. This treatment is scheduled utilizing the application rates of each main plot and the two irrigation events per week (irrigation run times are set on Tuesdays). Irrigation events for all treatments are cycled to prevent runoff. Rain is not subtracted from either the 3-month or weekly irrigation treatment quantity but may result in cancellation of an irrigation event.

[w]N-fertility treatments applied uniformly to subplots by hand application. P_2O_5 applied as needed, according to annual soil test in December. K_2O applied in April, May, June, November and December at a rate of 1.2 lb K_2O/1000 ft^2 per application (for a total of 6.0 lb K_2O applied during the year). Note: irrigation used to water in fertilizer will be subtracted from irrigation treatments.

[v]TBD = to be determined.

Uniformity of Chemigation in Microirrigated Permanent Crops

Project Leaders:
Larry Schwankl
UC Cooperative Extension
University of California
Davis, CA
(530) 752-4634

Terry Prichard
UC Cooperative Extension
University of California
Davis, CA

OBJECTIVES

1. Develop information on the water and chemical travel times and on application uniformity of both readily soluble products (e.g. liquid nitrogen fertilizers) and of low solubility materials (e.g. potassium sulfate) injected via solutionizer machines.
2. Develop recommendations in the form of best management practices for chemigation in order to attain uniform application of chemicals.
3. Conduct a series of workshops on chemigation of microirrigation systems.

DESCRIPTION

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

RESULTS AND CONCLUSIONS

Six commercial orchards/vineyards were evaluated for chemigation uniformity. Evaluations included determining water/chemical travel times through drip irrigation system mainlines/submains and through drip lateral lines. Chemical application uniformity was also determined. Drip irrigation systems travel times were measured by injecting chlorine (calcium hypochlorite) and monitoring its passage through the drip irrigation system using a pool/spa chlorine test kit. Chemical application uniformity was determined by injecting potassium chloride and collecting all the discharge from drip emitters at key locations in the drip irrigation system. The collected samples were then analyzed for potassium content at the UC DANR Analytical Laboratory.

Table 1 shows the travel times through the drip irrigation systems for the commercial vineyards and orchards evaluated. Note that there is a wide range of water/chemical travel times in both the mainline/submain and in the drip lateral line portions of the irrigation system. As the drip irrigation system designs vary from site to site, so do the water/chemical travel times through the irrigation system. No general recommendations on injection time periods to achieve high chemical application uniformity is appropriate for all drip irrigation systems. A one-time, field determination of water/chemical travel times is necessary for each drip irrigation system.

Additional work was done on a single drip lateral line to evaluate the impact of chemical application uniformity of varying the injection times and the post-injection irrigation times. The results of some of these evaluations are shown in Table 2. The lateral line evaluated was a 500-foot drip lateral (16 mm polyethylene tubing) with a 1 gallon per hour (gph), pressure-compensating, drip emitters installed every 5 feet. It was determined through field evaluation that the travel time for water/chemicals passing through the lateral line was 25 minutes.

Note that excellent chemical application uniformity was achieved when: (1) the injection period was equal to or greater than the water/chemical travel time to the end of the drip lateral (25 minutes in this case), and (2) the post-injection irrigation time was equal to or greater than the lateral line's water/chemical travel time. The results in Table 2 also show that there are two injection strategies to avoid. First, avoid injection periods which are less than the drip system's water/chemical travel times to the end (hydraulically) of the system. Secondly, an injection should always be followed by a period of "clean" water irrigation. This post-injection irriga-

Table 1. Water / chemical travel times through the pipelines and drip lateral lines for the vineyard and orchard field sites evaluated.

Site	Mainline and Submain Travel Time (min.)	Mainline/ Submain Length (ft)	Lateral Line Travel Time (min.) Advanced	Recession	Lateral Line (ft)
1	22	1000	10	12	175
2	30	1500	10	12	340
3	65	5000	10	12	340
4	15	1400	23	33	630
5	8	700	23	32	625
6	17	820	28	28	600

tion period should be at least as long as the water/chemical travel time to the end of the drip irrigation system. The worst chemigation uniformities would result from a too short (less than the end-of-system travel time) injection period followed by drip system shutdown.

RECOMMENDATIONS

As a result of our field evaluations, the following drip irrigation chemigation practice is recommended:

1. A one-time field determination of water/chemical travel times through the drip system should be done. Of particular importance is the determination of the time it takes for injected chemical to travel from the injection point to the hydraulic end of the drip irrigation system. Travel times can be readily determined by injecting chlorine and timing its movement through the drip system by testing for chlorine in the irrigation water using a pool/spa chlorine test kit.
2. Once the water/chemical travel time to the hydraulic end of the drip system is determined, the injection strategy to achieve high chemigation uniformity should consist of the following steps:

   Step 1: Allow the drip system to fill and come up to full pressure.

   Step 2: The injection period should be at least as long as the water/chemical travel time to the hydraulic end of the drip irrigation system. A longer injection period is even better.

   Step 3: The post-injection irrigation time should again be at least as long as the travel time to the hydraulic end of the drip irrigation system. A longer post-injection irrigation period is better.

Table 2. Chemigation uniformity in a drip lateral (500-feet long with 1-gallon per hour drip emitters installed at 5-foot intervals) for various injection time periods and various post-injection clean water irrigations. The water/chemical travel time to reach the end of the drip lateral was 25 minutes.

Injection Time (min)	Post-Injection Irrigation Time (min)	Relative Uniformity
50	50	100
50	25	98
50	0	25
25	50	90
25	25	95
25	0	11
13	25	81
13	0	7

California Certified Crop Adviser Program

Project Leaders:
Marilyn Martin/ Hank Giclas
Western Growers Association
Phoenix, AZ
(602) 265-0970

Arthur Bowman
Salida Ag. Chemicals, Inc.
Salida, CA

OBJECTIVES

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

1. Administrating the program by managing testing, continuing education, and participant record keeping.
2. Coordinating the CCA activities within the policies and goals of the national program and according to the direction of the State CCA Board.

SUMMARY

In 1992, the Certified Crop Advisor (CCA) Program was introduced in California and fully implemented by August 1994. The program is intended to respond to growing concerns at local, state and national levels that the improper use of fertilizer and related agricultural products was contributing to a variety of environmental problems including non-point source pollution. The CCA Program in California is designed to help raise the awareness and professional standards of individuals making recommendations for the use of agricultural fertilizers, pesticides and related products by providing a certification program which includes testing and education requirements of the highest levels.

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 units (CEU's) every two years.

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 advisors certifications (CEU's accumulated, tests, status etc). In addition in the last year the California 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.

The California Certified Crop Adviser Program offers information about the program on its web site: (**http://www.cacca.org**). For information about becoming a CCA, contact Marilyn Martin at the number above.

The following section contains summaries of other research and demonstration projects related to FREP's mission of efficient use of fertilizing materials. These projects are not funded by FREP, but they complement FREP's goals and will help provide the reader with a greater understanding of the scope of nutrient and irrigation research being conducted in California. The summaries were provided by the Project Leaders and were reviewed and edited by FREP staff. Readers are encouraged to contact the Project Leaders or UC SAREP for further details.

UC Sustainable Agriculture Research and Educational Program: Program Update 1999

Education Coordinator:
David Chaney
Sustainable Agriculture Research and Education Program
University of California
Davis, CA
(530) 754-8551

The UC Sustainable Agriculture Research and Education Program (SAREP) was established in 1986 by the University of California in response to California Senate Bill 872. SAREP provides leadership and support for scientific research and education that promote agricultural and food systems that are economically viable, sustain natural resources and biodiversity, and enhance the quality of life in the state's diverse communities for present and future generations. In support of that mission, SAREP's programmatic goals are that:

- California farmers and ranchers are more able to manage their land and businesses in ways that are economically viable and that protect and enhance both human and natural resources and biodiversity;
- Consumers have a closer connection to agriculture and California's rural and urban communities are strengthened through participation in sustainable food systems; and
- Government programs and policies encourage and support the development of sustainable farms, ranches and communities in California.

SAREP is a statewide Cooperative Extension program within the UC Division of Agriculture and Natural Resources. As such, we work with UC faculty and staff, as well as other organizations, community groups and institutions to: 1) fund basic and applied research, education and demonstration projects; and 2) provide practical information to producers on sustainable farming and ranching practices, and support the development of community-based food and agricultural systems.

GRANTS PROGRAMS

Since 1987, SAREP has funded 263 research, education and demonstration projects totaling more than $6.8 million covering a wide range of topics relevant to the state's farmers, ranchers, and communities. SAREP currently administers several different grant programs, which include:

- Sustainable Agriculture Research and Education
  - Crop and Livestock Production
  - Community Development
  - Public Policy
- Biologically Integrated Farming Systems—BIFS (extramural funds)
- Alternatives to Methyl Bromide (extramural funds)
- Educational Events
- Sustainable Agriculture Graduate Awards (SAGA)

Specific information on these programs, and grant criteria and requests for proposals are available at the SAREP Web site (**www.sarep.ucdavis.edu**) or by calling SAREP at (530) 752-7556.

