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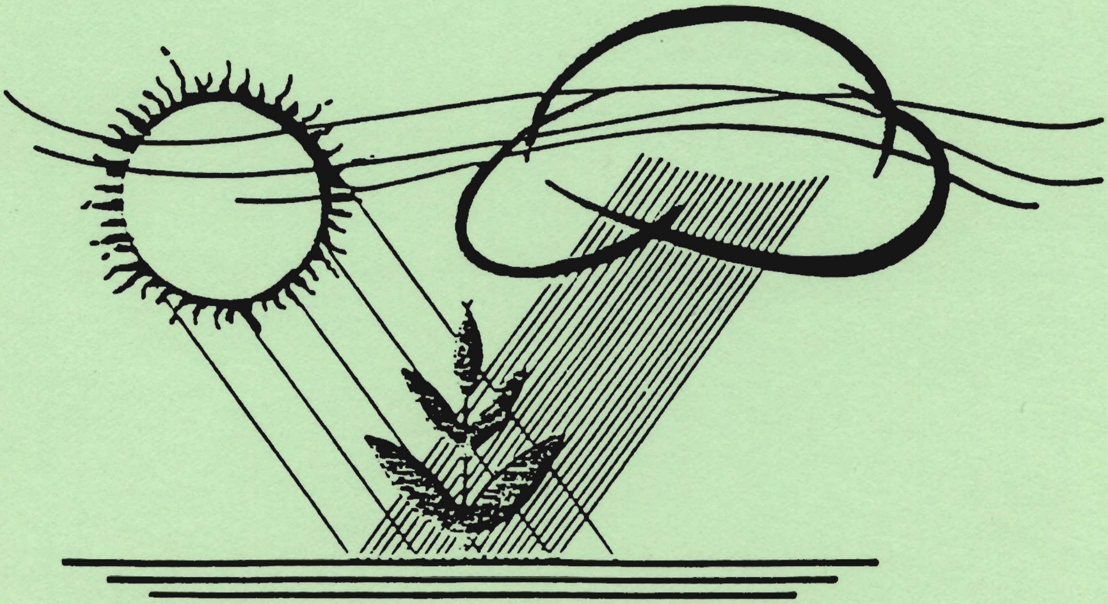
1991
CALIFORNIA PLANT AND SOIL CONFERENCE

URBANIZATION and AGRICULTURE COMPETITION FOR RESOURCES



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January 31 – February 1, 1991
Embassy Suites Hotel
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ASPECTS OF IRRIGATION MANAGEMENT AS THEY RELATE TO PESTICIDE CONTAMINATION OF GROUND WATER

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Since crop production in most portions of California depends on irrigation, management of irrigation water will be a key element in strategies developed to maintain pesticide residues within the crop root zone. The importance of irrigation water in the contamination of ground water by pesticides parallels the importance of vector control in virus diseases of plants. In that pathogen-host relationship, a virus infects a plant and causes a disease, but a vector is needed to move the virus from infected to non-infected plants. Aphids are an example of a vector and through their elimination, the virus disease may be controlled. The analogous situation for ground water is that non-volatile pesticide residues are moved from their original site of application to ground water through the movement of water. Since water acts as a vector, considerations in control of water management with respect to deep percolation and runoff will be crucial in preventing further contamination.

Knowledge of the pathways of ground water contamination provides a framework from which specific aspects of agricultural water management can be identified for further study on prevention of contamination. Pathways of ground water contamination may be classified into two broad categories. One I call direct-streaming where a conduit or pipeline to ground water exists facilitating rapid movement of surface water to ground water. Much of the concern in this area is related to integrity and construction of wells. Recent recommendations have been to:

1) Store, mix, and load pesticides and rinse equipment away from the wellhead.
2) Channel water away from wells and surrounding areas to prevent possible direct movement of pesticide residues in water down the well.

Some considerations in the delivery and eventual disposal of irrigation water concerning direct-streaming problems are:

1) In chemigation, systems should contain devices that prevent backsiphoning of water into wells. This is required by CDFA regulation.
2) Does the runoff water contact a well?
3) Is the disposal of runoff water designed to be a direct-streaming process, such as in the use of dry wells?

Measures to address direct-streaming problems are being developed under the Department's Wellhead Protection Plan.

The second pathway is called leaching where residues move down through the soil with deep percolating water that normally recharges a ground water aquifer. If deep percolating water is minimized or eliminated then residues will be retained in the upper layers of soil. Since degradation of pesticides is greatest in the upper layers of soil, keeping residues in the upper layers should not only enhance efficacy but also promote degradation ensuring that residues are broken down within a finite time interval (Morill et al., 1982; Ou et al., 1988).

To date, the California Department of Food and Agriculture (CDFA) has changed the use of all pesticide active ingredients that continue to be registered for crop use and that have been detected in ground water as a result of normal agricultural use (Cardozo et al., 1989). However, none of the regulations have required modifications in water management. Although there is an intuitive link between water management and residue management, additional studies on environmental fate of pesticides are needed to determine exactly how irrigation systems can be managed to prevent leaching. Water budgeting methods, that were developed by UC researchers under contract by the Office of Conservation, Department of Water Resources, appeared to be of utility because efficient use of water involved minimizing the amount of deep percolating water (Snyder et al., 1985). Existence of these programs lead us to examine how climatic measures of water loss from soil could be used for managing pesticide residues in soil. Since there were no studies that compared movement of pesticide residues between different methods of irrigation when water was applied under similar conditions, a study was undertaken with the cooperation of Jim Brownell and Charles Krauter at the California State University at Fresno to:

1) Illustrate the effects of deep percolation of water on pesticide movement.
2) Determine if water budgeting could be used to prevent pesticide leaching.
3) Determine if there were potential problems in recommending one water budget approach for different methods of irrigation.

The soil distribution of inorganic water tracers, bromide or chloride, and an herbicide, atrazine, was measured in treatments where water was applied over a 40 day interval at three amounts and by three methods of application (Troiano et al., 1990). Sprinkler applications were applied one day/week and basin-flooding and furrow irrigations were applied in 1, 2 or 3 events. There was a high correlation between the amount of deep percolating water produced within an irrigation method and pesticide residue leaching: amount and depth of pesticide leaching directly increased as the amount of deep percolating water increased (Figure 1). However, the magnitude of leaching differed between methods of water application: pesticide leaching was less in sprinkler than in basin-flooding irrigations, and it was greatest in furrow irrigation (Figure 2). The difference between sprinkler and basin-flooding methods of application could be explained by greater evaporation in sprinkler treatments. Use of the LEACHM model, which models the movement of pesticide residues in soil in relation to water movement, indicated that more water evaporated in the more frequent sprinkler treatments, resulting in less water lost to deep percolation than in the larger, infrequent basin-flooding applications (Hutson et al., 1989). It should be noted that the study was conducted on bare soil. In the presence of a crop, part of the water lost to evaporation in sprinkler treatments would have been available for crop transpiration. In contrast, less water would have been available for crop transpiration in basin treatments because more water percolated below the area of significant root extraction. Since the soil was approximately 90% sand, application of the same volume of water to only 1/2 the plot surface area through furrows may have resulted in greater local downward flux of water and explain the difference in pesticide movement between basin-flooding and furrow methods.

