

PROCEEDINGS
OF THE
FIRST ANNUAL

FERTILIZER RESEARCH
AND EDUCATION PROGRAM CONFERENCE

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California Department of Food and Agriculture

California Fertilizer Association

Public Service Research and Dissemination Program
University of California, Davis, California

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CONFERENCE PROGRAM

- 7:30 Registration
- 8:10 **Welcome & Remarks** - Mr. A. J. Yates, *Deputy Director, California Department of Food and Agriculture (CDFA)*.
- 8:20 **Opening Remarks** - Mr. Steven Beckley, *Executive Vice President, California Fertilizer Association*.
- 8:30 **Fertilizer Research and Education Program (FREP): Introduction and Background** - Mr. Jacques Franco, *FREP Program Coordinator, CDFA*.
- 8:55-10:00 **Agriculture and Nitrate in Ground Water: Conflict or Cooperation?** Moderated by Charles Tyson, *Department of Conservation, Agricultural Land Conservation Program*
- A Grower - Industry - Government Panel:**
Mr. Eliseo Samaniego, *Board Member, State Water Resources Control Board, Sacramento, CA*.
Mr. Glenn Anderson, *Anderson Almonds, Hilmar, CA*.
Mr. Sig Christerson, *Major Farms, Salinas, CA*.
Mr. Jim Saake, *Manager, Unocal Chemicals Division, Agricultural Marketing and Technical Services, Los Angeles, CA*.
Ms. Roberta Parry, *Agricultural Policy Analysis, U. S. Environmental Protection Agency*
- 10:00-10:15 **Break & Refreshments**
- 10:15-12:00 **Project Reports**
- Improvement of Nitrogen Management in Vegetable Cropping Systems in the Salinas Valley and Adjacent Areas*
- Dr. Stuart Pettygrove, *Department of Land Air & Water Resources, UC Davis*.
- Optimizing Drip Irrigation Management for Improved Water and Nitrogen Use Efficiency*
- Dr. Timothy K. Hartz, *Department of Vegetable Crops, UC Davis*.
- Educating California's Small and Ethnic Minority Farmers: Ways to Improve Fertilizer Use Efficiency and Reduce Contamination on their Farms through the Use of Best Management Practices (BMP)*
- Dr. Ronald Voss, *UC Small Farm Center/Department of Vegetable Crops, UC Davis*.
- Influence of Irrigation Management on Nitrogen Use Efficiency, Nitrate Movement and Ground Water Quality in a Peach Orchard* - Dr. Scott Johnson, *UC Kearney Agricultural Center, Parlier CA*.
- 12:00-1:00 **Lunch**
- 1:00-1:30 **Agriculture and Nitrate in Ground Water: A National Perspective**
Dr. Roland Hauck, *Senior Scientist, National Fertilizer and Environmental Research Center, Tennessee Valley Authority, Muscle Shoals, Alabama*.

PROGRAM

(CONTINUED)

1:30-2:45 **Project Reports**

Nitrogen Fertilizer Management to Reduce Ground Water Degradation - Dr. Steven Weinbaum, Department of Pomology, UC Davis.

Field Evaluation of Water and Nitrate Flux through the Root Zone of a Drip/Trickle Irrigated Vineyard
- Dr. Donald W. Grimes, UC Kearney Agricultural Center, Parlier, CA.

Citrus Growers Can Reduce Nitrate Ground Water Pollution and Increase Profits: Using Foliar Urea Fertilization in the Spring to Increase Fruit Set and Yield and Reduce Citrus Thrips Populations and Fruit Scarring - Dr. Carol J. Lovatt, Department of Botany and Plant Sciences, UC Riverside

2:45-3:00 **Break & Refreshments**

3:00-4:15 **Project Reports**

Development of Diagnostic Measures of Tree Nitrogen Status to Optimize Nitrogen Fertilizer Use
- Dr. Patrick Brown, Department of Pomology, UC Davis

Potential Nitrate Movement below the Root Zone in Drip Irrigated Almonds
- Dr. Roland D. Meyer, Department of Land Air & Water Resources, UC Davis

Nitrogen Efficiency in Drip Irrigated Almonds - Dr. Robert J. Zasoski, Department of Land Air & Water Resources, UC Davis

4:15-4:30 **Conference Evaluation & Closing Remarks**

Introduction

Nitrate contamination of groundwater is a widespread problem in California and part of the nitrate comes from agriculture. Some of the agricultural sources of nitrate in groundwater are the target of a California Department of Food and Agriculture (CDFA) program. It's called the Fertilizer Research and Education Program--FREP, for short.

In January of 1990 the Nitrate Management Program (NMP) was established by the Director of the California Department of Food and Agriculture (CDFA) with the support of the California fertilizer industry. Its objectives were to identify and prioritize nitrate sensitive areas throughout California and to develop research and demonstration projects to reduce agriculture's contribution to groundwater contamination from fertilizer use.

First year activities concentrated on the above mentioned activities and helping secure funding and technical expertise to start research and demonstration projects in the Salinas Valley, the East side of the San Joaquin Valley and the Fall River Valley.

Recently the program name was changed to the Fertilizer Research and Education Program (FREP) as a result of a broader mission: to support activities directed toward the environmentally safe and agronomically sound use and handling of fertilizer materials.

Most of FREP's current work is concerned specifically with nitrate contamination of groundwater. That involves working with other agencies and with growers and industry to develop, demonstrate and promote the most effective ways to reduce nitrate pollution from agriculture.

Today, FREP is participating in programs in several California farm areas where nitrate in groundwater is a significant problem. In these activities, FREP:

- Funds research to find out more about the crucial relationships among crops, irrigation methods and nitrate in the soil as well as other environmental issues related to fertilizer use.

- Delivers information to growers, researchers, the agricultural supply and service industry, public officials, and the public.

- Organizes educational programs, and supports the efforts of other agencies in this area. All this has developed out of decisions made in the late 1980's by the CDFA and the California fertilizer industry about the problem of nitrate in groundwater.

As part of its ongoing outreach efforts FREP welcomes growers, farm advisors, researchers, public officials, agricultural supply and service organizations and other interested parties to its first annual conference. We hope that participants will gain a greater understanding and appreciation for the complexities involved in protecting one of California's most important resources.

INTRODUCTORY ADDRESS

A.J. Yates, Deputy Director
California Department of Food and Agriculture

On behalf of the California Department of Food and Agriculture we would like to welcome you to the first Fertilizer Research and Education Program Annual Conference. I would like to acknowledge the foresight of the California fertilizer industry in supporting this very important program as well as growers, commodity groups, the University of California, its researchers and all the other participants and contributors. Their involvement has been critical to the early success of the Fertilizer Research and Education Program.

If anything has been constant in the last years it is **change**. Society's past goal for agriculture has been the production of abundant food at reasonable prices. The joint effort and creativity of California growers, researchers, government and support industries have delivered outstanding results. Now, however, society is placing new demands on our growers: the production of abundant food and fiber while maintaining the integrity of natural resources and the environment. This new goal makes sense because we have the responsibility to safeguard for future generations the renewable bounty that supports us all. From a practical standpoint it is much easier to prevent damage to our natural resources than to restore it.