In 1998-99, our latest funding cycle, SAREP granted about $1 million to 27 projects addressing the sustainability of California agriculture. Special allocations from the state legislature allowed us to fund six new projects evaluating alternatives to the soil fumigant methyl bromide, and seven Biologically Integrated Farming Systems (BIFS) projects addressing rice, walnut, citrus, prune, strawberry, dairy/forage, and apple production systems. From our standard budget allocation, grants were also awarded to projects looking at dairy waste management, cover cropping, conservation tillage, nitrogen management in almonds, soil organic matter, and the transition to low-input and organic production systems. An additional seven projects were funded in the community development/public policy area. For a complete list and description of current SAREP projects, visit the SAREP Web site.

EDUCATION AND OUTREACH

SAREP works with a variety of organizations and groups to examine critical problems and provide assistance and educational programs on sustainable farming and ranching practices, community economic development, community food systems, and other topics related to the sustainability of California's agriculture. These outreach efforts are geared toward a variety of audiences and complement and extend the projects SAREP is supporting through its competitive grants programs. Educational activities include conferences, workshops, field days and short courses on a range of topics related to farming, ranching, education and community development. We also produce a regular newsletter, and a variety of extension publications and educational/information resources. Recent publications and resources have addressed such topics as soil quality and management, cover cropping, biological control, habitat management, eco-labeling, community food systems, entrepreneurial community gardens, and crop-specific information on winegrape and apple production. Materials are available in print and electronic form on SAREP's nationally recognized Web site (**www.sarep.ucdavis.edu**).

With our shared goals of environmental stewardship and farm profitability, SAREP and FREP have cooperated on a variety of projects and programs. We have had the opportunity of co-funding several research projects, and actively sought ways to facilitate the development and exchange of critical information related to environmentally sound nutrient management. SAREP is pleased to take a more active role in this year's annual conference, and looks forward to enhancing our partnership with FREP in the future. For the purpose of more clearly identifying the SAREP-sponsored projects being presented at the conference, we are including them in this special section.

For more information on SAREP, contact: David Chaney, Education Coordinator, University of California, Sustainable Agriculture Research and Education Program, One Shields Ave., Davis, CA 95616. Tel. (530) 754-8551 email: dechaney@ucdavis.edu

Organic Matter and Long-Term Soil Fertility

Project Leader:
William R. Horwath
Department of Land, Air and Water Resources
University of California
Davis, CA
(530) 754-6209

DESCRIPTION

Maintaining soil fertility and optimizing nutrient retention and cycling are important goals in developing a sustainable cropping system that enhances the long-term fertility of soil. The increase in soil fertility is associated with the buildup of soil organic matter or, in more scientific terms, humic substances. Crop residue decomposition is a critical component of processes that lead to the formation of humic substances in soil. Crop residues are consumed by soil microorganisms and other soil fauna and in turn their waste products and bodies are the starting material for the formation of humic substances. Humic substances are composed of a wide range of materials consisting of all sorts of chemical molecules. These molecules interact with soil minerals, especially clay, and impart changes on soil structure and chemical makeup. These changes positively influence physical and biological soil properties. Therefore, soil organic matter maintenance is an essential process that controls ecosystem sustainability and is an important indicator of soil quality that can be used to diagnose long-term soil fertility.

Soil organic matter has qualities that contribute directly to crop growth through its effect on physical, chemical and biological soil properties. Organic matter in agricultural soils influence crop production by controlling soil fertility (N, P, S, exchangeable cations and trace elements), maintaining low bulk density, reducing the effects of soil compaction; increasing water holding capacity; and reducing soil erosion through enhanced soil structure. Conventional agricultural practices may ultimately degrade soil depending on the type of soil, degree of disturbance, and length of cultivation. Cultivation has been shown to reduce soil organic matter by destroying soil aggregates and structure making organic matter normally unavailable to microorganisms available for their consumption. The reduction in soil organic matter reduces the capacity of soil to mineralize nutrients thus requiring the input of additional fertilizers and soil amendments to compensate for the loss of soil organic matter. In California, irrigation and fertilization have made it possible to generally ignore the benefits of soil organic matter. Ground water pollution problems, soil erosion, salinity, and higher cost of production and transportation of fertilizers now necessitates a reassessment of past conventional agricultural practices.

Soil management has been shown to directly affect soil processes that control the amount of organic matter in soil. Sustainable cropping system research has shown that the accumulation and subsequent mineralization of organically stabilized nutrients initially occurs slowly and is dependent on crop residue input and soil disturbance. The lag in soil organic matter accumulation is a result of rate-limiting processes associated with the decomposition of residues and the subsequent stabilization of products and nutrients into soil organic matter. Once established, soil organic matter will supply nutrients for plant uptake through their utilization and turnover by soil microorganisms. The conversion from conventional to alternative agriculture management that enhances soil organic matter often requires five years of alternative management before the soil can significantly increase its capacity to supply nutrients for plant uptake.

Residue management, legumes in rotation, conservation tillage and recycling of agricultural wastes are sustainable low-input alternatives to conventional fertilizer practices that have been shown to increase soil organic matter. These types of low-input practices are intended to promote cropping system sustainability through nutrient stabilization in soil organic matter and enhancement of soil structure. Many of these practices are cost effective and would easily be adopted by California agriculture. However, the initial conversion to low-input practices may lead to lower crop yields as a result of nutrient immobilization by soil microorganisms and other loss, such as nitrate leaching. This often postpones and or delays the acceptance of these alternative practices in intensively managed California agriculture. The ideal sustainable nutrient cycling system should create a balance between plant nutrient use and microbial immobilization and mineralization of nutrients. The competition for nutrients between crop plants and soil microorganisms will ensure minimal environmental impact by minimizing root zone escape and off-site nutrient export from soil erosion. In turn, a soil with sufficient levels of organic matter will positively influence long-term soil fertility and enhance soil quality for future generations.

SOIL QUALITY ISSUES AND INITIATIVES IN CALIFORNIA'S CENTRAL VALLEY

Jeffrey Mitchell
Department of Vegetable Crops
University of California, Davis
Kearney Agricultural Center
Parlier, CA
(209) 646-6565

DESCRIPTION

Over the last several decades, growers in California's Central Valley, as in many other agricultural areas throughout the world, have become increasingly aware of the importance of soil organic matter (SOM) in relation to sustained soil quality or function. Soil carbon (C), which typically constitutes about half of SOM, is closely linked to many desirable soil physical, chemical and biological properties that are associated with enhanced soil productivity and quality. Soils become enriched in carbon from crop residues and deliberate inputs of organic amendments such as compost, manure and cover crops. Over the last decade, a number of studies have been conducted throughout California to evaluate the impact of these amendments on soil quality, nutrient cycling and farm economics. In 1995, the West Side Biologically Integrated Farming Systems (BIFS) Project was started by several farmers from the Five Points–Mendota region to monitor and evaluate on-farm demonstrations of various soil management practices and to gain better understanding of the effects of organic amendments with respect to their long-term management goals.

In this project, sixteen on-farm demonstration comparisons were established in large, side-by-side field plots. Applications of compost or manure were made to BIFS, or alternative management fields 25 times during the project. Late summer or winter cover crops were grown as green manures 9 times and combinations of cover crops and compost or manure applications were used twice. We have no data on current general patterns of use of these types of amendments throughout the West Side region, however, it is very unlikely that they are used on more than 5 percent of farmland annually. A 75 percent adoption of cover cropping or applications of compost or manure as was done during the three years of this project far exceeds current use patterns. Differences in a number of indicators including total soil carbon, microbial biomass carbon and nitrogen, exchangeable potassium, and soil organic matter content were observed when somewhat consistent and deliberately different management programs between the conventional and alternative fields were maintained throughout the project.

The use of soil quality indices has been proposed as a possibly useful means for farmers and land managers to organize the types of information that has been compiled as part of the West Side BIFS Project, and to help interpret how management practices affect soils and agroecosystems. We are currently using the minimum data set that was developed as part of the West Side BIFS Project to develop such a soil quality index that may be a useful point of departure for other studies.

Awareness has also recently increased concerning the negative impact tillage has on SOM storage. While moderate tillage may provide more favorable soil conditions for crop growth and development and weed control over the short term, intensive tillage of agricultural soils has historically led to substantial losses of soil C that range from 30 to 50 percent. Conventional tillage practices disrupt soil aggregates exposing more organic matter to microbial degradation and oxidation, and are one of the primary causes of tilth deterioration over the long-term. Micro and macro channels within the soil, created by natural processes such as decaying roots and worms may also be destroyed by tillage. Deep tillage, as is customarily done as a routine "soil preparation operation," is also costly and requires high energy and increased subsequent effort to prepare seed beds. A recent survey documenting a 40 percent decline in SOM since intensive tillage practices began in the Salinas Valley confirms the conclusion drawn from other long-term crop rotation studies (the Morrow Plots at the University of Illinois, the Sanborn Field Plots in Columbia, Missouri, and the Columbia Plateau Plots near Pendleton, Oregon) that intensive tillage typically leads to decreased soil C via gaseous CO_2 emissions in virtually all crop production systems. There is mounting evidence as well as concern that this C source has been a significant component of the historic increase in atmospheric CO_2, and the potentially associated greenhouse effect that is attracting attention worldwide.