The data for the sprinkler method of application also illustrated the importance of maintaining residues in the biologically active zone (Figure 1).

As residue was driven deeper into the soil, it was subject to less degradation. This point is especially critical in light of the low organic carbon content of many soils in California. Since hydrophobic pesticides are adsorbed onto the organic carbon component of soils, residue movement is directly related to the amount of organic carbon present (Rao et al, 1985; Shea, 1989). In another CDFA study conducted to determine potential differences in pesticide movement between soils located in a coastal and an inland basin, soil sampled in the coastal basin near Santa Paula, Ventura County, contained greater amounts of organic carbon down to the 3 meter soil-depth than soil sampled in the inland basin near Lindcove, Tulare County (Figure 3) (Welling et al., 1985). Since that time, soil-applied herbicides have been detected in well water sampled in Tulare County but not in wells in Ventura County (Cardozo, et al., 1989). The soil profile for organic carbon at the Fresno irrigation study site was similar to the Tulare County site with significant amounts of organic carbon found only within the upper 0.3 m of soil (Figure 3). Water management in areas where soil organic carbon is low will be critical in assuring that residues remain in the upper layers of soil where they will react with organic carbon and where they will eventually degrade.

I briefly would like to mention two other areas of water management which will require further investigation. The first area is determining the appropriate way to set pesticide residues into soil. Most pre-emergent herbicide labels contain advisory language stating that, because the material acts through the roots of plants, it must be set into the soil with a small rainfall or irrigation event. Usually sprinkler irrigation is recommended. Initial calculations indicate problems might occur with herbicides that have a low water solubility. For example, if a 1 cm application of water is used to water-in a compound with a water solubility of 5 ppm (5 mg/l), 0.5 kg of material on a hectare basis could potentially be solubilized. Application rates around 2 kg per ha are quite common so only 25% of that application would be set into the soil by a 1 cm event. The remaining 75% of the material would reside on the soil surface where it would be available for offsite movement in subsequent large irrigation or rain events. It should be noted that providing a uniform irrigation event of only 1 cm could be problematic for certain types of irrigation methods.

Lastly, the timing of a pesticide application in relation to major irrigation events may be important. This last slide is a graphical representation of water use of citrus for 1986 (Figure 4). Peak use in summer was around 9 cm. If irrigations were scheduled so that the irrigation period was fixed to provide 9 cm of water and the frequency of application varied in order to match increases in water demand by the crop, one 9 cm application in early spring would produce a relatively large amount of deep percolating water because crop water use and evaporation would have been insufficient to deplete the root zone of 9 cm of water. If a pesticide application were to occur prior to this event, then residues could move with the deep percolating water below the active root zone. Another example of the effect of timing would be the use of irrigation water for frost protection. Since these irrigations are scheduled in relation to the need for frost protection and not crop water needs, deep percolation can occur. Again, if pesticides are applied prior to these irrigations, residues present in soil during frost protection irrigations would be available for movement with deep percolating water.

In summary, management of irrigation water should be viewed as an integral part of pesticide applications because it is a critical aspect: 1) in the proper placement of pesticide residues into the soil; and 2) in the maintenance of pesticide residues in the biologically active root zone of crops. The CDFA is only in the initial phases of identifying features of agricultural water management that are important in pesticide residue management. More research and interest in this area will be needed to develop use recommendations that are both practical and effective in preventing further movement of residues into ground water.

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Figure 1. Soil distribution of atrazine affected by 3 rates of deep percolation of water applied by sprinkler irrigation.

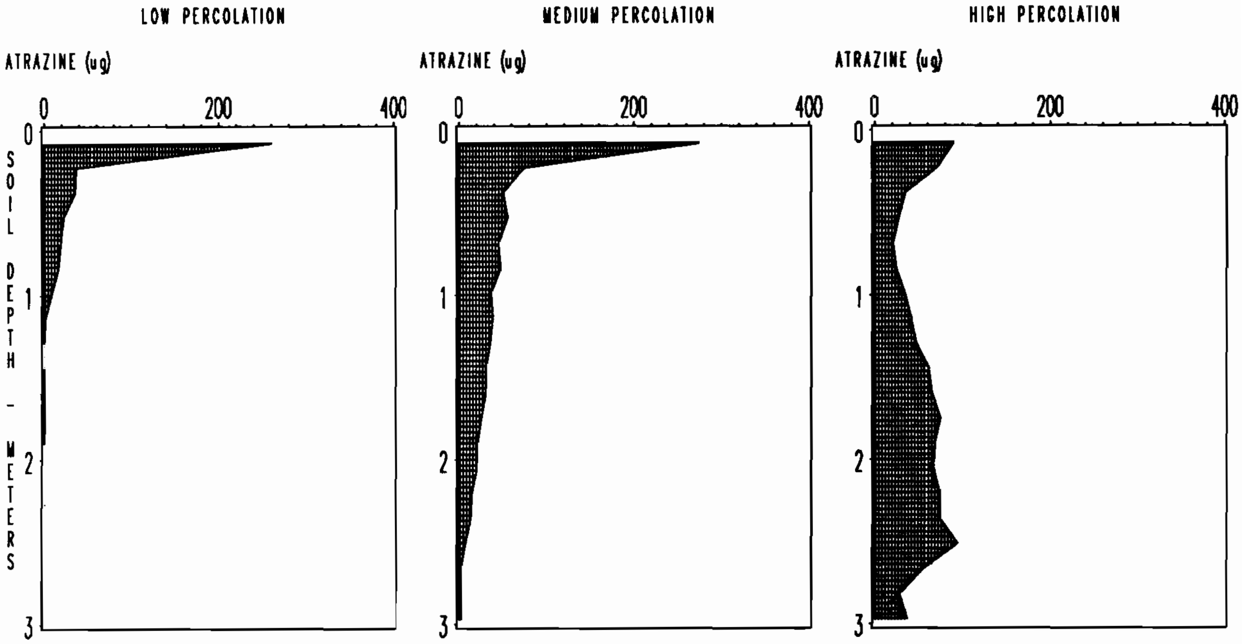


Figure 2. Soil distribution of atrazine affected by 3 methods of water application at the low percolation treatment.