This responsibility poses many challenges and opportunities for everybody. I am convinced we can enhance the environmental performance of our agricultural production and maintain its economic viability. As a matter of fact, I believe that improved stewardship of resources will become a requirement to remain viable in the competitive agricultural production sector.

Therefore we need to work with all parties to show that we can improve and enhance our land and water resources. If we fail, regulation will come. When and how I don't know, but it does not look encouraging from the experience of growers in other states such as Arizona and Nebraska. The way I see this situation is: pay now or pay later, and later is usually more expensive. We, in agriculture, are and should continue to be part of the solution. We recognize the complexity of the situation but would rather develop solutions that fit farming constraints than have others tell us how to farm.

Growers care and have a vested interest in maintaining the viability of the resources that make farming possible and so successful here in California. We at the California Department of Food and Agriculture are part of that team effort. Today you will hear about our program activities and progress reports of some of the projects that we are helping support.

INTERPRETIVE SUMMARIES

IMPROVEMENT OF NITROGEN MANAGEMENT IN VEGETABLE CROPPING SYSTEMS IN THE SALINAS VALLEY AND ADJACENT AREAS

Principal Investigators:

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Nitrate contamination of groundwater is a significant water quality problem in the Salinas Valley and other coastal areas of California. Irrigation of cropland – especially land used for shallow-rooted, but high-N-requiring vegetable crops like lettuce and celery – has been identified as an important source of the nitrate. In 1991, the University of California received funding from the State Water Resources Control Board (through the Monterey Co. Water Resources Agency) and the California Department of Food and Agriculture to develop and demonstrate ways to reduce agriculture's contribution to groundwater nitrate in the Salinas Valley and adjacent areas. The project is now in its second year and will continue through 1993.

The first activity of the project was to review more than 300 scientific publications -- mostly research reports -- on the nitrogen fertilizer requirements of lettuce, broccoli, cauliflower, and celery. The reviewers found that a large amount of information already existed on the amount and rate of N uptake by these crops. Also, many researchers have measured the concentration of N in plant tissue that indicates sufficiency of N supply. However, little work has been done on soil and plant tissue quick-test methods, which are required if farmers are to use soil and plant tissue testing in making nitrogen fertilization decisions. Another gap was that little work had been done on how to prevent leaching and maximize crop use of nitrate that has accumulated in the soil as a result of decomposition of organic matter. This is important because in the mild, wet winters of coastal California, crop residues are microbially decomposed very rapidly leading to high levels of accumulated nitrate at a time when crops are often not present. A third gap in the literature was that some of the more important tools used by soil and plant nitrogen researchers have not been extensively applied to vegetable crop production. For example, nitrogen budgets and fates could be understood better if there were more research using fertilizers labeled with N-15. N-15 is a stable isotope of nitrogen. Its use in research has greatly enhanced understanding of nitrogen behavior in cereal grain systems. Little work has been done to adapt existing computer models of plant-soil-water relationships from cereal grain crops to vegetable crops. Such models can be used to make reasonable inferences about the effects (for example) of irrigation and fertilizer decisions on nitrate leaching.

A second project finding was the result of field experiments with winter cover crops conducted in three grower fields during the winter of 1991-92. In two of the fields, the presence of cover crops reduced soil nitrate levels significantly below the level in the conventional bare fallow plots. The cover crop species used included some well-known species like rye and some less-known like *Phacelia tanacetifolia*.

Like rye and oats, phacelia is efficient in extracting nitrate from the soil; but unlike rye and oats, it is slow to flower during the winter and does not produce large amounts of stiff straw or woody stems which are hard to incorporate and can result in a poor seed bed for the following vegetable crop.

A third focus of the project is on the use of drip irrigation for vegetable production. Most vegetables in the Salinas Valley and in all other areas of California are produced with a combination of sprinkler and furrow irrigation. Low uniformity of water application and less-than optimal timing and amounts of water applied lead to leaching of nitrate, requiring the farmers to apply even more fertilizer. Previous studies in the Salinas Valley have shown that even with well-managed irrigation systems, leaching will be high due to the typically shallow (12 - 24 inch deep) root systems of the cool-season vegetables. Leaching is especially likely to be high on coarse-textured soils which are common in some areas of the Salinas Valley. Drip irrigation can provide water more uniformly and allows both water and fertilizer to be spoon-fed to plants at just the required rate. The capital cost and the higher management and monitoring requirement are an impediment to adoption, but these costs will drop as farmers find ways to increase yield and quality, spread the capital costs over more years, and as technical information becomes available on how to manage drip systems.

The University of California project participants are working with cooperating growers in two locations. Near Soledad, a 2-3 year experiment was begun in 1991 to compare the performance of drip and furrow irrigation under near-commercial conditions. The soil is a sandy loam to a depth of 6 feet or more with a very low water-holding capacity. In a portion of an 880-ft long field (typical for the area), cooperative extension staff are measuring the amount and uniformity of water applied, crop yield, crop and soil nitrogen content, and the amount of nitrate down to a depth of 6 ft present between cropping periods. While much data is still to be collected and analyzed, some lessons learned during the first year are (1) shallow or surface placement of drip irrigation tape does not appear practical, due mainly to the damage inflicted on it by cultivation for weed control. Drip tape placed at a depth of eight inches (level with the bottom of the bed) is not harmed by cultivation or by tillage for reforming beds between crops. (2) Furrow irrigation during the first crop did not perform very well, and it was difficult to apply less than about 3 inches. A switch to surge irrigation during the second crop resulted in a much better ability to irrigate lightly without reducing uniformity. Surge irrigation is a modification to conventional furrow irrigation in which water is pulsed on and off at predetermined intervals. Water flowing down a furrow that was wetted during a previous interval will soak into the soil less and reach the end of the field faster. This is especially advantageous in coarse-textured soils.

Another finding in the Soledad study was that even though fertilizer had been applied conservatively to the first crop, very high levels of nitrate existed in the soil profile in December, two months after harvest. More than 200 lb N/acre were found in the furrow-irrigated area and more than 100 lb N/acre were in the drip-irrigated areas to a depth of six feet. By April 1992, 10 inches of rain had fallen. This resulted in a substantial increase in nitrate below the two-foot depth -- too deep to be retrieved by the spring lettuce crop. Even so, nitrate levels in the top two feet of soil were still high enough that -- had the project participants known at the time -- no fertilizer N would have been applied to the crop, at least through the first half of the season.

Another area of work has been to develop specific monitoring tools for the farmer to use in managing water and nitrogen. Work has been done mainly with a vegetable grower in the Hollister area who has been using drip irrigation for several years. The procedure being demonstrated involves weekly sampling of petioles and soil solution from several spots in the field. Soil solution is collected with a hand pump from ceramic-tipped tubes inserted into the soil to a depth of 14 inches. These measurements have provided convincing evidence to the grower that nitrate levels are very high early in the season, apparently due to the high level of residual nitrate from the breakdown of previous crop residue. With this information, the grower has felt comfortable in withholding nitrogen fertilizer until late in the season. In one case, the grower produced a satisfactory broccoli crop while applying only 98 lb N/acre, less than is typically applied in the area.