Most current SJV annual crop production systems are very tillage intensive. Typically 9 to11 tillage operations are made in most fields following harvest in preparation for a succeeding crop at about 18 to 24 percent of a farmer's seasonal budget. Tillage in these production systems is typically done in a "broadcast" manner throughout a field, without deliberate regard to preserving dedicated crop growth or traffic zones. Studies by Carter over the last several decades however, have confirmed the potential to eliminate deep tillage, decrease the number of soil preparation operations by as much as 60 percent, reduce unit production costs, lower soil impedance and maintain productivity in a number of SJV cropping contexts using reduced, precision or zone tillage practices that limit traffic to permanent paths throughout a field thereby reducing soil compaction and preserving an optimum soil volume for root exploration and growth . Recent work by the author also in the SJV evaluating a mulch transplanted processing tomato production system has also demonstrated the potential to sustain productivity under certain mulches and increase soil C and earthworms using a CT approach. Given the successes of these component research studies and in anticipation of increasing energy and production costs (P. Goodell, Personal communication) as well as out of a growing desire among producers to improve soil quality via C sequestration, we have initiated a number of research studies to develop and extend information on CT practices in long-term cropping systems evaluations in California where they currently are not used.

Changes in Organic Matter Under Conventional and Alternative Agricultural Management

Project Leader:
William R. Horwath
Department of Land, Air and Water Resources
University of California
Davis, CA
(530) 754-6209

DESCRIPTION

The importance of soil organic matter in cropping system sustainability is in its ability to store nutrients and improve soil structure. These are important attributes of soil quality that are required to enhance long-term soil fertility. Our research efforts have focused on defining the characteristics of soil organic matter that contribute to cropping system sustainability. In order to address the impact of soil organic matter on long-term soil fertility, we studied soils that have been managed fundamentally differently for nine years at the University of California Davis Sustainable Agriculture Farming System (SAFS) Project. The SAFS study consists of two conventional and two alternative systems that differ primarily in crop rotation and use of external inputs. These include 4-year rotations under conventional, low-input, and organic management with processing tomatoes , safflower, corn and bean. In the low-input and organic treatments, common vetch serves as a winter cover crop to supply additional nitrogen. The cover crop nitrogen in the alternative systems is supplemented by reduced chemical fertilizer in the low-input treatment and composted poultry manure in the organic treatment.

The SAFS project provided us with a model experiment to address long-term changes in organic matter under conventional and alternative agricultural management. The interest of local farmers in the SAFS's project is tremendous and allowed us to disseminate our result to the local farm community. Greater farmer appreciation is expected since the research results generated for SAFS is applicable to other agricultural regions in California, especially the San Joaquin Valley. We used stable carbon and nitrogen isotopic methods to determine the effects of the transition from conventional to low-input/organic farming management on the turnover of soil organic matter. We examined the turnover of soil organic matter on the basis of progressive changes in isotopic composition of humic fractions of soil where corn (C4 crop) is in rotation with C3 crops and composted manure and/or legumes are used in the alternative agronomic treatments. These natural inputs provided us with a tracer to study the cycles of carbon and nitrogen in soil as they are affected by the different cropping system management.

The results show a significant increase in soil organic matter in alternative system (low-input/organic) vs. conventionally managed plots. The addition of partially composted poultry manure increased soil organic matter more than any other treatment. However, because of the large amount of carbon and nitrogen added to the organic system, this system lost more carbon and nitrogen through mineralization compared to the conventional system. The low-input system appears to be the least efficient in retaining carbon input, or in other words converting crop residues into soil organic matter. The conventional treatment was the most efficient at converting crop residues into soil organic matter. However, since the conventional system received less carbon and nitrogen inputs than the alternative systems, it produced less soil organic matter than the alternative systems. The low-input treatment, which uses a winter cover crop and reduced fertilizer input, was the least efficient at converting crop residues into soil organic matter. The increase of soil organic matter in the organic treatment shows the importance of recycled agricultural wastes, such as composted poultry manure, in increasing soil organic matter. In contrast, the low-input system was the most efficient at storing nitrogen compared to the conventional and organic systems. These results show that formation of soil organic matter is dependent on both soil management and types and/or quality of soil inputs.

The quality of soil organic matter is also influenced by both soil management and types and/or quality of soil inputs. We have shown that the low-input treatment has had comparable or in many cases increased yield compared to the conventional system. However, using standard assays, such as "potentially mineralizable nitrogen" of soil organic matter, we have found that the low-input systems has the lowest potentially mineralizable nitrogen. Or in other words, the low-input system produces the least amount of available N compared to the other systems. These results indicate that standard assays of soil fertility are not always applicable and may also not be suitable for soils managed alternatively since these methods were primarily developed for conventionally managed soil. The above results may be explained by the timing of soil nutrient release for plant uptake. Even though the low-input system produced the least available N it may have supplied the nitrogen it mineralized at the time of maximum plant uptake. These results show the importance of designing cropping system practices that influence both the level of soil organic matter and the ability to supply nutrients when crops demand them.

USING THE BIFS* APPROACH TO IMPLEMENT INTEGRATED FARMING PRACTICES WITH SPECIAL EMPHASIS ON PEST MANAGEMENT

Project Leader:
Clifford P. Ohmart
Lodi-Woodbridge Winegrape Commission
Lodi, CA
(209) 367-4727

DESCRIPTION

An integrated farming program is of no value unless growers practice it on their farms. Therefore, there needs to be an effective way to bring the program to growers and PCAs and to encourage them to put it into practice. The technical word for this process is 'implementation'.

The Biologically Integrated Farming Systems (BIFS) model appears to be an excellent way to implement an integrated farming program. Lodi-Woodbridge Winegrape Commission (LWWC) began an integrated pest management program in 1992 and through time it evolved into an integrated farming program, which focuses on the whole farming system, not just pests. In 1995 LWWC was awarded a BIFS grant from UC Sustainable Agriculture Research and Education Program and this grant allowed LWWC to greatly increase the effectiveness of their integrated farming program implementation.

LWWC'S BIFS PROGRAM STRUCTURE

LWWC developed a multilevel program structure designed to reach the entire grower and PCA population, recognizing that growers' management practices fall along a continuum from conventional to 'biointensive'. Some program components focused on the entire Commission membership while others involved working with either small groups of growers and PCAs or one-on-one interactions.

There are three basic components to LWWC's BIFS program: Grower outreach; field implementation, and evaluation. Grower outreach addresses the entire LWWC membership by providing information on integrated farming strategies to growers, PCAs and winery personnel. The field implementation component involves working with individual LWWC growers and PCAs one-on-one in specific vineyards to implement integrated farming strategies. These growers in turn influence neighboring growers, who talk with the BIFS growers and observe the strategies being implemented in the BIFS vineyards. The evaluation component measures the impact of grower outreach and field implementation on vineyard inputs and growers' management practices.

A management committee was formed to guide the BIFS program and bring to the table representatives of key groups such as growers, PCAs, University Cooperative Extension, University Research, the federal government, and LWWC staff. Each group is viewed as an equal partner on the committee.

Pest Management

Monitoring and the use of economic thresholds for pest management decision-making are the foundation of any BIFS program. One of the best ways to minimize pesticide use is to establish an effective monitoring program and to encourage growers and PCAs to develop and adhere to economic thresholds. Therefore, LWWC's BIFS program emphasized vineyard monitoring.

Monitoring for pests can be a very 'individual' thing, each grower and PCA commonly using methods they have developed over time. The BIFS monitoring program was designed as a 'lead by example' program rather than an attempt to design the perfect monitoring program for all situations, growers and PCAs. However, there are certain basic aspects of a successful monitoring program:

1. Each BIFS vineyard was monitored on a weekly basis by BIFS staff. This time interval is feasible for most growers and PCAs and is frequent enough so that most problems will be identified with ample time to watch them develop and actions can be taken in a timely and well thought out manner. Sometimes a problem is missed, since it is impossible to check the entire vineyard each week, and weekly monitoring is frequent enough to usually pick up missed problems the following week before they become economically damaging.

*Biologically Integrated Farming Systems (BIFS)

2. It is important that one person monitor the same vineyards each week to develop an in depth knowledge of these vineyards and know what parts have been checked recently and what parts have not.
3. Every effort is made to check a vineyard on the same day each week so the grower knows when they will get a data sheet, making it easier to plan vineyard management activities. Furthermore, if a grower wants to talk with the field checker they know when to be around to see them. This encourages frequent, face-to-face contact between the grower and field checker so they can discuss what is happening in the vineyard. The more the contact between the grower and PCA, the better the pest management decision-making process becomes.
4. A data sheet is left with the grower immediately after the vineyard is checked and at the end of the day a copy of the data sheet is faxed to the PCA who checks that vineyard. The data sheet serves two purposes; it provides a written record for the grower of what the field checker saw in the vineyard and it lets the grower know that the field was checked, even if they were not around when the field checker was there.
5. The data was entered into the BIFS database the day the monitoring was done.

Lessons Learned from LWWC's BIFS Program

All the components of the BIFS model contribute to its success but during the course of LWWC's BIFS program certain aspects stood out as being particularly important to the evolution of a successful program:

1. Good communication among all stakeholders in the program.
2. The program was grower-driven.
3. All stakeholders in the local industry were involved in the program.
4. Recognition that integrated farming implementation occurs along a continuum.
5. The program was run by a full-time program manager.