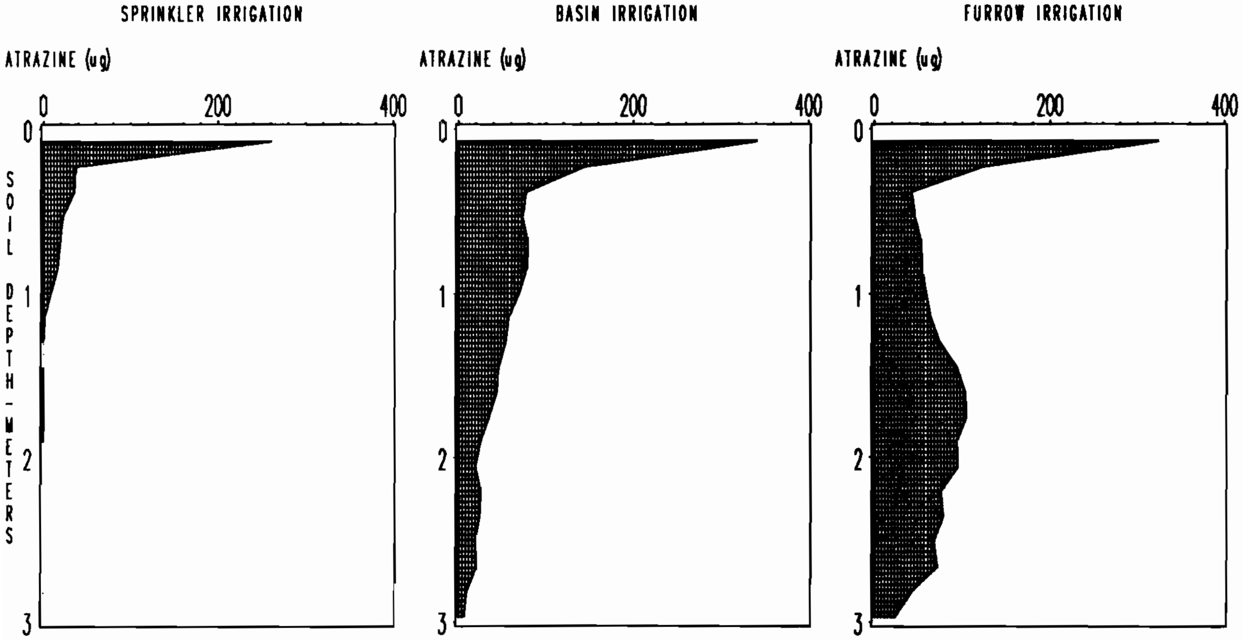


Figure 3. Comparison of organic carbon content of soils sampled in CDFA studies conducted in Ventura, Tulare and Fresno counties.

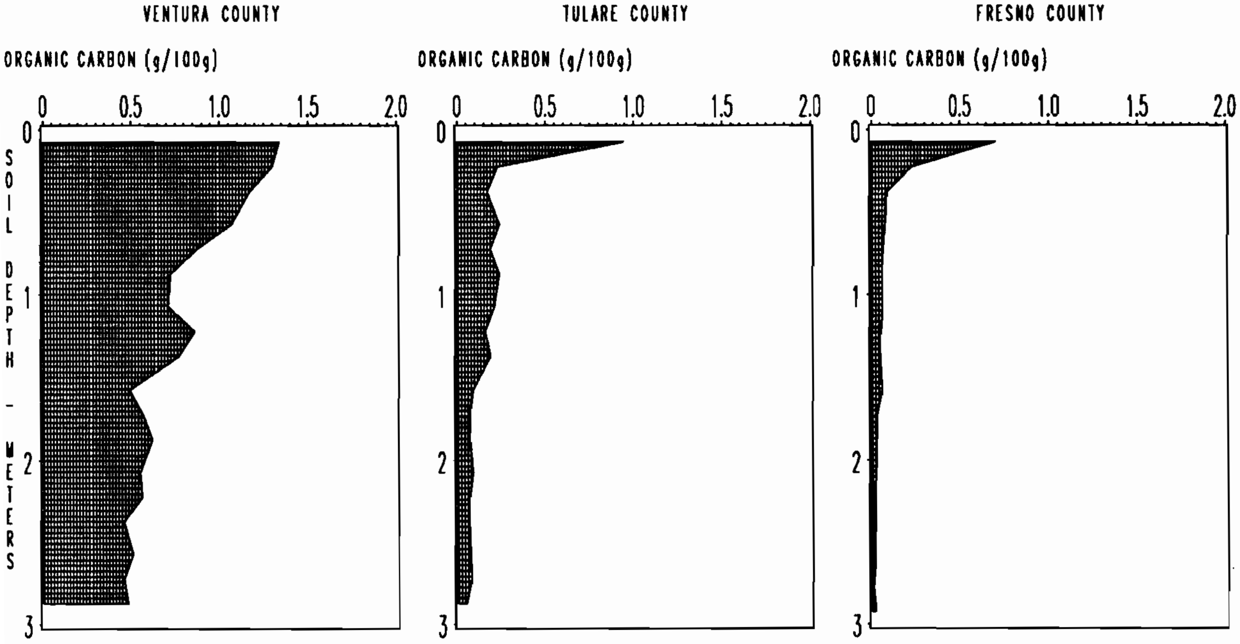
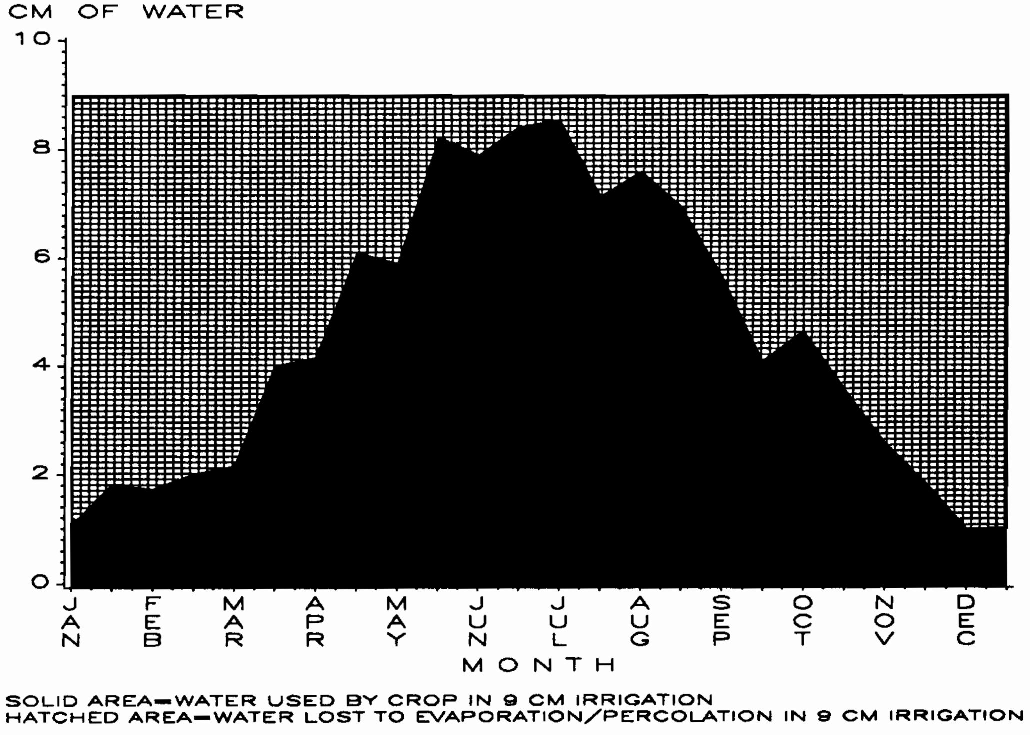