OPTIMIZING DRIP IRRIGATION MANAGEMENT FOR IMPROVED WATER AND NITROGEN USE EFFICIENCY

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Cooperator:

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Project Objectives:

This project proposed to include both field research and educational efforts designed to improve irrigation and nitrogen fertigation management practices of commercial vegetable producers. Specific objectives were:

- 1) Document the importance of drip irrigation/fertigation management practices on nitrate leaching losses,
- 2) Determine the accuracy and reproducibility of field techniques to rapidly measure soil moisture and soil and plant tissue nitrogen levels,
- 3) Conduct educational programs throughout the state to improve grower competence in drip irrigation and nitrogen fertility management.

Executive Summary

Irrigation studies on fresh market tomatoes were conducted at the UC South Coast Field Station (SCFS) in Santa Ana and the West Side Field Station (WSFS) in Five Points. The 1991 SCFS trial, the final season of a three-year study, compared drip irrigation scheduling based either on soil moisture depletion or on evapotranspiration estimates (ET_0) generated by the California Irrigation Management and Information System (CIMIS); ET_0 was multiplied by a crop coefficient based either on tabled values or the percentage of crop canopy coverage. It was determined that $ET_0 \times \% \text{ canopy}$ was a simple, efficient scheduling system that integrated the effects of environmental conditions and crop growth stage. The 1992 WSFS trial confirmed that irrigation in excess of 100% of CIMIS ET_0 , adjusted for crop growth stage by estimated % crop canopy coverage, is unnecessary and may negatively impact yields.

Field trials to establish appropriate nitrogen fertigation regimes for fresh market tomato and bell pepper production were conducted at WSFS and the University of California, Davis (UCD), during the summer of 1992. Five seasonal N rates ranging from 0 to 300 lb. per acre were applied in replicated plots in weekly increments. In all trials, no significant yield response was seen above 150 lb. N/acre. Through periodic tissue sampling and whole plant sacrifices to determine total dry matter production, nitrogen sufficiency guidelines at various crop growth stages were developed for these crops.

In these replicated fertility trials, an estimate of seasonal nitrate leaching losses was made by the use of buried cylinders of anion exchange resin to trap NO_3^- ions in leached water. This technique was at least partially successful in distinguishing differences in nitrate leaching related to irrigation and fertigation management, but leaching estimates were relatively low, even where N fertilization was clearly excessive. Weekly soil solution sampling also showed NO_3^- -N levels at 30 inches (trap depth) to be very low during the last half of the production season. The deep, vigorous root systems developed under drip irrigation apparently were able to efficiently extract nitrate from soil solution before deep leaching. These studies indicate that drip-irrigated vegetable crop culture can minimize nitrate leaching

during the cropping season, but careful nitrogen management is still important to minimize leaching losses during the winter fallow period.

Three field nitrogen monitoring techniques were evaluated: suction lysimeters (also called soil solution access tubes), a portable nitrate-selective electrode, and a leaf reflectance meter. Soil solution sampling has a high degree of inherent variability due to stratification of nitrate in the root zone, inefficiency in nitrogen or water delivery, and variability in plant vigor. Suction lysimeters, when replicated in a field (3 or 4 per management unit), can be used to determine nitrogen sufficiency, particularly early in a cropping cycle when crop N needs are minimal. They should not be used to determine when nitrogen is deficient, particularly during periods of rapid N uptake; a measure of tissue nitrogen status is more appropriate.

The nitrate-selective electrode (Horiba 'Cardy' meter) was used to measure $\text{NO}_3\text{-N}$ content of sap pressed from petioles of mature, recently expanded leaves. Correlations between fresh sap $\text{NO}_3\text{-N}$ as measured by selective electrode and dry tissue $\text{NO}_3\text{-N}$ concentration were evaluated for three crops: lettuce, pepper, and tomato. In general, the selective electrode worked well, giving good overall correlations across varieties, locations and growth stages. The relationship of fresh sap to dry tissue varied significantly among crops; this relationship is important for interpreting fresh sap values since virtually all 'sufficiency' guidelines are based on dry tissue. Despite these promising results, the fresh sap values as measured by selective electrode can be viewed as only semi-quantitative; main sources of error are calibration of the electrode and collection and handling of the petiole samples. Individual samples may vary considerably from the general relationship of fresh sap to dry tissue. Careful attention to detail and analyzing duplicate samples can minimize these variations.

The leaf reflectance meter (Minolta SPAD 502) provides an estimate of relative chlorophyll content, which is empirically related to nitrogen status. Unfortunately, this relationship is not exact and can be confounded by varietal and site-specific environmental variables. This instrument cannot be used as a general diagnostic tool since the 'sufficiency' leaf reflectance value varies by site, variety and growth stage. However, our testing showed that leaf reflectance measurement might be a valid indicator of nitrogen status in situations where an in-field reference of known N sufficiency is available.

The educational component of this project was conducted through a range of activities. Oral presentations were made to academic and industry groups; total audience for these presentations exceeded 1000. The information generated by the field studies provided information for scientific and trade publications with a broad audience.

Acknowledgement:

The information contained in this report was developed with invaluable contributions from UC Farms Advisors Richard Smith (San Benito County), Michelle LeStrange (Tulare County) and Don May (Fresno County).

EDUCATING CALIFORNIA'S SMALL AND ETHNIC MINORITY FARMERS ABOUT WAYS TO IMPROVE FERTILIZER USE EFFICIENCY AND REDUCE CONTAMINATION ON THEIR FARMS THROUGH THE USE OF BEST MANAGEMENT PRACTICES, (BMP)

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Executive Summary:

Small farmers and ethnic farmers constitute the vast majority of farmers in California. Yet they are not targeted for education on Best Management Practices (BMP), because they do not individually use as much fertilizer and other inputs as larger farmers and because no educational group or institution specifically identifies them as their unique clientele - *except the Small Farm Program.*

These farmers have an acute need for this education because:

- They tend to cluster around urban areas where ground water contamination is more of an issue.
- Their use of fertilizers may be less sophisticated than the large farms, so they have a greater need of education in BMP.
- The number of small farms is increasing relative to large farms.
- Vegetables and other high value crops tend to be grown on smaller farms, (compared to agronomic crops), and most vegetables are relatively inefficient users of fertilizer.
- Ethnic minority farmers frequently have language and cultural barriers that require special educational methodologies to surmount. These methodologies differ from those required by larger and conventional farmers.

The *Small Farm Program* is using the funds to augment and focus projects already underway on the techniques for Best Management Practices, and to fund three field days per year held across the state under the auspices of *Cooperative Extension* with the specific objective of reaching small and ethnic minority farmers who are not normally touched by the extension techniques that work for conventional large farmers. The SFP will support these field days with a publication printed in English, Spanish and Laotian that explains basic BMP technology.

A survey will be conducted during the field day that asks the participants if they learned anything new and if they will change the way they farm as a result of the new information.