Effect of Cover Crops on a Merlot Vineyard in the Northern San Joaquin Valley

Project Leader:
Chuck Ingels
UC Cooperative Extension, Sacramento County
Sacramento, CA
(916) 875-6413

Cooperators:
Terry Prichard
UC Cooperative Extension
Stockton, CA

Kate Scow
Department of Land, Air and Water Resources
University of California
Davis, CA

Desley Whisson
Department of Wildlife, Fish and Conservation Biology
University of California
Davis, CA

Project Funding:
UC Sustainable Agriculture Research and Education Program
Lodi-Woodbridge Winegrape Commission

DESCRIPTION

This three-year trial is being conducted in a Merlot vineyard in Sacramento County, which was planted in 1993. The vineyard spacing is 7 x 11 feet and the rootstock is 5BB. The soil type is San Joaquin silt loam. The vineyard is drip irrigated, with sprinklers available for frost protection and cover crop germination.

Each treatment occupies the row middle on either side of one entire 175-vine row; i.e., one plot consists of two adjacent middles. Each plot is separated by one disked middle. All plant and soil measurements are made from or adjacent to 10 contiguous vines. Drip irrigation is applied uniformly across all treatments, and vine nutrients are applied through fertigation. A 4-ft. herbicide strip is maintained in each vine row.

The experiment consists of five treatments and four replications in a randomized complete block design. The treatments used are as follows:

1. "Big 3" California native perennial grass mix (Calif. barley, Calif. brome, blue wildrye—25 lb/acre; 25 lb N/acre in the fall and again in winter), mowed once in early spring and again after reseeding
2. Winter annual forage mix (bell beans, field peas, common vetch, barley – 80 lb/acre; no fertilizer), planted every fall after disking, mowed and disked in late spring
3. Winter annual reseeding legumes (subclover, bur medic, crimson clover, rose clover—25 lb/acre; no fertilizer), mowed once in late winter and again after reseeding
4. Cereal mix (100 lb/acre; 20 lb N/acre at seeding and again in winter), planted every fall after disking, mowed high in frost season, then mowed and disked in late spring
5. Resident vegetation – disked periodically, no tillage or fertilizer

RESULTS AND CONCLUSIONS

Results presented here are based on the data collected during 1998 and 1999.

Cover Crop Measurements

Table 1 shows the results of measurements taken on the cover crops. All cover crops reduced weed growth in 1998. Bell bean/vetch biomass in 1998 was very high, but was far less in 1999, which is also reflected in increased weed growth in 1999. The native grass treatment effectively reseeded in 1998 and it had very little weed growth in 1999. The N, P, and K content of the cover crops reveal interesting trends. In both years, the N content of annual clovers was at least as high as that of the bell bean/vetch mix. However, because the biomass of the bell bean/vetch mix was sharply reduced in 1999, much less total N was produced. The K content of the

Table 1. Cover crop measurements

Cover Crop	Weed Biomass -lb/acre-		Cover Crop Biomass -lb/acre-		N Content -%-		N Content -lbs/acre		P Content -%-	K Content -%-
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Big 3	367 b	7 b	6,477 b	3,179 bc	1.12 b	1.27 b	72.5	40.4	0.21 a	2.02 b
Forage	156 b	324 a	8,070 a	3,960 ab	2.40 a	2.59 a	193.7	102.6	0.17 a	2.03 b
Clovers	241 b	88 ab	4,833 c	4,796 a	2.72 a	2.56 a	131.5	122.8	0.17 a	3.09 a
Cereals	678 b	93 ab	6,634 b	2,212 c	0.68 c	0.93 c	45.1	20.6	0.22 a	1.55 c
Disked	1,934 a	-	-	-	-	-	-	-	-	-

Means followed by the same letter in each column are not significantly different (Fisher's protected LSD, $P<0.05$).

clovers was also quite high. In 1999 the barley/oat mix was mowed to about 10 inches well before samples were taken and did not regrow appreciably.

Vine Measurements

Results of vine measurements are shown in Table 2. Shoot growth in the native grass and clover treatments was somewhat less than in other treatments, probably because the grass and clover continued to use water after the other treatments were disked. This difference in growth could be seen by looking down the vine rows. Fresh cane cuttings were weighed from the 10 sample vines; the weights in the native grass treatment were significantly lower than the disked control. Water potential measurements, which were taken before the first irrigation, were lower (under greater stress) in the native grass and clover treatments than in the disked control in 1998. However, water potentials did not differ in 1999 (data not shown), probably because the grower chose to water while the vines still had plenty of soil moisture. In 1998 petiole NO_3 levels at veraison were highest in the bell bean/vetch treatment and lowest in the native grass treatment. In 1998, yields of the clover treatment were somewhat lower than the other treatments, and there were no differences in soluble solids, pH, or titratable acidity of the juice (data not shown). In 1999, the soluble solid content of the bell bean/vetch treatment was significantly higher than that of the clover treatment, and the juice pH in the bell bean/vetch mix was slightly but significantly lower than that of most other treatments.

Gophers

The effect of cover crop treatments on gopher populations is shown in Table 3. In all months, gophers showed a distinct preference for the clover cover crop. No fresh activity was observed in the barley/oat cover crop or the disked treatment. It is unknown if the native grasses and other treatments would have had more gophers in the absence of the clovers.

Table 2. Vine measurements

Cover Crop	Shoot Lengths -ft./shoot-	Fresh Summer Prunings -lb/vine-	Water Potential -MPa-	Veraison Petiole Nitrate -ppm-	Fruit Yield -lb/vine-	Soluble Solids (Brix) -%-	pH
	6/99	7/99	6/98	1998	1998	1999	1999
Big 3	3.57 b	0.5 a	-0.92 a	693 c	26.0 a	22.2 ab	3.62 ab
Forage	3.83 ab	0.9 ab	-0.86 ab	1585 a	23.6 ab	22.8 a	3.54 b
Clovers	3.59 b	1.0 ab	-0.91 a	1183 ab	21.9 b	21.9 b	3.63 a
Cereals	3.91 a	1.1 b	-0.82 b	1435 ab	25.6 a	22.6 ab	3.64 a
Disked	4.22 a	1.3 b	-0.83 b	1093 bc	25.4 ab	22.2 ab	3.66 a

Means followed by the same letter in each column are not significantly different (Fisher's protected LSD, $P<0.05$).

Table 3. Proportion of total pocket gopher activity in each cover crop treatment in 1999 (fresh mounds).

Cover Crop	*January*	*February*	*March*
Big 3	0.09	0.00	0.0
Forage	0.06	0.03	0.0
Clovers	0.85	0.97	1.0
Cereals	0.00	0.00	0.0
Disked	0.00	0.00	0.0
# Mounds	33	64	183

Soil Microbiology

The presence of cover crops increased the size of soil microbial biomass relative to that in non-cover cropped soils. Not surprisingly, microbial biomass was also much greater in the cropped portion of the vineyards than in the berms. Annual clover and the native grass mix supported higher microbial biomass than did the control, bell bean vetch, and barley oat mix.

Differences in microbial community composition among the soil samples were greatest between the berm and cover crop samples and the results suggested a larger fungal component in the berm soil communities. Preliminary analysis of the data indicates that differences in microbial community composition among the different cover crop treatments (including the control treatment, which had weed growth) were small at this sampling time. Future sampling and further analysis will confirm whether this is a consistent trend.

Economics

In the first year, the use of the native grass is substantially more expensive than the other mixes because of the cost of seed (Table 4). The cost of maintaining native grasses in future years is relatively low—mainly requiring mowing and extra fertilizer. The cost of annual clovers is lowest in the long term, assuming that the stand does not decline and require replanting in future years (which it often does). Seed for the two annually sown cover crops used in this trial are relatively inexpensive, however, the requirements for repeated disking make these mixes costly each year.

Table 4. Cover crop costs per vineyard acre.

Cover Crop	*Fall Disking (2x)*	*Seed Cost*	*Plant Seeds*	*Nitrogen Fertilizer*	*Springtime Mow*	*Springtime Disk*	*Summer Disking*	*Total Cost Year 1*	*Total Cost Yr. 2 & on*
Big 3	15.34	116.00	13.55	13.00	18.74	0.00	0.00	176.63	31.74
Forage	15.34	19.00	13.55	0.00	9.37	7.67	30.68	95.61	95.61
Clovers	15.34	27.00	13.55	0.00	18.74	0.00	0.00	74.63	18.74
Cereals	15.34	11.00	13.55	13.00	18.74	7.67	30.68	109.98	109.98
Disked	7.67	0.00	0.00	13.00	0.00	7.67	30.68	59.02	59.02

Sources: Klonsky et al. (1992), Verdegaal et al. (1994), Klonsky (pers. comm.).

Avoiding Vine Competition from Cover Crops

Project Leader:
Michael J. Costello
Costello Agricultural Research & Consulting
Tollhouse, CA
(559) 855-2847

Project Funding:
UC Sustainable Agriculture Research and Education Program

DESCRIPTION

Cover cropping has become an integral part of vineyard management for many grape growers. They recognize that a well managed cover crop can improve soil structure and water infiltration, and help manage vine water status. Cover crops can also fix N, reduce dust, and allow equipment to be used in wet conditions. The contribution of cover crops to improved vine water status and dust reduction can play a role in the management of pests such as spider mites. Many of these benefits can be achieved by managing the resident vegetation (weeds) as a cover crop. However, maintaining vineyard floor cover well into the growing season is something which many growers are reluctant to do, partly because it increases the risk of early spring frost damage, and also because of the potential competition between the cover crop and the vines for water and nutrients. Raisin growers maintain a vegetation-free floor to prepare for raisin drying.