Figure 4. Calculated water use of citrus based on 1986 Fresno CIMIS reference evpotranspiration values and crop coeficients.



A VIEW OF POTENTIAL FOR WATER RESOURCE COMPETITION BETWEEN URBANIZING AREAS AND RURAL AGRICULUTURE

Robert D. Clark, Manager and Secretary
Glenn-Colusa Irrigation District

The Glenn-Colusa Irrigation District serves a gross area of about 175,000 acres on the west side of the Sacramento Valley. A little over 140,000 acres are irrigable with about 110 - 120,000 acres planted annually. The district has a wide variety of crops -from vegetables to orchards and pasture, however, the dominant crop is rice, with two-thirds to three-quarters of the acreage annually flooded. In addition, over 20,000 acres served by the district is in federal wildlife refuge which is flooded for wetland habitat. About 5,000 acres are also annually flooded for private wetlands.

The district enjoys the oldest appropriative water rights on the Sacramento River and on Stony Creek which is a tributary to the river as well as is a purchaser of supplemental summer supplies from the U. S. Bureau of Reclamation's Central Valley Project. Less than one-eighth of the supply is Central Valley Project water. Approximately 900,000 acre feet are diverted annually under these combinations of sources.

The district's main pump station has a 3,000 cubic foot per second capacity. The district has an extensive drain water recovery system through which 20 - 25% of the amount diverted is recovered from the drains for reuse within the system. A more recent investigation of the potential for groundwater development is underway and some exploratory drilling has been done.

The district has weathered the recent four year drought in California reasonably well. Nineteen ninety was the first year the district has faced a reduction in its planted acreage since 1977. Rice being one of the higher water use crops was reduced more significantly than other crops as might be anticipated.

WATER QUALITY - Agriculture within the Sacramento Valley has increasingly seen its return flow water scrutinized by downstream urban users, principally the city of Sacramento. The widespread use of rice herbicides in the spring and summer period cause small concentrations of these materials to appear at domestic river diversion points of the city of Sacramento. While no connection has been made to any health hazard as a result, the fact that man-made elements are appearing in drinking water supplies has created additional management challenges primarily for rice growers. Since this problem surfaced some years ago, significant improvement has been made in reducing the amounts of materials returning to the river.

There is no doubt that this will be an ongoing and expanding conflict as the Sacramento Valley is increasingly looked to as the major source of water supply for the growing urban areas of the state. Water quality could become as serious a restraint on upstream water use and development as water rights. This issue is included in the current State Water Resources Control Board Bay-Delta hearings which are examining the "global" impacts of water quality on the Bay and Delta areas.

WATER SUPPLY - Virtually all significant users of water in the Sacramento Valley watershed that are located downstream of the major state and federal water projects have water rights settlement agreements with either the state project or the federal project. Those agreements cover the quantities of water that each contractor has available for their use and provide for deficiencies under specific drought criteria. Virtually none of that water can be used outside the place of use designated in the contract without the consent of the state or federal project.

Environmentally oriented activists have for some time promoted the concept of a water marketing and transfer system. The legislature has passed laws that have been promoted to encourage a water transfer system to develop. Under present contractual restrictions these laws have obviously been ineffective. Sacramento River Contractors of the Central Valley Project have an exchange agreement among themselves which is blessed by the Bureau and has been useful. However, the agreement with the Bureau precludes the transfer of any water supplies south of Sacramento or to other users off the river itself.

As expanding urban areas face new demands for water supply to meet their needs, it is apparent that agriculture will be increasingly challenged to justify its water use.

One of the major criticisms leveled at agricultural users is that their efficiency could be increased and thus provide a significant water supply contribution to the state system. Certainly to the casual observer it would appear that the average rice field is very inefficient since water flows through the fields. What isn't taken into account is that the water is reused and recycled many times in the process of going through the valley agricultural system. Any excess water eventually ends up returning to the Sacramento River where it is again available for reuse.

In providing for the future needs of the State of California, additional water resources will need to be developed. If we look back at the history of California and the results of the major 1928 - 1934 dry period, we realize that urban, environmental and agricultural water users can best join in finding and developing new sources of water supply. More efficient conjunctive use and additional reservoir storage will be needed if California is to continue to grow. If we adopt a policy of taking water supply from rural areas that is now used for agricultural purposes and utilizing that supply for a growing coastal urban areas, we will end up with an even more crowded urban coastline and an inland desert.

FISHERY ISSUES - One of the major issues confronting water suppliers today is the ongoing problem of maintaining an adequate and abundant fishery while meeting California's water needs. It is appropriate to define this as another urban/rural conflict which has come about due to increasing urbanization of California, corresponding to rural areas where water development is at the forefront of changing water management. While California has a significant commercial fishing industry, the primary thrust of concern for the future of our fisheries comes from the increasing number of urbanites who see a conflict with their desired recreational pursuits.

CONCLUSION - The three issues that I have discussed here of water quality, water supply and the fishery issue will continue for a long time to raise conflicts between urban and agricultural interests. It is apparent that these issues are being used at times to accomplish goals of reducing agricultural water use. It will be a long term challenge for agricultural water suppliers to maintain the viability of their projects as California becomes increasingly urbanized.

Until such time as more serious shortages occur which disrupt portions of our economy or create significant hardship for influential sectors and the point of crisis is reached will our political leadership seriously address the issue of adequate water supply again.

Solving Nitrate Contamination Problems Through a Consensus Building Approach at the Local Level Salinas Valley, California

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Monterey County Water Resource Agency

INTRODUCTION

The purpose of this paper is to present the method employed by the Monterey County Water Resource Agency for coordinating a local effort designed to achieve consensus within the community on a course of action to solve documented problems of nitrate contamination in the Salinas Valley. Multiple interest groups from various economic and social sectors of the community were involved in a planning process that was designed to manage potential conflicts related to developing findings, objectives, and recommendations on programs and activities to reduce nitrate loading from all potential sources.