INFLUENCE OF IRRIGATION MANAGEMENT ON NITROGEN USE EFFICIENCY, NITRATE MOVEMENT AND GROUND WATER QUALITY IN A PEACH ORCHARD

Principal Investigators:

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Cooperators:

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Statement of Objective:

In order to minimize pollution of groundwater resources by leaching of nitrates, stone fruit growers must be provided with information on strategies to maximize nitrogen uptake efficiency while maintaining optimal production.

Objectives:

- 1) To measure soil nitrate movement under different low-volume irrigation regimes.
- 2) To investigate the interaction of fertilizer use and irrigation on the yield and fruit quality of peaches.
- 3) To obtain information on water and fertilizer use patterns of stone fruit growers.
- 4) To summarize existing information from the literature on fertilizer use efficiency and nitrate leaching in stone fruit.
- 5) To disseminate the information obtained under the first four objectives to stone fruit growers.

Summary of Results:

1. Literature Review: Literature dealing with the effects of cultural practices on nitrogen use and nitrate leaching in fruit crops was reviewed. A literature review and publication list have been prepared and made available to Cooperative Extension stone fruit farm advisers and specialists and to the California Department of Food and Agriculture. Dr. Johnson was co-author of a review of nitrogen fertilization of fruit crops published in Horticulture Technology, Jan-Mar, 1992.

Nitrate leaching can be limited by good fertilization and irrigation practices. These practices are summarized in the Newsletter Efficient Use of Nitrogen Fertilizers in Orchards, which was a product of this project. To date this article has been published in the following newsletters: Tulare County Orchard Notes. Jan-Feb, 1992 (591 subscriptions); Fresno County Tree Topics. Jan, 1992 (614 subscriptions). Some of the good management practices include:

- 1) Determining the amount of fertilizer to apply by,
 - a) Testing well water to determine nitrate content. This indicates how much nitrogen from the water is available for plant use.
 - b) Estimating the availability of N from the soil.
 - c) Estimating removal of N by the crop.
- 2) Avoiding winter fertilization.
- 3) Using split applications of N fertilizer.
- 4) Using fertigation procedures where feasible.

- 5) Using an N formulation appropriate to soil chemistry.
- 6) Using proper application procedures for different formulations.
- 7) Avoiding over-irrigation following application of fertilizer.
- 8) Scheduling irrigations to avoid deep percolation or run-off.

2. Preparatory Field Work for Plot Study: The vertical extent of the rootzone of peaches under different existing irrigation regimes and the horizontal and vertical distribution of nitrates in the rootzone were measured using backhoe pits dug in January 1992. The majority of roots were within 4 feet of the ground surface. The distribution of nitrates both horizontally and vertically was highly variable, and not attributable to historical irrigation treatments.

In order to follow movement of nitrates through the root zone, ceramic cup "suction lysimeters were installed at three depths within the rootzone and below the root zone in all treatment replicates in March, 1992.

3. Plot Study of Fertilization and Irrigation Regimes: The purpose of this task is to study the effect of different low-volume irrigation regimes in combination with different fertilization regimes on nitrogen use efficiency, nitrate leaching, yield, fruit size and tree water status. Multiple applications of N fertilizer through a low-volume system were compared to one-time applications within three different irrigation regimes. The three irrigation regimes were high-frequency supplying 100% of evapotranspiration (T1), low frequency supplying 100% of evapotranspiration (T8), and low-frequency supplying 150% of evapotranspiration during the final fruit growth stage (T3).

The fertilizer treatment was applied in April, 1992 and again in September, 1992. Soil nitrate levels of soil solution extracted via suction lysimeters have been analyzed for 12 dates following the April treatment. Nitrate levels vary widely, but a pattern of peaks following fertilization and then valleys can be seen within each treatment.

No significant effect of fertilization treatments was measured on yield or fruit size. Yield (total fresh weight) and number of fruit per tree were significantly reduced in treatment T3, which received 150% ET from June 15-August 15. The reduction in yield of 3.4 tons per acre for T3 is an economic reduction. Since mean fruit weight was not different, this reduction is attributable to the reduction in number of fruit per tree. All trees in this experiment were commercially thinned in March, 1992 to a target level of 250 fruit per tree. The fruit set in T3 was lighter than in T1 and T8, and resulted in less fruit being left on the tree by the thinners.

This lighter set is probably due to lower flower densities, which are due to decreased floral initiation the previous summer. The reduction in floral initiation may be due to increased shading of floral buds, or to the high soil water contents at floral initiation time. This topic will be further elaborated in the final report.

Conclusions

The spring nitrogen treatments (single application vs. split applications) did not significantly impact any measured parameters. The low concentration of nitrogen applied (30 pounds per acre) and the short period between the split applications probably account for lack of measurable differences. In September, 1992 a second fertilization cycle with 75 pound of N per acre and two week intervals between split applications was initiated, and soil nitrate levels are being monitored during the subsequent period.

Detection of differences in soil nitrate concentration due to irrigation (or fertilization) treatments is hindered by the spatial and temporal variability between replicates. However, this variability appeared to be decreasing by the end of the 1992 season, and we are hopeful that the fall treatments will produce measurably different results.

A few tentative conclusions regarding nitrate leaching and nitrogen fertilizer use efficiency can be made based on soil water content measurements and soil nitrate measurements made in 1992. The treatments receiving 100% ET (or possibly less) had little or no water leaching from the rootzone and little nitrate leaching below the 5 foot rootzone.

The treatment receiving 150% ET from June 15 through August 15 had a substantial volume of water leaching below the rootzone and apparently most of the nitrate with it, although increased levels of nitrate were not measured at any depth. This treatment also had a significant reduction in yield, probably not related to nitrate leaching. Leaf analysis data is needed to see if plant nitrate status was impacted by the increased nitrate leaching.

This treatment is similar to the common grower practice of applying excess water during the final fruit growth period. The measured reduction in yield is therefore important, since it is evidence for growers that over-irrigation during the final fruit sizing period is detrimental to their bottom line. This could be an impetus for reducing irrigation volumes during this period, which would contribute greatly to reduced nitrate leaching in the stone fruit industry.

NITROGEN FERTILIZER MANAGEMENT TO REDUCE GROUNDWATER DEGRADATION

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Project Objectives:

This study is being conducted in two mature almond orchards in the nitrate-sensitive region of the Northern San Joaquin Valley in Stanislaus County. The objectives of this project include:

- 1) Establishment of a broad range of leaf N concentrations, i.e., tree N status and accompanying soil nitrate levels as a result of different fertilizer N application rates.
- 2) Determine the relationship between leaf N concentration and the rate of applied fertilizer N. This will include an assessment of the sensitivity of leaf N concentration to over-fertilization and a reassessment of the validity of the currently accepted leaf N critical value.
- 3) Determine the relationship between leaf N concentration and tree productivity.
- 4) Assess the relationship between the rate of applied fertilizer N and the recovery efficiency of isotopically labeled (^{15}N -depleted) ammonium sulfate. (This objective will be addressed following establishment of the N differentials as a result of yearly applications of 0, 125, 250, or 500 lbs N per acre per year.)
- 5) Assess the magnitude of nitrate leaching below the root zone and its relationship to fertilizer N application rate, efficiency of fertilizer N recovery, and tree N status. This objective will be addressed following establishment of differential tree N status.
- 6) Refine current management guidelines for N usage which will help to maintain productivity while reducing the amount of fertilizer N leached below the root zone.