From 1993 to 1996 Kent Daane of University of California, Berkeley and I undertook a series of studies to determine the role of cover crops and resident vegetation on leafhoppers and their natural enemies. Two of the four experimental sites were managed with fall planted, cool season cover crops, which were mowed periodically beginning at budbreak. The cover crops were replaced by a complex of resident grasses. One site had a fall planted cover crop that was turned under in early June to prepare for raisin drying, and one site had a perennial native grass cover crop. We saw a consistent decrease in the number of late-season leafhopper nymphs at all sites except the raisin site. After looking at a variety of possible explanations for the phenomenon (natural enemies, temperature, vine condition) we concluded that lower vine vigor in the cover crop treatments was the most likely explanation for the lower leafhopper abundance.

Other trials were also conducted with cool season annual cover crops which were maintained well into the growing season, in part to look at the effect of competition on the vines. At a site in Madera County, the cover crop was disked under at budbreak, and compared to disking in early June, and in early August. At another site west of Fresno (Jameson), disking at budbreak was compared to disking in early July. At the Madera site, there was a pattern of declining vigor and yield the longer the cover crop/resident vegetation was maintained into the season. However, at the Jameson site there was no significant difference in vigor or yield between early and late disking. The difference between the two sites may be due difference in the management of the vineyard. The Madera site did not have any supplemental fertilizer, whereas the Jameson site received 80 units of N each year. In addition, the Jameson soil had a higher water holding capacity and was irrigated more frequently.

One of the most promising categories of cover crops are the perennial native grasses. 'Native' means that these grasses evolved in the western United States and were established here at the time of European colonization. Native perennial grasses of the west have adapted to arid conditions by slowing growth or going dormant during the summer, and they can be appropriate vineyard cover crops because their active growing periods are opposite that of the vines. As a result, they can provide the advantages of a perennial cover without the disadvantage of excessive competition.

A native grass trial was conducted in two wine grape vineyards at the Kearney Agricultural Center in Fresno County, at about the same time that Chuck Ingels established his native grass studies in Sacramento County. Soil type at the Kearney site was a Hanford fine sandy loam. Two separate experiments were established in the fall of 1996: one in a drip Barbera vineyard, the other in a flood irrigated Grenache vineyard. At each site, four native grass treatments were compared to blando brome (*Bromus hordeaceus*), and a clean cultivated control. For the drip irrigated block two of the original treatments included California melic (*Melica californica*), which did not establish. As a result the treatments were: 1) Resident vegetation, 2) Nodding needlegrass (*Nassella cernua*), 3) California barley prostrate (*Hordeum brachyantherum* ssp. *californicum*) and 4) California barley prostrate + nodding needlegrass. For the flood irrigated block treatments were: 1) purple needlegrass (*Nassella pulchra*), 2) nodding needlegrass, 3) California brome (*Bromus carinatus*) + blue wildrye (*Elymus glaucus*), and 4) California brome. The California brome/blue wildrye treatment originally included Meadow barley (*Hordeum brachyantherum* ssp. *brachyantherum*), but it did not establish. Soil moisture status and vine water status was measured from the nodding needlegrass and clean cultivated treatments, both within the vine row and between the vine rows. Yield and vigor were estimated from all treatments.

At the drip irrigated site, overall soil moisture status was higher in-row for the nodding needlegrass treatment at 1-4 feet, but soil moisture levels were higher between-rows for clean cultivation. At the flood irrigated site, soil moisture in the nodding needlegrass treatment was lower until the first irrigation. With each irrigation (July 10, July 27 and August 25), soil moisture status at the deeper levels was elevated in the needlegrass treatment. Very few significant differences were found among cover crop treatments in yield or pruning weight. The pattern of average yields at the drip irrigated site were: highest in the nodding needlegrass and Blando brome treatments, intermediate with clean cultivation, nodding needlegrass/California barley blend and resident vegetation, and lowest with the pure stand of California barley, and average pruning weights closely followed this pattern. These results suggest that California barley prostrate is more competitive than nodding needlegrass. Unfortunately, we did not have the resources to monitor water use in the California barley prostrate treatment, but it is possible that this grass is more water consumptive than the needlegrass. The pattern of average yields at the flood irrigated site were: highest in the clean cultivated treatment, intermediate in the blando brome, purple needlegrass and nodding needlegrass treatments, and lowest in the California brome/blue wildrye blend and pure stand of California brome.

Experiences with Using Dairy Lagoon Water as a Nutrient Source for Silage Corn

Project Leader:
Marsha Campbell Mathews
UC Cooperative Extension, Stanislaus County
Modesto, CA
(209) 525-6800

DESCRIPTION

The dairy industry is coming under increasing scrutiny from regulatory agencies and the public in accounting for the N and other constituents contained in dairy manure. On a typical California dairy, as much as 80 percent of the waste is handled using a flush system, where manure in alleyways and hard surface holding pens is washed into a lagoon. Usually, the lagoon water is recycled by using it in the flush system many times until the lagoon is emptied onto cropland. A recent study of five dairies in the Northern San Joaquin Valley indicated that cropland receiving dairy lagoon water often has elevated concentrations of NO_3 contamination in the shallow groundwater. It has been common for growers to not fully account for the N being applied in the lagoon water when fertilizing their crops because practical methods for doing so have not been available.

A series of research and demonstration projects have been focused on developing practical methods of monitoring and regulating applications of lagoon water nitrogen to field crops. Nutrient application monitoring was conducted to varying extents on seven locations in Stanislaus and Merced Counties during the summers of 1998 or 1999. This progress report will describe our experiences with several methods of measuring and controlling applications of dairy lagoon water.

METHODS OF MEASURING LAGOON WATER APPLICATIONS

To calculate N applications to an area, both the amount of water being applied and the concentration of N in the water need to be known.

Measuring Concentration

A four-minute colorimetric test for ammonium, the rapidly available N fraction in dairy lagoon water, was developed. This analysis was used with all volume and flow measurement methods to provide rapid, in-field assessment of both diluted and undiluted lagoon water ammonium. In some cases, a pen-type EC meter was used to predict or confirm lagoon water ammonium concentrations.

Measuring Volume

In these projects, five different methods of determining the volume of water applied were adapted for use with lagoon water. As many different methods as possible were used at each location depending on the individual circumstances.

Pond drop

The concept behind the pond drop method is to determine the surface area of the pond in acres, then multiply the pond surface acreage by the number of inches of vertical drop as the pond is used to irrigate a known number of acres. Multiplying the area of the pond (in acres) by the drop (in inches) gives the acre-inches of pond water that went out during irrigation. Acre inches multiplied by the pounds of nutrient per acre inch gives the total pounds of N applied. The pounds of nitrogen applied per acre is determined by dividing the total applied by the number of acres irrigated.

Pump output

With this method, the output of the pump (gpm) is estimated and the time the pump was run recorded. A lookup table or calculation gives total pounds of N applied. The total pounds of nitrogen applied divided by the number of acres gives the pounds of N applied per acre.

Flow of irrigation water using a hand held flow meter

A spot check of the combined district and lagoon water flow was made using a hand-held electromagnetic velocity meter attached to a pole inserted down a standpipe or vent accessing an underground concrete pipeline. The concentration of ammonium in the water coming out of the valve was determined, then the lagoon water flow was adjusted until a desired target concentration was achieved based on concentration, flow rate, estimated run time, and number of acres irrigated.

Flow meter on lagoon water outlet

An in-line flow meter on the lagoon water outlet pipe was used to measure the flow rate of undiluted pond water. Once the meter is installed and calibrated, the desired application rate of N is maintained by adjusting a valve until the flow meter displays a predetermined flow rate. This flow rate is established by estimating the amount of available N in the undiluted pond water and the expected irrigation run time, then consulting a chart or hand-held computer to determine the target flow. A valve is adjusted until the flow meter read out matches the target flow rate.

The in-line flow meter used in our projects was a Marsh McBirney model 282 electromagnetic flow meter. This meter is inserted into a 2" ball valve mounted on the pipe. This style meter was selected because it has several advantages over other types of meters including high resistance to fouling, the ability to move it from one location to another location, having the option of a 12 V power source, and the ability to characterize the velocity in the pipe by profiling the flow, which affords some limited flexibility when conditions are less than optimal.

In addition to flow rate in gpm, this meter displays the total number of gallons applied. Application of nitrogen can be calculated by multiplying the gallons applied by the concentration of N in the water (ppm X .008435 = lb. N per 1000 gallons), then dividing by the total acreage.

Totalized combined flow

To assess the degree of fluctuation in the combined lagoon water and district flows, a datalogging flow meter was installed in the underground pipeline accessed through a standpipe. Average velocity readings were taken at one minute intervals. This specialized research equipment would not usually be appropriate for grower use but was invaluable in verifying the reliability of the other methods.

All of these methods rely to some extent on an estimation of the amount of time an irrigation will take. The actual irrigation time may be quite different than expected. After the irrigation is completed, the N concentration is confirmed and run times adjusted to determine the actual application rate. Targeted N application rates are adjusted accordingly in subsequent irrigations.

RESULTS AND CONCLUSIONS

At least one method could be found to estimate lagoon water applications at each of the locations tested. Accuracy of the measurements were variable and depended greatly on the skill and motivation of the individual taking the measurements, as well as the ease of use of the system. Most challenging were situations where fresh water was being added to the pond at the same time as lagoon water was being put out, especially if there was no installed flow meter.