BACKGROUND

The primary purpose of the Monterey County Water Resources Agency, previously the Monterey County Flood Control and Water Conservation District, is the management and planning of the water resources of the County to derive the greatest economic return from the use of water, and to assure that long term supplies of adequate quality are available to meet the demands of all user communities. This includes developing both structural and nonstructural mechanisms for addressing the full spectrum of water resource problems. The Agency is legislatively defined and governed by the Monterey County Board of Supervisors. The specific powers and authorities are defined in the California Water Code.

In June of 1988, The Monterey County Flood Control and Water Conservation District released a technical report on nitrate contamination in the groundwater of the Salinas Valley (MCFC&WCD, 1988). The report was a summary of the data resulting from the District's ambient groundwater quality monitoring program. It demonstrated that nitrate concentrations are rising significantly basin wide. Prior to publication and wide circulation of the report, the Agency presented the results of the report to various agricultural and urban interests groups. This was done to avoid open confrontation at the decision- making level and to begin seeking consensus on a course of action prior to making recommendations to the Board of Supervisors. This also served to involve the agricultural community early in the decision process and reduced the level of conflict and alienation within this community. It further increased the credibility of the Agency and demonstrated a level of sensitivity to community interest.

In October of 1988, with the support of various community groups, the Monterey County Board of Supervisors passed a resolution forming the Ad Hoc Salinas Valley Nitrate Advisory Committee and assigned specific charges and purposes to the group. The Committee consisted of nine members and two alternatives, appointed by the Board of Supervisors. Representatives were appointed from the Fertilizer Industry, Flower Grower Association, Livestock Industry, Water Purveyor/Drinking Water, Central Coast Agricultural Task Force, Salinas Valley Water Advisory Commission, Agricultural Advisory Commission, and two representatives from cities in the Valley.

The Monterey County Flood Control and Water Conservation District served as lead agency to coordinate the activities of the group. Representatives from The Health Department, Division of Environmental Health; the Agricultural Commissioner; Agricultural Extension Service; and the Planning and Building Inspection Department also participated and provided staff input and assistance.

In 1987 the Budget Act directed the State Water Resources Control Board to prepare a report on nitrate contamination in drinking water supplies in the State(SWRCB, 1989). The California Department of Food and Agriculture also released a report titled "Nitrates and Agriculture in California" (DFA, 1989). These reports were heavily used in development of the final report of the local Committee.

CHARGES TO THE COMMITTEE

The charges and purpose of the committee were to;

1. Detail issues associated with nitrate contamination and define and prioritize problems to be addressed.

2. Identify practices that may contribute to nitrate contamination and that could have an impact on beneficial uses.

3. Serve as a forum to resolve conflict and seek concurrence within the community on issues regarding nitrate contamination of groundwater.

4. Detail current programs and agencies involved with mitigation of nitrate contamination.

5. Identify needed technical and scientific studies.

6. Identify alternative institutional or administrative programs available from both the public and private sector that will prevent nitrate contamination of groundwater supplies.

7. Monitor State task force activities.

8. Identify potential sources of funding for projects and programs related to solving nitrate contamination.

9. Report findings and make policy recommendations to the Board of Supervisors.

10. Advise County staff, the Board of Supervisors, and the mayors, council, members, and staff of the cities within the County on issues related to the development, approval, and administration of a course of action to prevent nitrate contamination of groundwater in the Salinas Valley.

11. Hold informal public meetings and workshops to provide the public information, and receive comment during preparation of a course of action and associated programs to prevent nitrate contamination.

The Nitrate Committee provided the means for public involvement in the decision making process and was designed to manage the potential conflicts that could arise in the course of identifying issues and generating recommendations.

PLANNING PROCESS

The early meetings of the Committee were held to provide background information to the members of the Nitrate Committee. A planning process was created to fulfill the charges assigned by the Board. Water resource planning is both a technical and political endeavor. The best scientific and engineering solutions will still be selected in context of a political process occurring at the state and local level and involving non technical decision makers. This is true of water quality issues in general, and nitrate contamination issues in specific. There are potential conflicts involving the social values and economic well-being of the numerous community interests.

Planning, in its broader sense, means to develop a course of action for deciding what to do and how to initiate or deal with change. Planning must be aimed at the optional use of available resources. Water quality planning involves examination of short-term and long-term needs, and the ways for meeting these needs. It involves the comparative evaluation of alternative solutions with respect to their technical, economic and social merits. It is an attempt to look into the future from a broad perspective, and to overcome inherent constraints imposed by different interests.

Planning is oriented toward the use of scientific methods while seeking solutions to problems of public importance. It is an approach to helping decision makers choose a course of action and carry out that course. This is done by comparing objectives and alternatives in light of their consequences, using a constructed framework to bring the decision makers judgment and intuition to bear on the problems.

The Agency goal was to develop a process to involve public sector and private sector interests in a cooperative effort. Action is needed to solve nitrate contamination and protect water supplies. The course of action tries to minimize adverse economic harm to individuals or any singular sector in the community.

The Committee decided that the nitrate problem should be broken down into specific issues. These issues could then be the basis of setting and prioritizing objectives and strategies for addressing the identified issues. The goal was to generate recommendations and create a work plan. Two separate subcommittees were formed to generate issues statements. These were the Urban and Drinking Water Subcommittee and the Agricultural Subcommittee. The Monterey County General Plan, the Greater Salinas Area Plan, and the Central Salinas Valley Area Plan contain the general goals that related to nitrate problems and served to shape the objectives and alternatives.

Alternatives for corrective action are constrained by:

1) Uncertainty about the effectiveness of various techniques to improve groundwater quality,
2) Financial feasibility and availability,
3) Time

The major problem faced by decision makers are often not technical. They are problems of reaching agreement on issues, findings, and objectives. Seeking on concurrence issues, findings, and objectives is necessary prior to analyzing alternatives and making recommendations. A planned process with public involvement is the basis for conflict management and the key to success in defining and meeting community needs. Public involvement and conflict management seek to lend legitimacy and acceptability to decisions. The Nitrate Committee attempted to operate in a way that would create incentive for reaching a middle ground and avoid polarization of competing interests. This will help to increase the probability of implementing successful programs. This process was designed to be "evolutionary" rather then "revolutionary".

CONCLUSIONS

Those members of the community that represent nitrate sources, and are potentially contributing to nitrate contamination, are the persons that must participate in developing solutions to the problem. They must sit at the table with those interest groups most impacted by the contamination problem. Technical representation from the public sector should serve as a resource, and not attempt to dictate a course of action. Staff should be a catalyst and not a reagent for change.