It appears axiomatic that the more fertilizer N applied to the soil, the greater is the potentiality for nitrate leaching, especially if the tree capacity for N uptake is exceeded. Two factors probably contribute to the

reduced recovery of fertilizer N at high application rates: (1) the capacity for N uptake is limited in trees at high N status and (2) recently applied fertilizer N may be diluted in the soil as a result of residual nitrate from previous fertilizations.

Two research plots have been established in nitrate-sensitive areas of Stanislaus County - one in Salida and one in Ceres. Both orchards, planted in 1980, are growing in Hanford sandyloam soils. After collecting baseline data on tree yields, midsummer leaf N concentrations, and soil nitrate concentrations (at two-foot increments to a depth of 10 feet), experimental treatments were initiated in October 1990. Differential rates of N fertilization are being applied as a 1/3 to 2/3 split in March and October, respectively. This fertilization regimen represents typical grower practice, although we suspect that fertilizer N recovery by the trees is reduced when applied as late as October. The presence of high residual levels of nitrate in the soil and the use of high nitrate irrigation water has delayed the attainment of low tree N status despite the fact that trees in certain treatments have not received fertilizer for two and one-half years. Attainment of a range of tree N status corresponding to the rates of fertilizer N applied will signal the time that isotopically labeled fertilizer N will be applied in the orchards. We anticipate that a range in July leaf N concentrations between 2.0% and 2.4% will be established in the Salida orchard in 1993.

Establishment Of Tree Soils And Nitrogen Differentials

Four treatments each with four two-tree replicates were randomized within the orchard with adequate tree buffers between treatments.

Treatment:

1. No fertilizer N applied.
- 2 N applied in a split application at the rate of 125 lbs N/acre/year.
- 3 N applied in a split application at the rate of 250 lbs N/acre/year.
- 4 N applied in a split application at the rate of 500 lbs N/acre/year.

Note: All treatments receive the N applied in the irrigation water. The N rates in treatments 2, 3, and 4 are exclusive of the N supplied in the irrigation water. To assess the N critical value, i.e., the leaf nitrogen concentration below which tree productivity is reduced, we must allow some trees to go deficient (treatment 1). Because significant amounts of N are being supplied with the irrigation water, N deficiency may not occur without planting a grass cover crop to compete with the trees for N. Our analyses indicate that 72 and 98 lbs N/acre/year are applied with the irrigation water in the two orchards.

Results And Preliminary Conclusions

Typical fertilizer N management practices appear to favor over-fertilization and are likely to contribute to groundwater pollution especially in coarse-textured soils. Over-fertilization occurs when the availability of N in the orchard system exceeds the tree's capacity to absorb it. Excessively high leaf N concentrations (> 2.6% N), high residual levels of nitrate in the soil, high nitrate concentrations in wells used for irrigation, and high rates of annual fertilizer application were found in our test orchards.

Leaf N concentrations decreased annually in all treatments relative to the 1990 (pretreatment) levels. However, leaf N concentrations declined the least among trees receiving 500 lbs N/acre. The greatest decrease in leaf N concentration occurred among trees receiving no fertilizer N and in 1992, midsummer leaf N concentrations as low as 2.13% were not associated with a statistically significant yield reduction relative to the well-fertilized (250 lbs N/acre, 500 lbs N/acre) trees. Annual leaf analysis would appear to be an important component of responsible fertilization management.

Since differential fertilizer N application rates did not influence tree yields statistically during the first two years of the project, it is apparent that annual fertilization is not necessarily required to maintain productivity. Thus, if the soil contains sufficient reserves of available non-fertilizer N, then fertilizer N is not likely to stimulate tree growth and productivity.

Soil nitrate concentrations decreased over winter by 50% to 75% in the root zone (to four feet of soil in both orchards). Although some denitrification may have occurred, the most likely explanation is leaching deeper in the soil profile, i.e., beyond the root zone. It would appear desirable to minimize residual nitrate in the soil over winter to limit nitrate leaching below the root zone--ultimately to reach the groundwater.

FIELD EVALUATION OF WATER AND NITRATE FLUX THROUGH THE ROOT ZONE OF A DRIP/TRICKLE IRRIGATED VINEYARD

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Summary Results and Conclusions:

Nitrates and pesticides are frequently detected in wells in the U.S. at levels of concern for human health. Intensive agriculture has a potential for being a nonpoint source of groundwater contamination. Chemigation, i.e., the application of agricultural chemicals using irrigation systems, has gained popularity in recent years especially where drip/trickle water delivery systems are used. The potential exists for ions like nitrates, that are relatively nonreactive at the soil particle surface, to move below the root zone.

In rainfed regions, carefully controlled time and amounts of fertilizer addition are used to control groundwater contamination. In irrigated areas such practices must also be tied to avoidance of extensive water movement below the crop root zone.

Perennial crops that are grown with relatively wide row spacing logically appear to be situations that might lead to water and nutrient flux below the crop root zone. This is especially true on sandy soils where drip irrigation with chemigation concentrates a water and nutrient release in a relatively small part of the crop root zone that is expected to fully meet ET_c and crop nutrient needs. This study was conducted to determine the extent to which water and nitrogen movement below the root zone occurs for a chemigated/drip irrigated, Thompson Seedless vineyard when fertilization and water amounts are at optimum levels. Soils of the U.C. Kearney Agricultural Center study location are primarily Hanford sandy loam.

Season-long water movement below the crop root zone was above one inch. With the measures nitrogen concentration in this amount of water, only about 1 1/2 pounds of nitrogen were moved below the effective root zone. These results clearly show that nitrogen fertilization and irrigation to fully meet water and nutrient requirements of grape vineyards can be done without contaminating groundwater.

Based on comparisons of measured flow with factory flow specifications, three different buried drip systems did not experience root plugging for any of the comparative materials during this first study year.

CITRUS GROWERS CAN REDUCE NITRATE GROUNDWATER POLLUTION AND INCREASE PROFITS BY USING FOLIAR UREA FERTILIZATION IN THE SPRING TO INCREASE FRUIT SET AND YIELD AND REDUCE CITRUS THRIPS POPULATIONS AND FRUIT SCARRING

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The overall goal of this research is to reduce pollution of groundwater from soil-applied nitrogen fertilizer and thripicides used in citrus production.