Estimating Concentration

The ammonium quick test method was well correlated with laboratory results (r^2=.99) and gave acceptable accuracy even when used under adverse field conditions. Although the test is not difficult to perform, there are a number of steps involved and some simple math. The grower cooperators preferred to use the EC meter to estimate ammonium concentration but the equation available at the time to predict ammonium concentration from EC was only valid to within 15 percent accuracy. This was acceptable to the growers but was not good enough for the researchers. Additional evaluation of the EC method of predicting ammonium concentration is ongoing and it is possible that accuracy can be improved on a site specific basis.

The EC meter was very useful when used to confirm a previously established ammonium concentration on a specific site. Once a lagoon water valve setting was established that would result in a desired N application rate (as measured by ammonium quick test and hand-held flow meter) an EC reading was taken of the combined flow. The irrigator could then maintain the ammonium concentration as the pond was drawn down by adjusting the pond water flow so as to maintain the original EC reading.

Estimating Volume Applied

Pond drop

The reliability of the pond drop data varied. Obtaining accurate pond drop readings was sometimes challenging for many reasons, such as odd shapes and non uniform side slopes, the presence of irregular areas of built up solids, other inflows to the pond, and the difficulty of establishing and using a measuring pole. If fresh water was being introduced into the pond at the same time as the pond was being drawn down, using pond drop was virtually impossible. Another challenge was in obtaining accurate readings because often irrigations would begin or end during the middle of the night when it is difficult to read a measuring pole even if a competent person was available to record the measurements. Since lagoons often have inflows, the accuracy of readings taken the following morning was questionable. For all these reasons, the pond drop method was sometimes unreliable. Where several methods were used simultaneously, the pond drop method was usually, but not always, in agreement with other the methods.

The pond drop method is best used to determine how much pond water has been applied and is also useful to check the accuracy of other methods of determining application. It can be difficult to use this method to achieve a target application rate because of the amount of acreage that must be irrigated before the rate of drop can be established and adjusted.

Pump output

In our tests, the pump output was read off a flow meter, rather than being estimated from pond drop, which would be the more normal situation. Consequently, N per acre calculated from the flow rate was in fairly good agreement with other methods.

Hand held flow meter

We found that the flow rate of the mixed district and lagoon water was not always consistent from one irrigation to the next, and sometimes was not consistent from one check to the next within the same field. This was due to differences in the amount of water delivered by the district and because of differences in pipeline characteristics such as slope and diameter. It was necessary to obtain a new measure of the flow each irrigation in order to determine the correct amount of lagoon water to apply. For grower use, inconsistencies in flow rate from one check to the next would probably be largely ignored.

Where there was a considerable lag between the time a change was made at the lagoon water outlet until the time the results of the change could be seen in the field, it was difficult to adjust the lagoon water output in a timely manner with this method, resulting in over- or under- application. Used under these circumstances, most growers and/or consultants would likely to find the hand held flow meter system to be frustrating because of the time required to properly adjust the flow rates.

Flow meter on lagoon water outlet

The in-line flow meter and gate valve system was installed at two separate dairies. This was by far the easiest system to operate and obtain reliable results. Initial assembly and calibration of the equipment took several hours and required some skill. With this system, obtaining a desired target application rate was relatively simple, even when the distance between the field and the lagoon was great. After each irrigation, the total flow going out onto each check was recorded and the pounds of applied NH_4-N was calculated based on actual run times and confirmed quick test results. Targets were adjusted as appropriate in subsequent irrigations. Using this method, it was possible to apply lagoon water NH_4-N to within +/- 6 percent of the targeted rate on each of six 2 to 6 acre demonstration irrigation checks. This technique was also used by the grower cooperators on additional acreage with satisfactory results.

The Effect of Nutrient Deficiencies on Stone Fruit Production and Quality

Project Leader:
R. Scott Johnson
Department of Pomology
University of California, Davis
Kearney Agricultural Center
Parlier, CA
(559) 646-6547

Cooperators:
Carlos Crisosto
Kearney Agricultural Center
Parlier, CA

Harry Andris
UC Cooperative Extension
Fresno, CA

Kevin Day
UC Cooperative Extension
Visalia, CA

Brent Holtz
UC Cooperative Extension
Madera, CA

Bob Beede
UC Cooperative Extension
Hanford, CA

Many nutrients are regularly applied to stone fruit trees with the belief that fruit quality and tree health will be improved. Other than N and zinc, other nutrients do not have much scientific justification for their use under typical orchard conditions.

This three-year project will establish large sand-filled tanks in the field where nutrient deficiencies on mature peach, plum and nectarine trees will be imposed. Preliminary experiments in 10-gallon buckets have shown that deficiencies can be quickly induced, so it is possible to manipulate nutrients to approximate desired levels. The end goal of this project is to develop nutrient deficiency symptoms so as better define critical levels for each nutrient.

Critical levels will be defined not only in terms of growth and productivity but, more importantly, in terms of fruit quality such as size, color firmness, sugar content and disease susceptibility. Extra tanks will also be installed so nutrient interactions by inducing multiple deficiencies and different nutrient ratios can also be investigated. This information will be useful in helping diagnose problems, deciding whether applications of certain nutrients are justified and providing scientific input into evaluation methods such as DRIS.

The study will also be utilized to produce high quality pictures of deficiency symptoms on leaves and fruit. These will be incorporated into a sturdy, laminated field guide. The pictures will also be useful for updating publications such as the UC stone fruit production manual and providing slides for numerous extension talks and presentations. Many people will benefit from this project including stone fruit growers, field men, PCA's, CCA's, farm advisors, extension specialists, diagnostic lab personnel and scientists.

Development of an Educational Handbook on Fertigation for Grape Growers

Project Leader:
Glenn T. McGourty
UC Cooperative Extension,
Mendocino and Lake Counties
Ukiah, CA
(707) 463-4495

An illustrated handbook will be written for grape growers to assist them in developing environmentally safe and effective fertigation programs for their vineyards. The primary focus of the book will be on utilizing drip irrigation systems to deliver fertilizers to vines. Included in the publication will be information on how to assess the need for fertilizing vines; equipment for applying materials; the materials that work well in fertigation; evaluation of water and potential plugging and clogging problems and how to chemically condition the system to avoid this difficulty; calibration and monitoring of injection equipment during fertigation; and strategies to provide adequate nutrition and balanced vines.

The publication will be clear and concise, and targeted to wine grape growers in California. Upon completion of this grant, a camera-ready publication will be submitted to DANR Publications, or other suitable publisher.

Nitrogen Fertilization and Grain Protein Content in California Wheat

Project Leader:
L.F. Jackson
Department of Agronomy and Range Science
University of California
Davis, CA
(530) 752-0701

Cooperators:
Cass Mutters
UC Cooperative Extension Butte County
Oroville, CA

Doug Munier
UC Cooperative Extension Glen County
Orland, CA

Jerry Schmierer
UC Cooperative Extension Colusa County
Colusa, CA

Ron Vargas
UC Cooperative Extension Madera County
Madera, CA

Steve Wright
UC Cooperative Extension Tulare/King County
Visalia, CA

Brian Marsh
UC Cooperative Extension Kern County
Bakersfield, CA

The nitrogen fertilization requirements for wheat depend on factors such as yield potential, the previous crop and residual fertility from it, soil fertility, and plans for irrigation. Nitrogen applications are made preplant, with seed, at tillering and/or at various other growth-stages during the season. In practice, total seasonal N applications may vary from 0 to over 300 lb N/acre. Anthesis-time (flowering-time) nitrogen applications, in combination with irrigation, can be made to increase grain protein content and improve baking quality.

Such applications can increase grain protein content by 1-3 percent. However, growers currently are unable to determine what the ending protein status of the crop is likely to be under such management—that is, is the potential 3 percent increase from 11 to 14 percent or from 8 to 11 percent. If the former is true, the grower may qualify for a price premium based on grain protein content. If the latter is true, no price premium will be available.

This project seeks to link nitrogen status and crop yield potential (based on biomass) at anthesis with a specific response of grain N content (eg., final grain protein content of 13 percent) to specific rates of anthesis-applied N. The project will measure the response of grain protein content to different rates (0 to 90 lb N/acre) of anthesis-time N fertilization under different pre-anthesis N management practices (thus different yield potentials). The overall goal is to identify, based on the N status and yield potential of the crop at anthesis, the N fertilization rate that will result in a grain protein content of 13 percent (price premium triggering level).

In order to produce high quality wheat consistently and economically, growers need to be able to determine: (1) if anthesis-time N fertilization is needed to reach the target (13 percent) grain protein level and, if so, (2) how much N must be applied. Wheat growers (primarily in the Central Valley), crop consultants, farm advisors, and PCA's will be able to apply findings from the project in their attempt to produce high quality wheat in a cost-effective manner.

Relationship Between Fertilization and Pistachio Diseases

Project Leader:
Themis J. Michailides
Department of Plant Pathology
University of California-Davis
Kearney Agricultural Center
Parlier, CA
(541) 737-5445

Cooperator:
Pinghai Ding
Department of Horticulture
Oregon State University
Corvallis, OR

Fertilization side effects, both good and bad, make it increasingly important to apply fertilizers as efficiently as possible. This is particularly true since the amounts of fertilizers applied can influence pathogens and insect pests of fruit and nut trees. In general, N fertilization and K have long been recognized as being associated with changes in the levels of disease and pests of plants. Pistachio growers use different amounts of fertilizers and follow various practices while fertilizing the orchards. The question arises, how do these different fertilization rates affect diseases in pistachios grown in California. This project will investigate the relationship between fertilization levels of the macronutrients (N, P, K) and diseases in California pistachio. The research will be focused on the most important and destructive diseases such as *Botryosphaeria* panicle and shoot blight and *Alternaria* late blight of pistachio.