The early stages related to problem identification and issues clarification made it easier to establish findings, set objectives, and generate more specific recommendations in later stages of the planning process.

The Ad Hoc Committee provided the vehicle for these key players and interest groups to get together and develop a plan to mitigate additional contamination from reaching the valley water supplies. The Committee gave conflicting groups the chance to hear the "opposition's" issues in a managed environment. The citizens committee was a means of expressing community values. It increased the level of community awareness, created a network of important groups, and served to make conflicting interests more sensitive to the positions of those previously viewed as the opposition. Citizens' participation and coordination allowed potential adversaries to become advocates of a unified solution. Participants received the technical information needed to make reasoned choices. It successfully served as a means of managing the potential conflicts.

It is always more favorable to attempt a voluntary or "managed" solution first, rather than to immediately seek a compulsory or "regulated" solution. This mentality encourages cooperation and participation, rather than confrontation, conflict and animosity. It is believed that the key to success of a voluntary program will be to educate rather than regulate, and to develop incentive for implementing solutions.

Data collection and monitoring will be the basis for annually evaluating the success of this approach and for alteration to the original findings, objectives, and recommendations. Program revisions can occur in a planned fashion with feedback designed into the process. It has been recognized that a time may come for additional regulatory efforts. It is anticipated that the process as designed will make such a regulatory program far easier to implement in the future if it becomes necessary.

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Agricultural Land Preservation in California:
The Central Valley Example

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California cropland shrinks by over 44,000 acres each year due to urbanization. The state's population growth and attendant urbanization affect agricultural land in all areas of the state, but probably no area as critically as the Central Valley, the heart of California'a agricultural industry.

The average rate of urbanization for the ten-county Central Valley area (from Yolo and Sacramento County in the north to Kern County in the south) between 1974 and 1986 was 12,000 acres per year. In the rapidly developing counties, the rate of urban growth ranged from 3,600 acres per year in Sacramento County and 2,200 acres per year in Stanislaus County to 2,000 acres annually in Fresno County.

Rates of urbanization and farmland loss are probably higher today. Since 1986, population growth in the ten counties has averaged nearly 100,000 people per year, compared to the 75,000 annual average of the previous twelve years. Population projections to the year 2000 indicate an average annual increase of 100,000 people per year, a figure that could be revised upward if the current growth trend continues. More people in the Central Valley means more housing, further expansion of urban areas, and increasing conversion of farmland.

Projecting Farmland Loss

The indicators for future growth in the Valley are strong, and farmland will disappear in ever larger amounts as the influx of new residents and subsequent construction of subdivisions, shopping centers, and commercial and industrial complexes continues. In order to gauge the future location of growth and rate of farmland conversion, the American Farmland Trust developed and analyzed data using Local Agency Formation Commission (LAFCo) sphere of influence boundaries, environmental impact reports, and population projections.

LAFCo Spheres of Influence

One way to project the location of future growth is to assess land uses within the sphere of influence boundary established by Local Agency Formation Commissions, or LAFCos, for incorporated cities in California. Sphere of influence boundaries define "...a plan for the probable ultimate physical boundaries and service area of a local agency...," that is, an incorporated city.

AFT surveyed land use within each sphere of influence for incorporated areas in the Central Valley counties to determine the amount and quality of agricultural land within these urbanizing areas. In the ten-county study area, over 325,000 acres of farmland lie within LAFCo sphere of influence boundaries. Though these boundaries can shrink or expand according to decisions made by county LAFCo's, the land within them is planned for urban use.

For over half the cities in the Central Valley there is more farmland than urban land within their sphere of influence boundaries. In other cities, the amount of farmland within sphere of influence boundaries is significant though less than the amount of urban land. In the cities of Fresno and Visalia, for instance, there is over 56,000 acres of farmland in their combined spheres of influence. More importantly, several cities with very large amounts of farmland in their spheres also have recently experienced large increases in population. The City of Fresno, with over 33,000 acres of farmland in its sphere, grew by nearly 14,000 people between 1988 and 1989. Modesto, which grew by over 8,000 people during that same time period, has over 11,000 acres of farmland within its sphere of influence boundary.

Equally important to the amount of cropland in LAFCo spheres is the quality of that land. A significant amount of the agricultural land within LAFCo boundaries is classified prime. In Fresno, Kern and Yolo counties, between 58 and 60 percent of the farmland within the spheres of influence is prime agricultural land. In Stanislaus

County 85 percent is prime farmland.

Environmental Impact Review of Proposed Developments

To better understand what has been happening to farmland in the Central Valley since 1986, the American Farmland Trust reviewed information derived from recent Environmental Impact Reports. Through this review, it was possible to gauge the level of development being considered for the near future.

Between July 1987 and April 1989, projects in the ten-county study area would convert 87,000 acres of farmland. At that rate, 500,000 acres of farmland in the Central Valley could be subject to development in the next ten years.

In Fresno County, 7,000 acres has been proposed for development; in Yolo, Stanislaus, Merced, and Madera counties, between 3,000 and 4,000 acres of farmland in each county is being considered for development. Kings and Tulare counties have the least amount of proposed development activity, from 500 to 1,000 acres of farmland proposed for conversion.

SOURCE: Risks, Challenges, and Opportunities: Agriculture, Resources and Growth in a Changing Central Valley, American Farmland Trust (415-543-2098)

WEED CONTROL USING NOVEL APPROACHES

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Herbicides are an effective tool in controlling weeds in most agricultural situations. However, increased pressure is being placed on growers to reduce all pesticide use, due to food safety and groundwater concerns. Growers are reluctant to change their weed control practices away from herbicides due to a perception that costs would increase and effectiveness decrease. The non-chemical weed control methods available to growers include cultivation, biological control, crop competition, fire (flamers), irrigation management, crop rotation, mulches, and mycoherbicides. Biological control and mycoherbicides do not currently fit into most agricultural cropping systems in California. Improvements in cultivation equipment and methods make this a viable option that growers all use to some extent. Fire (flamers) is not used widely because of the greater selectivity of herbicides, but more recently, due to fuel costs. Crop rotation is used in almost all field or row crop farms to some extent, but is guided by economics as much as by pest management. The other three methods, crop competition, irrigation management, and mulches, have been used, but only to a limited extent. This paper reports on specific studies in which crop competition, irrigation management, or mulches have been manipulated for weed control purposes.

Research

<u>Crop competition</u> was evaluated as a mechanism by which

alfalfa could maintain its competitiveness against weeds. Generally, maintaining a solid canopy prevents weed germination, weed growth, or both. Alfalfa stands naturally thin with age or other stresses, preventing rapid canopy closure; they are more sensitive to weed invasion at this time. The objective of this study was to evaluate the interseeding of oats into established alfalfa, as a means of improving the crops competitive ability against weeds and its effect on hay yield.