The results of Embleton *et al.* (1986) demonstrated that even if growers used soil applications of nitrogen at the minimal level required for citrus production (225 kg NO₃⁻/ha/yr), nitrate pollution of the groundwater would result. Most citrus growers fertilize with significantly higher rates of nitrogen. Worse still, Ca(NO₃)₂ applied to the soil at rates from as low as 100 to 300 kg/ha/yr increased soil salinity from 0.93 to 1.56 dS/m (Embleton *et al.*, 1986). Thus, the continued use of soil-applied nitrogen in citrus production is a real and significant threat to both water and soil quality in California and in other citrus-producing states in the United States. In addition, the potential exists that the citrus industry is contributing to the degradation of water and soil quality in California through the use of chemical pesticides to control citrus thrips (*Scirtothrips citri* [Moulton]). Since the early 1900s, one to four chemical sprays have been applied during the pre-bloom and post-petal fall period to control this pest in much of California's citrus (Horton, 1981; Morse and Brawner, 1986). According to the California Department of Food and Agriculture, over the years 1983-1986, pesticide use for control of citrus thrips in California was 174.6, 190.5, 271.6, and 387.3 (thousand) lbs. active ingredient per year, respectively (Atkins *et al.*, 1989). Because even the potential degradation of water and soil quality by chemical pesticides is a sensitive issue, we need to provide citrus growers with a non-pesticide alternative to control citrus thrips. The growers in the San Joaquin Valley, which comprises a majority (54%) of the state's citrus acreage, have historically used chemicals to control citrus thrips which precludes the use of biological control for other insect pests. With a non-pesticide strategy to control citrus thrips, it would be possible to convert the San Joaquin Valley citrus acreage to biological control (Luck *et al.*, 1986). Our preliminary results and those of others suggest that foliar-applied urea may be efficacious as a non-pesticide option to control citrus thrips.

Our objective is to test the hypothesis that foliar urea applied April 1 to June 1 can do triple duty (i) as a "non-pesticide" to control citrus thrips and reduce fruit scarring; (ii) as a "growth regulator" to improve fruit set and increase yield without reducing fruit size or quality; and (iii) as a nitrogen fertilizer by supplying a portion of the nitrogen to be applied in a given year thus reducing the amount applied to the soil. The goal of our research is to provide citrus growers with the optimal time and rate of foliar-urea application needed to successfully improve fruit set and yield and control citrus thrips to reduce fruit scarring. If our research is successful in improving yield and/or reducing the economic loss due to fruit scarring caused by citrus thrips, our research will provide an economic incentive for citrus growers to reduce their use of soil-applied nitrogen in favor of a spring foliar application of urea. Thus, if successful, the results of our research will not only improve citrus productivity and grower profits, but it will also

reduce pollution to the groundwater from nitrate and reduce the amount of chemical pesticides currently used to control citrus thrips which results in less potential pesticide pollution of the soil and groundwater. The project is a success if a spring foliar-application of urea increases yield and/or reduces economic losses due to fruit scarring by citrus thrips.

The research employs 17-yr-old 'Frost nucellar' navel orange trees on Trifoliate orange rootstock under commercial production by Paramount Citrus in the Ivanhoe area of the San Joaquin Valley. The research will be replicated for two years due to alternate bearing.

There are five treatments each replicated as eight randomized blocks (six rows wide by 15 trees long). Data are being collected from six individual trees per block for a total of 48 data trees per treatment. Trees used for leaf $\text{NH}_3\text{-NH}_4^+$ content, yield, and fruit scarring assessment are separate from those used to determine population levels of *Scirtothrips citri* and *Euseius tularensis* because the sampling technique in each case is destructive to the tree and might impact yield. Foliar low-biuret urea was applied on April 7, April 21, May 5, or May 20 for treatments 1 through 4, respectively. Treatment 5, the control, is Paramount Citrus' best management practice. The $\text{NH}_3\text{-NH}_4^+$ content of leaves was determined the day before the foliar application of urea and on day 1, 8, and 15 after the treatment to determine to what level leaf $\text{NH}_3\text{-NH}_4^+$ content increased and how long it remained elevated. Total nitrogen analyses will be done by Paramount Citrus each September in order to monitor the total nitrogen status of the tree as is currently done commercially.

Citrus thrips population levels were assessed the day before the foliar application of urea and on day 1, 3, 8, and 15 after the urea spray from the inside of rows 2 and 5 of at least four of the eight treatment blocks. Sampling employed 20 data trees number 1-10 in row 2 and 11-20 in row 5 to collect four jar samples per block as follows: jar 1 - start on tree 1, make 20 D-Vac entries, low on odd trees, high on even; jar 2 - start on tree 20, make 20 D-Vac entries, low on odd trees, high on even.

For leaf $\text{NH}_3\text{-NH}_4^+$ content and citrus thrips populations, control trees were sampled simultaneously with each treatment. Odd-numbered trees were sampled for the April 7 and May 5 treatments and even-numbered trees for the April 21 and May 19 treatments.

Euseius tularensis (hibisci) population levels were assessed weekly starting March 23 through May 25 (nine weeks) for the control and starting the week before the foliar application of urea for each treatment through May 25 on rows 3 and 4 in each treatment block. Five leaves were collected in each of four quadrants from each of four data trees per block. The results of this part of the study provided clear evidence that foliar application of low biuret urea had no negative effect on the population levels of the beneficial predatory mite *Euseius tularensis*.

Harvest will occur sometime in March 1993. Fruit weight per tree, fruit number per tree, fruit size distribution on 75 randomly selected fruit, and degree of thrips scarring will be determined.

Progress reports on the results of the first and second year of research will be provided at the specified times. The final report will present in detail the effect of urea sprays on leaf content of $\text{NH}_3\text{-NH}_4^+$ and *Scirtothrips citri* and *Euseius tularensis* populations and a cost/benefit of the use of a spring foliar urea spray.

DEVELOPMENT OF DIAGNOSTIC MEASURES OF TREE NITROGEN STATUS TO OPTIMIZE N FERTILIZER USE

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Statement of Objective:

Orchard crops utilize large amounts of fertilizer N and are potentially major contributors to groundwater pollution in many areas of California. Large acreages of orchard crops are grown in areas designated as nitrate 'sensitive' in recent water quality assessments. Fertilizer management of orchard crops is, however, poorly regulated and the dynamics of N in orchard crops is the least well understood of any cropping system. In this research we aim to improve plant N-monitoring techniques so that fertilizer applications can be better managed. This aim will be achieved by monitoring the concentration, composition and distribution of a range of N-compounds in mature trees and relating this to plant, yield, fertilizer N application and nitrate movement in the soil. Research of this type has been performed in annual crops but has not been adapted to perennial systems. Preliminary research in our lab has provided some very promising results and demonstrate that the aims of this research are achievable. Specific objectives of the project are to:

- 1) Reassess the sensitivity of currently accepted diagnostic criteria and develop more sensitive criteria of tree N status.
- 2) Develop plant sampling strategies to determine availability of applied N fertilizers. Relate N application rates and soil N testing to tree N status.
- 3) Develop recommendations based on soil and/or plant testing to maximize fertilizer use-efficiency and reduce the contribution of orchard crops to nitrate contamination of groundwater. Results will be used to develop fertilizer recommendations and monitoring procedures for orchard crops that will maintain profitability, optimize crop nutrient uptake and minimize nitrate leaching from the root zone.