Specific objectives are:

1. Determine the levels of *Botryosphaeria* and *Alternaria* blights of pistachio as affected by the different, main nutritional elements in inoculation studies, which will be conducted in a greenhouse
2. Determine the effects of various levels of fertilization on production of phenolics, lignin, and other disease resistance/susceptibility compounds in pistachio leaves and fruit
3. Determine whether pistachio diseases are affected by different fertilization rates in growers fields under natural disease pressure.

Criteria to evaluate this project's success will be a) the new knowledge gained from this study; b) the actual changes or adjustments in fertilization practices that could be followed by California pistachio growers during and after the period when this study is made known to the growers.

Irrigation and Nutrient Management Conference and Trade Fair

Project Leader:
Sonya Varea Hammond
UC Cooperative Extension Monterey and Santa Cruz Counties
Salinas, CA
(831) 759-7350

Cooperators:
Kathleen Thomasberg
Monterey County Water Resources Agency
Salinas, CA

Charles Burt
Department of Agricultural Engineering
Caly Poly
San Luis Obispo, CA

Timothy K. Hartz
Department of Vegetable Crops
University of California
Davis, CA

Tom Lockhart
Resource Conservation Monterey County
Salinas, CA

Water availability and quality continue to be important problems on the Central Coast. Eighty percent of all water use is attributed to agriculture. Although agriculture is a 2.3 billion contributor to the economy, it is blamed for contaminating the groundwater of the Salinas Valley and Santa Cruz County coastal areas. It is imperative that growers modify their irrigation and fertilizing practices to improve the water situation and to negate any need for a regulatory approach.

Nitrate leaching is a major documented problem that occurs in this area. As in the case of seawater intrusion, the California State Water Resources Control Board (SWRCB) and the Regional Water Quality Control Board (RWQCB) deem agriculture responsible for contaminating the groundwater.

Though the Salinas Valley Water Project Plan (SVWPP), extension of information has been identified as a very weak link in the remediation efforts. Clearly there is a need for continuing research, but the existing body of proved, effective practices and methods of irrigation and fertilization needs to be more widely used to impact water quality/quantity.

The objectives of this project are to:

- Present the latest fertility and irrigation management findings and techniques
- Present options and sources of suppliers
- Promote adoption of new techniques
- Provide a non-regulatory approach to protecting the groundwater
- Survey growers for unique, successful practices

These objectives will be met by :

1. Presenting a large workshop in February 2000, similar to the six previous conferences, including a trade show. This full-day conference will consist of presentations from noted experts, grower panels and breakout sessions for in-depth teaching.
2. Follow-up the conference with field days (two per year) in order to continue the momentum of the initial conference and to reinforce learning.

Development of Fertilization and Irrigation Practices for Commercial Nurseries

Project Leader:
Richard Evans
Department of Environmental Horticulture
University of California
Davis, CA
(530) 752-6617

Large container-grown trees (5-gallon container and large) have become an important agricultural commodity in California. Large trees are in demand for urban landscapes; local ordinances in many cities require installation of trees in new developments, and experience has shown that large specimens are less subject to vandalism. Although there has been no published research on the fertilizer and water requirements of trees in large containers, it is apparent that there is a need for such information. Some nurseries specializing in large tree production have been identified, or accused, of being point sources for nitrate contamination of water supplies. Researchers familiar with tree nurseries estimate that fertilizer and water applications may exceed plant demand by an order of magnitude.

This project will provide information about seasonal nitrogen and water requirements of several common tree species, and will evaluate relative nitrogen use efficiencies of some commonly use sources of fertilizer N. Specific objectives are:

1. Determine water requirements of eight important tree species grown in 5-gallon containers. Daily water use will be determined gravimetrically and compared to values for ET_0.
2. Determine N use of trees. For the same species, a nitrogen balance will be determined by measuring applied and leached N during growth for one year. Nitrogen use efficiency of three common methods of fertilizer application (fertigation with NO_3-N, fertigation with polymethylene urea, and premix application of controlled release fertilizer) will be determined.
3. Determine dry weight gain of trees.

Results will be used by growers, advisors, and fertilizer companies and distributors for recommending rates of irrigation and N fertilization in nurseries, and may also provide information on nitrogen and water requirements that could be applied to young trees in the landscape, where pertinent information about fertilizer requirements is sorely needed. The project will produce reports documenting water use, N use, and N leaching across the three fertilizer treatments; field days describing the research findings, presentations at extension and industry meetings, and published guidelines for fertilizer and irrigation practices.

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

Project Leader:
Marc Buchanan
Buchanan Associates
Scotts Valley, CA
(831) 459-6857

Cooperators:
Santa Clara Valley Water District
Nitrate Management Program
San Jose, CA

Uesugi Farms
Gilroy, CA

Elevated NO_3 levels in various surface bodies and groundwater of the Pajaro River watershed are believed to be due to excessive loading from residential septic systems, animal enclosures, agricultural fertilizer, and other non-point and point sources. This is particularly of concern in the Llagas Basin in Santa Clara and San Benito Counties. Vegetable production, particularly lettuce, peppers, corn, tomatoes, garlic and onions, is an important sector of the agricultural economy in the Basin region. The high value of these crops along with market demands for quality, make growers reluctant to increase economic risk by reducing N and/or irrigation inputs. Recognition and adoption of in-field monitoring as a N management tool in this region has been limited due to the lack of a significant research and education effort as has occurred in the Salinas Valley.

Pronounced water x N interactions in climates similar to the Santa Clara-San Benito region have significant impacts on crop yield, N fertilizer use efficiency, and N leaching potential. The use of drip irrigation (surface and sub-surface) has increased in the Santa Clara and San Benito County areas in recent years and represents an opportunity to improve irrigation efficiency, reduce total water demand, and theoretically improve N use efficiency. However, little information is available to growers documenting the impact of this technology on N fertilization efficiency, residual soil NO_3, and NO_3 leaching potential in comparison to sprinkler irrigation.

There has been a limited amount of research, multi-year demonstration, and education which has provided continuous information and training on in-field nitrate testing for growers within the Basin. The Santa Clara Valley Water District [SCVWD] is in the early stages of implementing a Nitrate Management Plan. This two-year project aims to develop an educational program which provides training on the concepts and use of N balances and new methods for evaluating soil and crop N status, as well as a series of local on-farm studies designed to reevaluate optimal N management practices for important crops with the Basin. The primary objective is to assist the Basin's growers in evaluating and adopting the use of in-field nitrate testing and nitrogen management planning to improve fertilizer use efficiency and profitability, while potentially reducing nitrate loading to ground, and surface water.

Field trails and data will support an outreach and educational effort to growers in the Basin and Pajaro watershed region. The project will hold two grower workshops per year and produce a technical sheet providing information in English and Spanish.

This is a cooperative project involving Buchanan Associates, a private research-consulting business, the SCVWD, Santa Clara Farm Bureau, Santa Clara County UC Cooperative Extension, the Central Coast Resource and Conservation Development Council, and growers in the Llagas Basin region.

Ammonia Emission Related to Nitrogen Fertilizer Application Practices

Project Leader:
Charles F. Krauter
Center for Irrigation Technology
California State University
Fresno, CA
(559) 278-5114

Cooperators:
Christopher Potter
NASA Ames Research Center
Moffett Field, CA

Steven Klooster
CSU Monterey Bay and
NASA Ames Research Center

The three scientists listed as Project Leader and Cooperators are currently conducting a study funded from May, 1999 to September, 2000 by the California Air Resources Board (ARB) and NASA-Ames with these objectives:

1. Determine the major agricultural field sources of atmospheric ammonia emissions in the Central Valley of California.
2. Determine the seasonal flux rates of atmospheric ammonia emissions in the Central Valley of California.
3. Determine a regional budget of annual atmospheric ammonia emissions in the Central Valley of California.

This project involves the adaptation of techniques currently used to measure trace gasses in the atmosphere of urban areas, to the monitoring of ammonia from agricultural applications of various N fertilizers. The data collected in the field will be used with GIS databases for the valley to model the occurrence of atmospheric ammonia related to fertilizer application. Ammonia has significance to air quality both as a buffer against atmospheric acidity and as a precursor of PM2.5 particles. The ARB funded project will focus on the monitoring of fertilizer applications and the validation of the sampling method.

This three-year CDFA-FREP project will use the methodology and equipment 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 atmospheric ammonia levels are found in a field, existing literature suggest those levels exist for only a short time. In order to accurately model the ammonia from cultivated crops, monitoring of the atmospheric levels during the rest of the crop season should be done as well. This project will enable the resources developed through the ARB funding to be utilized for two more seasons to refine the models of ammonia in the atmosphere with more relevant and longer term field data.