Studies on oat interseeding in established alfalfa were conducted at a number of locations between 1987 and 1990. In 1990, what had been learned in previous years was evaluated at a trial in Santa Ynez, California. Previous studies evaluated oat variety, oat seeding rates, and nitrogen application rates (Lanini et al. 1990). In 1990, oat interseeding trials evaluated seeding method, broadcast followed by harrowing to incorporate the seed versus seed that was drilled. Nitrogen rate and application timing, 0 lb/a, 30 lbs/a, 60 lbs/a (each at planting) or 30 lbs/a at planting and 30 lbs/a in early March, were also compared with 'Montezuma' oats at 50 lbs/acre. The 1990 trial was planted on December 11, 1989. The form of nitrogen used was ammonium nitrate (34-0-0). Oat treatments were compared to paraquat treatments, cultivation (each applied the same day as oat interseeding), or an untreated check.

Weed cover in each plot, was visually assessed in randomly placed quadrats (0.5 m^2) prior to each harvest. Yield determinations were made at each harvest, using a flail type forage harvester, cutting a 6 foot by 20 foot section from the center of each plot and weighing. Subsamples were taken for moisture determination and conversion of harvest weight to dry weight.

In 1990, weed cover was reduced in almost all instances by interseeding oats into alfalfa compared to untreated in April and compared to paraquat treated in July and August (table 1). Paraquat was also effective at controlling weed growth through the first cutting, but summer weeds were more prolific in these plots compared to untreated plots. Cultivation did not change weed cover relative to untreated (table 1). Cultivation removes existing weeds but also brings new weed seeds to the surface where they can germinate in openings in the alfalfa stand. In oat plots, weed cover did not increase during the summer months. By interseeding oats, less openings occur for weeds to germinate and competition is greater for those weeds which do survive (Lanini et al. 1991). The added competition provided by oat interplanting prevented or reduced germination of summer weeds (summer weeds normally germinate in early spring before the first cutting), whereas paraquat reduced both the alfalfa and winter weed cover, allowing more summer weeds to germinate.

First cutting yields were increased by the addition of oats relative to all non-oat treatments (table 2). Broadcast planting appeared visually to be superior to drilling oat seed, but yield data indicated no differences (table 2). Rate and timing of nitrogen application to oats also failed to have a significant effect on yields. Paraquat treatments reduced yields relative to untreated or cultivated plots (table 2). Paraquat treatments initially controlled weeds but also burned back the alfalfa. Alfalfa, as it emerged from new buds, was attacked by weevils, which reduced first cutting yields. Cultivated and untreated plots were also attacked by weevils, but the damage was less severe.

Irrigation management by the use of sub-surface drip irrigation (buried drip) has been shown to increase yields in many cases and has been observed to aid in weed control. In studies conducted at UC Davis in 1987 and 1988, weed control was evaluated when using sub-surface drip irrigation (buried 10 inches below bed top) compared to furrow or sprinkler irrigated treatments.

Trials conducted in 1987 were first sprinkler irrigated to germinate the processing tomato crop and allow roots to extend down to the depth of the buried drip line. Tomatoes were then cultivated and thinned to remove existing weeds, and the three irrigation treatments initiated. Weed cover and biomass were evaluated during the growing season, and tomato yield was evaluated by hand harvesting 15 feet out of the center two beds in each plot.

The cultivation prior to the initiation of the irrigation treatments eliminated most established weeds and crop competition from the tomatoes prevented further growth on the bed tops (table 3). The lack of water near the surface in the sub-surface drip plots prevented annual weeds from germinating; weeds observed in these plots were those missed by the cultivation. Sprinkler and furrow irrigated plots, without herbicides, had a tremendous amount of weed pressure, primarily in the furrows; addition of the herbicide reduced weed biomass by approximately 90 percent. The addition of the herbicide on the sub-surface drip treatments, had no effect on tomato yields (table 4). Tomato yields on sub-surface drip plots was significantly higher than on sprinkler or furrow irrigated plots if no herbicides were used. The high weed biomass on the furrow and sprinkler plots (without herbicides) provided a significant amount of shade to tomatoes during the latter stages of crop development, which likely contributed to the yield reductions observed on these plots.

In 1988, the study was continued with the exception that no crop was planted. Instead, weed seeds were planted and the three irrigation systems utilized from planting until harvest. Four weed species were used; barnyardgrass, black nightshade, redroot pigweed, and lambsquarter. In addition to broadcasting seed followed by light disking for incorporation. Seed was also planted at four specific depths; 1/2 inch, 1 inch, 1-1/2 inch, and 2 inches. Again, sub-surface drip plots had less weeds than did furrow or sprinkler irrigated plots (data not shown). Sprinkler irrigated plots consistently had the greatest number of weeds followed by furrow. Barnyardgrass, a large seeded species, did, however, germinate fairly well on the sub-surface drip plots when it was planted two inches deep. Weeds that did germinate on the sub-surface drip plots, did so directly above the drip line where normally the crop would be planted. This potentially could provide more competition to the crop then weeds on the side of the bed. The use of transplants which would not require sprinkler irrigation to germinate and which would compete well against any early germinating weeds would enhance the effectiveness of a sub-surface drip system. Burying the system deeper (we buried our lines 10 inches) might also prevent all but the most vigorous weed seeds from germinating or emerging as moisture would be further from the surface.

<u>Mulches</u> are being used by an increasing number of field and vegetable growers to control weeds and reduce evaporative water loss (Lanini et al. 1989). Mulches, such as black plastics, that completely block light are the most effective for weed control. Drawbacks to plastic mulches is the time needed to install them, difficulty in keeping them in place, and disposal of used plastics. Living mulches, or mulches grown in place, have been suggested as one way of avoiding some of the problems with plastic mulches. Living mulches are grown during a fallow period ahead of the cash crop, and either die naturally prior to or shortly after crop planting, or they are chemically killed at or before crop planting. The living mulches, in addition to suppressing or controlling weeds, may also help improve soil conditions (tilth, drainage, etc.), add nitrogen in the case of legumes, and reduce the potential for pesticide movement off site by binding the pesticide (organic matter) and increasing microbial activity for breakdown. Objectives of our research were to evaluate several living mulch types for weed control, when acting as a dead mulch.

Research on living mulches for weed control was conducted in several crops, including sweet corn, lettuce and broccoli. The species examined as potential living mulches included several varieties of subterranean clovers, ryegrass, oats, barley, and bell beans. These mulches were compared to conventionally cultivated, herbicide treated plots. Mulches were seeded in October 1986 at Riverside, November 1987 and October 1988 at Davis, and December 1985 and 1986 at Salinas. Subterranean clovers were mowed during the winter period to help manage weeds, while other species were grown without other inputs. Oats, barley, and bell beans were killed by mowing in the 1986 Salinas trial and by desiccating with glyphosate at the 1987 Salinas trial. Vegetables were planted into the dead mulch using minimum tillage; a fertilizer shank creating a slot and a double disk opener type planter. Weed cover was monitored during the vegetable growing season.