This research is of direct value to the many almond growers in California and will be readily adaptable to other orchard crops such as peach, prune, apricot etc. This project has been developed in close cooperation with, and has received partial funding from the Almond Board of California.

The use of tissue tests to determine fertilizer practices is new to orchard crop growers. Our preliminary results demonstrate the potential usefulness of this methodology. With the development of simply and effective N-test we will be in the position to provide new management strategies that maintain profits and minimize groundwater pollution. Acceptance of the results will be facilitated by our close association with the Almond Industry, the use of commercial orchards in our experiments, presentation of results at field days and growers meetings.

POTENTIAL NITRATE MOVEMENT BELOW THE ROOT ZONE IN DRIP IRRIGATED ALMONDS

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Objectives

- (1) To assess the extent of nitrate movement under drip emitters from different nitrogen rates each applied at two water levels.
- (2) To evaluate nitrate movement beneath drip emitters when different nitrogen sources are utilized. (Second year).
- (3) To evaluate the effects of different nitrogen rates applied at two water levels on growth, nutrient concentrations in leaves and twigs, and nut yields of almonds.
- (4) To develop recommendations for nitrogen, irrigation and soil management for use in the establishment and early maturity stages of drip irrigated almond orchards.
- (5) To evaluate changes in soil acidity and nutrient (N, K, Ca, Mg) movement within the drip zone as a result of different applied nitrogen rates at two water levels and also different sources of nitrogen fertilizer.
- (6) To evaluate the effects of two rates of potassium on growth, nutrient concentrations in leaves and nut yields.

Project Description

Drip and other limited soil area irrigation is a unique method of providing water to trees which makes for a number of challenging management situations. Even though it is practiced on a smaller percentage of the irrigated acreage in the state, (perhaps <10%) drip irrigation has and will undoubtedly continue to increase because of the rising cost and reduced availability of water. Since water is applied to a more limited soil area, excessive amounts may move and also leach nutrients more rapidly than when other irrigation systems are used. Having a relative small volume of soil being used as the reservoir for water and nutrient uptake which is saturated a high percent of the time during the summer provides a setting for several unusual chemical reactions in the soil. The use of an acidifying nitrogen fertilizer such as urea or any other ammoniac form increases the solubility of potentially toxic elements like manganese and aluminum. In an experiment which has been underway for several years, soil sampling of the high nitrogen-high water treated plots has indicated some nitrates have been leached below the root zone immediately below the drip emitter. The low nitrogen-low water treatment samples suggest little or no leaching of nitrates. A reevaluation of nitrate and other nutrient movement in the high and low nitrogen rate treatments as well as several of the three intermediate rates at the two water levels is proposed for this project. In the second year, soil sampling of another experiment having several different nitrogen sources is proposed. This project will support and expand an ongoing study that has been partially funded by the Almond Board wherein growth, nutrient concentrations in leaves and twigs, and nut yields of almonds are being measured.

This study is being conducted in an orchard that was planted at the Nickels Soil Laboratory near Arbuckle, CA in the spring of 1981 to three almond varieties--Butte, Carmel and Nonpareil on a 12' X 18' spacing (202 trees/A). In the spring of 1982, five-5 tree plots were selected from each of the four-28 tree rows of each variety to which the two replications of the ten treatments were assigned. The ten treatments included two water levels-0.6 and 1.0 of evapotranspiration (ET) each with five nitrogen

rates-0, 0.5, 1.0, 1.5 and 2.0 oz/tree in 1982; 0, 0.8, 1.7, 3.5 and 7.0 oz/tree in 1983; 0, 2, 4, 8 and 16 oz/tree in 1984; 4, 8, 16, 24 and 32 oz/tree in 1985; 6, 12, 24, 36 and 48 oz/tree in 1986; 8, 16, 32, 48 and 64 oz/tree in 1987 and 1988; 6, 12, 24, 36 and 48 oz/tree in 1989; 4, 8, 16, 24 and 32 oz/tree in 1990, 1991 and 1992. Rates planned for 1993 are 4, 8, 16, 24 and 32 oz/tree. Urea is the nitrogen fertilizer source and it is applied on a monthly basis in five (6 in 1986-89) equal increments beginning April 1st. The 1.0 ET irrigation level is based on climatic data from CIMIS and the 0.6 ET treatments receive 60% of the water quantity of the 1.0 ET treatments. In a second experiment different nitrogen sources have been used for several years. They are: urea, calcium nitrate, urea-calcium nitrate in alternating years, UN 32, N-phuric and 5 additional urea treatments to which different soil pH amendment materials will be added.

Results and Conclusions

The first observations taken at the beginning of each year, usually early January, have been tree trunk circumference or diameter measurements to monitor tree growth the previous season. Tree cross-sectional area was calculated for the 1991 growing season (299 trees) and the data analyzed to indicate that the high water level along with some of the higher and lower nitrogen rates had significantly greater increases in growth. The intermediate nitrogen rates at the low water level generally resulted in the smaller growth increases. These growth increases are similar to those observed in 1990 but somewhat different from earlier years when nitrogen rate was the more dominant factor in influencing trunk growth than water level. Significant differences were observed between varieties as the Butte variety had greater growth increases than the Nonpareil and both had larger increases than the Carmel. Previous year's growth increases have indicated that Butte has had equal or greater increases than Nonpareil and that Nonpareil has had equal or greater increases than the Carmel variety.

Twig samples taken in January (60 plots) indicated significant differences among nitrogen rate-water level treatments for total nitrogen (N), sulfur (S), zinc (Zn) and manganese (Mn) but no differences for phosphorus, potassium and calcium. Higher twig total N, S and Mn concentrations were associated with higher applied N rates and the lower water level. Twig total Zn was highest with the higher N rates irrespective of water level. No significant differences were observed in twig total phosphorus (P), potassium (K) and calcium (Ca) for the nitrogen rate-water level treatments.

Significant differences in leaf nutrient concentrations for the nitrogen rate-water level treatments were observed in the April sampling: N, P, K, Ca, Mg, S, Mn and Cu; the May sampling: N, P and K; the June sampling: N, P and K; the July sampling: N, K, Ca, Mg, S, Mn, Cu and B; and the August sampling: N and K. No significant differences were noted in the April sampling for leaf total Zn and B or in the July P and Zn. Responses were generally of two types: those where leaf nutrient concentrations increased as the applied nitrogen rate increased at both water levels and the second type where the leaf concentrations decreased as applied nitrogen increased again at both water levels. The sample date-nutrients in the first response type were the April N, S, Mn, Cu; May N; June N; July N, Mg, S, Mn, Cu; and the August N. The sample date-nutrients in the second response type were the April P, K, Ca, Mg; May P, K; June P, K; July K, Ca, B; and the August K. The nutrient concentrations for the July sample date indicated that the three highest applied nitrogen rates (16, 24 and 32 oz/tree) were all above the minimum suggested of 2.2%. The minimum concentration of each of the other nutrients were 0.10% P, 1.30% K, 2.85% Ca, 0.89% Mg, 1280 ppm S, 12 ppm Zn, 60 ppm Mn, 5 ppm Cu and 29 ppm B. The highest manganese concentration of 530 ppm was reached in the highest nitrogen-lower water treatment. The last leaf sampling will be conducted in early October and higher manganese concentrations may appear at this later date in the season.