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

Project Leaders:
John Kabashima
UC Cooperative Extension
South Coast Research and Extension Center
Irvine, CA
(949) 733-3970

Laosheng Wu
Department of Environmental Sciences
University of California
Riverside, CA

The Newport Bay/San Diego Creek Watershed is the first watershed in California that will be required to implement Total Maximum Daily Load (TMDL) allocations mandated by the Federal Clean Water Act. The primary objective of this project is to document non-point source pollution from commercial nursery and agricultural sites located within the Newport Bay/San Diego Creek Watershed and initiate educational hands-on workshops with the goal of assisting agricultural operators in meeting the TMDL compliance deadlines issued for agricultural runoff by the Regional Water Quality Control Board.

Because historical data on water quality from agricultural runoff in this watershed is lacking, baseline water quality monitoring is required to provide a comparison with water quality after the implementation of Best Management Practices. In order to gather representative data, the watershed will be divided into three zones based on topography, soil type, and crops.

A total of nine agricultural sites within the three zones will have surface runoff sampled on a weekly basis. Samples will be analyzed for ammonium, nitrate, nitrite, and phosphates. Additional water quality parameters such as pH, dissolved oxygen, electrical conductivity, and total continuous flow will be monitored to insure a complete assessment of the quality of surface runoff from agricultural sites. Upon complementation of baseline monitoring in July 2000, the project will implement hands-on workshops that demonstrate technology that can be used to monitor the nutrient status of irrigation and runoff water, the soil and the crop. In addition, direct interaction with agricultural operators in the watershed will include on-site assessment of the operators' irrigation and nutrient management practices.

With CDFA/FREP funding it is intended to immediately begin baseline monitoring of representative agricultural sites within the watershed as well as for supporting the development and initiation of workshops and seminars to meet the 2002 TMDL requirement.

Completed Projects

The following is a list of FREP projects completed prior to October 1999. Summaries of many of these projects appear in the 1998 FREP Conference Proceedings and on the FREP web site. Final reports are available by calling FREP or ordering through FREP's Resource Guide.

FRUIT/NUT AND VINE CROPS

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

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

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

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

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

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

Nitrogen Efficiency in Drip Irrigated Almonds
Robert J. Zasoski

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

Nitrogen Fertilizer Management to Reduce Groundwater Degradation
Steve Weinbaum

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

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

VEGETABLE CROPS

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

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

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

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

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

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

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

FIELD CROPS

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

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

Establishing Updated Guidelines for Cotton Nutrition
Bill Weir and Robert Travis

EDUCATIONAL AND OTHERS

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 in to California's Science Framework Curriculum
Mark Linder and Pamela Emery

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

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

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

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

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

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

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

Irrigation and Nutrient Management Conference and Trade Fair
Danyal Kasapligil

EDUCATIONAL VIDEOS

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

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

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

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

Project Leader/Speaker Contact Information

Jose Aguiar
UC Cooperative Extension, Riverside County
46-209 Oasis Street, Room 103
Indio, CA 92201
(760) 863-7949
jlaguiar@ucdavis.edu

Mary Lu Arpaia
Department of Botany and Plant Sciences
University of California, Riverside
Riverside, CA 92521
(909) 787-3335
arpaia@uckac.edu

Patrick Brown
Department of Pomology
One Shields Ave.
University of California, Davis
Davis, CA 95616
(530) 752-0929
phbrown@ucdavis.edu

Marita Cantwell
Department of Vegetable Crops
One Shields Ave.
University of California, Davis
Davis, CA 95616
(530) 752-7305
micantwell@ucdavis.edu

David Chaney
Sustainable Agriculture Research and Education Program
One Shields Ave.
University of California, Davis
Davis, CA 95616
(530) 754-8551
dechaney@ucdavis.edu

Michael J. Costello
Costello Agricultural Research and Consulting
P.O. Box 165
Tollhouse, CA 93667
(559) 855-2847
michaelcostello@mindspring.com

Ken Giles
Department of Biological and Agricultural Engineering
One Shields Ave.
University of California, Davis
Davis, CA 95616
(530) 752-0687
dkgiles@ucdavis.edu

Larry Godfrey
Department of Entomology
One Shields Ave.
University of California, Davis
Davis, CA 95616
(530) 752-0473
ldgodfrey@ucdavis.edu

Robert Green
Department of Botany and Plant Sciences
University of California, Riverside
Riverside, CA 92521
(909) 787-2107
robert.green@ucr.edu

Thomas Harter
Department of Land, Air and Water Resources
University of California, Davis
Kearney Agricultural Center
9240 S. Riverbend Ave.
Parlier, CA 93648
(209) 646-6569
thharter@ucdavis.edu

Tim Hartz
Department of Vegetable Crops
One Shields Ave.
University of California, Davis
Davis, CA 95616
(530) 752-1738
tkhartz@ucdavis.edu

William R. Horwath
Department of Land, Air and Water Resources
One Shields Ave.
University of California, Davis
Davis, CA 95616
(530) 754-6209
wrhorwath@ucdavis.edu

Chuck Ingels
UC Cooperative Extension, Sacramento County
4145 Branch Center Road
Sacramento, CA 95827
(916) 875-6413
cingels@ucdavis.edu

Jack King, Jr.
Research for Hire
1696 South Leggett Street
Porterville, CA 93257
(209) 784-5787
jkingls@lightspeed.net

Michelle Le Strange
UC Cooperative Extension, Tulare County
Agriculture Building, County Civic Center
Visalia, CA 93291
(209) 733-6366
mlestrange@ucdavis.edu

Stefan Lorenzato
State Water Resources Control Board
P.O. Box 944213
Sacramento, CA 94244, CA
(916) 657-3222
LORES@dwq.swrcb.ca.gov

Carol Lovatt
Department of Botany and Plant Sciences
University of California, Riverside
Riverside, CA 92521
(909) 787-4663
carol.lovatt@ucr.edu

Marilyn Martin
Western Growers Association
California Certified Crop Adviser
2450 W. Osborn Road, Suite 1
Phoenix, AZ 85015
(602) 265-0970
mmartin@wga.com

Marsha Campbell Mathews
UC Cooperative Extension, Stanislaus County
3800 Cornucopia Way, Suite A
Modesto, CA 95358
(209) 525-6800
mcmathews@ucdavis.edu

Donald May
UC Cooperative Extension, Fresno County
1720 S. Maple Ave.
Fresno, CA 93702
(209) 456-7553
cefresno@ucdavis.edu

Jeff Mitchell
Department of Vegetable Crops
University of California, Davis
Kearney Agricultural Center
9240 S. Riverbend Ave.
Parlier, CA 93648
(209) 646-6565
mitchell@uckac.edu

Gene Miyao
UC Cooperative Extension, Yolo County
70 Cottonwood Street
Woodland, CA 95695
(530) 666-8143
emmiyao@ucdavis.edu

Richard Molinar
UC Cooperative Extension, Fresno County
1720 S. Maple Ave.
Fresno, CA 93702
(209) 456-7555
rhmolinar@ucdavis.edu

Clifford P. Ohmart
Lodi-Woodbridge Winegrape Commission
1420 South Mills, Suite K
Lodi, CA 95242
(209) 367-4727
ipm@lodiwine.com

Stuart Pettygrove
Department of Land, Air and Water Resources
One Shields Ave.
University of California, Davis
Davis, CA 95616
(916) 752-2533
gspettygrove@ucdavis.edu

PROJECT CONTACT INFORMATION

Dan Putnam
Department of Agronomy and Range Science
One Shields Ave.
University of California, Davis
Davis, CA 95616
(916) 752-8982
dhputnam@ucdavis.edu

William Rains
Department of Agronomy and Range Science
One Shields Ave.
University of California, Davis
Davis, CA 95616
(530) 752-1711
derains@ucdavis.edu

Carolyn Richardson
California Farm Bureau Federation
2300 River Plaza Drive
Sacramento, CA 95833
(916) 561-5500
cfbf@cfbf.com

Paul Robins
Yolo County Resource Conservation District
221 W. Court Street, Suite 8
Woodland, CA 95695
(530) 662-2037 ext 202
rcdnatives@hotmail.com

Charles Sanchez
University of Arizona
Yuma Valley Agricultural Center
6425 W. 8th Street
Yuma, AZ 85364
(520) 782-3836
sanchez@ag.arizona.edu

Blake Sanden
UC Cooperative Extension, Kern County
1031 S. Mt. Vernon Ave.
Bakersfield, CA 93307
(661) 868-6218
blsanden@ucdavis.edu

Larry Schwankl
Department of Land, Air and Water Resources
One Shields Ave.
University of California, Davis
Davis, CA 95616
(530) 752-4634
ljschwankl@ucdavis.edu

Lisa Stallings
School of Agriculture
California State University
Chico, CA 95926
(530) 898-4146
lstallings@csuchico.edu

Robert Travis
Department of Agronomy and Range Science
One Shields Ave.
University of California, Davis
Davis, CA 95616
(530) 752-6187
rltravis@ucdavis.edu

Chris van Kessel
Department of Agronomy and Range Science
One Shields Ave.
University of California, Davis
Davis, CA 95616
(530) 752-4377
cvankessel@ucdavis.edu

Larry Williams
Department of Viticulture and Oncology
University of California, Davis
Kearney Agricultural Center
9240 S. Riverbend Ave.
Parlier, CA 93648
(209) 646-6558
williams@uckac.edu

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To order additional copies of this publication, contact:

California Department of Food and Agriculture
Fertilizer Research and Education Program
1220 N Street, Room A-472
Sacramento, CA 95814

Telephone: (916) 653-5340

Fax: (916) 653-2407

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

E-mail: ccady@cdfa.ca.gov

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