Almond yield determinations for 1992 are currently being processed with the last variety harvest planned for this week (Sept 24th). Hull, shell and kernel (meat) fractions will also be determined along with the total nitrogen of each fraction for calculating nitrogen removal by the harvested crop.

Plans are to take soil samples during October and November from selected nitrogen rate-water level treatments immediately under and at various distances from the emitters. This will indicate the degree of nitrate movement below the root zone for different nitrogen rate-water level treatments. Earlier sampling has shown that the lowest nitrogen-lower water level treatment has very low nitrate concentrations in the soil profile but almond yields have only been 20 to 50% of the highest recorded yield. The highest nitrogen rate-high water level treatment was also sampled earlier and indications were that considerable nitrate movement had occurred below the root zone.

NITROGEN EFFICIENCY IN DRIP IRRIGATED ALMONDS

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Objectives

This research is designed to determine the fate of fertilizer N applied to a drip irrigated almond orchard under acidified soil conditions. This information does not currently exist for finer textured soils nor for sandy soils. The use of stable isotopes will allow us to directly measure whole plant uptake (tops, roots and the crop). Knowing uptake, N efficiency in drip systems can then be calculated.

Project Description

Three replications of drip irrigated Nonpareil almonds on Lovell peach root were pre-treated (fertilized) with ammonium sulfate or calcium nitrate to produce differences in soil acidity in the wetted soil volume. Fertilizer application rate for two years prior to treatment was 800 lbs per acre in split monthly or bimonthly applications for 1989 and 1990 respectively. Beginning in April 1991 ¹⁵N-depleted ammonium sulfate (at a rate of 200 lbs acre) was applied to the ammonium sulfate and calcium nitrate treatments. On January 21 and 22, 1992 six treated trees were extracted from the ground chipped and weighed to determine the biomass in branches, stems, medium roots and coarse roots. Subsamples of these components were analyzed for total and isotopic N ratio in order to determine total N uptake and recovery of the applied label. Soil cores from treated plots were obtained in March to determine root distribution and fine root mass as well as nitrogen distribution around the treated trees. Vacuum soil solution samplers and platinum electrodes have been installed to measure soil solution composition and aeration status in the drip zone.

Results and Conclusions

Before the ¹⁵N-depleted ammonium sulfate was applied the ammonium sulfate treatments were distinctly more acid than the calcium nitrate plots. In the surface two feet, pH measured in 1:2.5 CaCl₂ averaged 5.59 for the calcium nitrate plots and 4.23 in the ammonium sulfate plots. In spite of the differences in pH, there were no differences in the total soil nitrogen after two years of heavy fertilization. However, extractable ammonium and nitrate distribution was different between the treatments. Nitrate extracted by KCl averaged 5.5 mgkg⁻¹ while extractable ammonium was 1.1 mgkg⁻¹ in the upper 36 inches of the calcium nitrate plots. In comparison the average nitrate level was 12.5 mgkg⁻¹ and extractable ammonium averaged 38.8 mgkg⁻¹ in ammonium sulfate plots. Thus prior to application of the ¹⁵N-depleted material, soils in the calcium nitrate plots were less acidic and lower in extractable nitrogen than soils of the ammonium sulfate pretreatments. In previous years foliage from the ammonium sulfate plots had been higher in total nitrogen than foliage from the calcium nitrate plots.

Examination of Table 1 shows that the majority of the biomass is associated with the tree stem and branches, which averaged 264 lbs per tree. None of the component biomasses were significantly different between the calcium nitrate and ammonium sulfate pretreatments. Likewise for the total nitrogen content there were no significant differences between pretreatments. The roots greater than 1/4 inch in diameter accounted for 16% of the total measured biomass but contained 36% of the nitrogen in these components (Table 2). This reflects the fact that the woody tissue such as stem and branch wood is generally low in nitrogen. Average above ground biomass combined with the coarse and medium roots was 336 lbs per tree.

This calculates out to be 33.9 tons of dry material per acre. Another way to view this data is to consider that about 360 lbs of N are need to construct the above ground structures plus the coarse and medium roots in this orchard. Additional N is cycled into the foliage and fine roots. This additional N is retained in the orchard, while some N is removed in the crop. We are in the process of determining the amounts for these additional components.

Table 1. Dry weights of tops, coarse roots, medium roots and stumps of trees extracted in late January 1992. (Pounds of dry weight per tree)

Treatment	Tops	Coarse Roots	Medium Roots	Stump	Total
Ammonium sulfate					
AVERAGE	254	30	24	22	323
SDEV	25	8.5	4.2	4.0	23
Calcium Nitrate					
AVERAGE	273	24	31	20	348
SDEV 39		2.6	1.5	2.6	40

Table 2. Total nitrogen contained in the tree components (lbs per acre).

Treatment	Top	Coarse Roots	Medium Roots	Stump	Total
Ammonium sulfate					
AVERAGE	211	62	64	11	348
SDEV	4	23	17	1	39
Calcium nitrate					
AVERAGE	221	51	86	10	369
SDEV 16		7	13	3.5	17

Table 3 contains the data for nitrogen in the various tree and crop components which has been derived from the ¹⁵N-depleted source. In the calcium nitrate plots a greater fraction of the total N for all components was derived from the ¹⁵N-depleted fertilizer source. These differences were statistically significant for all of the components except the tops which is affected by one replication that is substantially lower than the other two in the calcium nitrate treatments. Using the crop values for 1991 and the 1992 biomass data total uptake derived from the ¹⁵N-depleted material was 42 lbs per acre for the ammonium sulfate plots and 63 lbs per acre for the calcium nitrate plots. This accounts for 21 and 31% of the N applied (200 lbs per acre) during the 1991 season. The reason for this greater utilization in the calcium nitrate plots is not known. Since there was less available N in the calcium nitrate plots prior to ammonium sulfate addition, the fertilizer would have been a greater fraction of the available N pool in the calcium plots. However, further analysis is necessary to elucidate the reasons for this substantial difference between treatments in the total N labeling. Data for fine root biomass and nitrogen content as well as soil solution N and extractable N are currently being processed. With these data a more complete N budget can be constructed and the effects of soil acidity and nitrogen form on N use will be more apparent.

Table 3. Nitrogen (% of total N) derived from ¹⁵N-Depleted fertilizer in 1991 and 1992. Component means with an *, ** or *** are significantly different at the 0.05, 0.01 and 0.001 level respectively between treatments.

Treatment	Tops	Component				
		Fine Roots	Coarse Roots	Stump	Kernel	Husk & Shell
Ammonium sulfate						
AVERAGE	9.09	14.24	10.79	12.50	5.34	4.16
SDEV	0.51	1.77	0.77	1.57	1.22	0.60
Calcium nitrate						
AVERAGE	12.85	20.87***	15.48** 1	7.91**	8.59**	6.91**
SDEV	3.23	0.84	1.72	1.64	0.95	0.98