Weed cover was consistently high on the subterranean clover mulch plots, compared to cultivated or herbicide treated sweet corn plots (table 5). In non-mulch plots, cultivation eliminated weeds prior to planting. At Davis, plots were cultivated twice before planting and fewer weeds germinated after these cultivations, and thus less weeds were found in the untreated plots. This differed from what was observed at other locations (tables 5 and 6). Reducing tillage was found to reduce weed density at Riverside and Salinas in the mulch plots, as soil was not stirred up, bringing viable weed seeds to the surface. It was also found that thicker mulches reduced weeds more than did mulches with less biomass (table 7). However, thick mulches were also observed to be more difficult to plant through, especially for small seeded crops where seed placement is more critical. Yield varied considerably between sites and years (data not shown). In some instances, yields on mulch plots equaled or exceeded cultivated plots (lettuce and broccoli, Salinas 1987). With other trials, sweet corn or lettuce yields were equal to or less than cultivated plots (Salinas 1988 or Riverside 1987). In those years, weeds and/or a cover crop that failed to die, provided stiff competition to the crop. When the mulch was sufficient to suppress weeds, the crop stand was poor due to planting problems. Work is still continuing in this area, examining mulch types, management methods (ie. mowing, herbicide treating, etc.), and planting techniques. Possibly no-till planters or mini-rototillers in front of the planter may make this practice more feasible.

Conclusions

Most summer weeds germinate during the spring growth period, prior to the first cutting. Competition provided by oats reduces germination of most of these weeds and thus less weeds were observed in all cuttings. Although paraquat controlled winter weeds, summer weed invasion was not influenced by the winter paraquat application. 'Montezuma' oats has been identified by most growers as the preferred variety due to availability of seed and favorable forage characteristics (fine stemmed and leafy).

Sub-surface drip irrigation can effectively control weeds in the absence of summer rainfall. The increase in yields, reduction in herbicide cost, and reduction in water use (this is a very efficient system) may offset the initial cost (estimated at $1000/acre) for some growers.

Mulches have demonstrated potential for suppressing weed growth in vegetable crops. The additional benefits of mulches, increased numbers of beneficial insects, cleaner fruit, easier access after irrigation or rainfall, increased organic matter, and less erosion, make this practice something worth striving for. Resolving the difficulties of planting through the mulch and managing weeds that are not controlled by the mulch will further increase the use of this practice.

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Table 1. Weed Cover in 1990 relative to treatment at Santa Ynez.

	Treatment[1]	Weed Cover (%)			
		Mar 8	Apr 16	Jul 7	Aug 21
1	Oat - Broadcast + 30 lb/a N	3.75	12.50	11.25	4.00
2	Oat - Drilled + 30 lb/a N	2.75	17.50	2.50	4.25
3	Oat - Drilled + 0 lb/a N	1.00	18.75	2.50	3.25
4	Oat - Drilled + 60 lb/a N	1.75	16.25	7.50	4.00
5	Oat - Drilled + 30+30 lb/a N	1.50	21.25	15.00	4.50
6	Paraquat 0.5 lb/a	1.25	18.75	32.50	12.25
7	Cultivated Check	1.25	28.75	8.75	5.75
8	Untreated Control	3.00	33.75	10.00	5.75
	LSD .05	ns	14.00	16.20	6.20

[1] Montezuma oat seeded at 50 lbs/a in all oat plots.

Table 2. Yields in 1990 at each cutting relative to treatment at Santa Ynez.

Treatment[1]	Forage Yields (Tons/acre)					
	Apr 25	Jun 4	Jul 7	Aug 21	Oct 10	Total
Oat - Broadcast + 30 lb/a N	1.64	1.74	1.67	1.79	1.58	8.42
Oat - Drilled + 30 lb/a N	1.45	1.64	1.81	1.96	1.34	8.20
Oat - Drilled + 0 lb/a N	1.49	1.82	1.84	1.87	1.46	8.48
Oat - Drilled + 60 lb/a N	1.47	1.85	1.84	1.86	1.54	8.56
Oat - Drilled + 30+30 lb/a N	1.50	1.70	1.75	1.78	1.44	8.17
Paraquat 0.5 lb ai/a	0.53	1.50	1.68	1.60	1.50	6.82
Cultivated Check	0.92	1.80	1.82	1.84	1.40	7.77
Untreated Control	0.86	1.76	1.83	1.70	1.54	7.70
LSD .05	0.27	0.22	ns	0.20	ns	0.66

[1] Montezuma oat seeded at 50 lbs/a in all oat plots.

Table 3. Weed cover or biomass relative to irrigation type, 1987.

Irrigation Type	Weed Cover (%)		Weed Biomass (kg/ha)[1]	
	Jul 17	Aug 13	Beds	Furrows
Furrow	9	20	337	3948
Furrow + Herbicide	12	8	16	368
Sprinkler	12	31	394	4462
Sprinkler + Herbicide	16	12	410	348
Sub-surface Drip	2	5	87	2
Sub-surface Drip + Herbicide	4	3	141	8
LSD .05	ns	9	370	2166

[1] Biomass measured at harvest on Sept. 23, 1987.

Table 4. Tomato yield relative to irrigation type, Sept. 1987.

		Fruit Yield (tons/acre)		
	Irrigation Type	Reds	Greens	Rots
1	Furrow	35	3	2
2	Furrow + Herbicide	45	7	3
3	Sprinkler	35	4	4
4	Sprinkler + Herbicide	47	7	3
5	Sub-surface Drip	53	2	4
6	Sub-surface Drip + Herbicide	52	2	4
	LSD .05	9	2	1

Table 5. Weed cover in June relative to treatment; sweet corn.

		Weed Cover (%)	
	Treatment	Davis 1988	Riverside 1987
1	Subterranean clover Dalkieth & Geralton	77.9	51.7
2	Subterranean clover Enfield	95.8	34.1
3	Cultivation	45.4	1.6
4	Herbicide	34.4	14.5
5	Untreated	60.4	90.0
	LSD .05	39.0	35.0

Table 6. Weed density in broccoli relative to treatment, 1987.

		Weed Density (No./8 ft^2)	
	Treatment	No Herbicide	With Herbicide
1	Barley mulch	46	14
2	Oat mulch	49	18
3	Cultivation	73	28
	LSD .05	25.0	

Table 7. Weed density in lettuce relative to treatment, 1987.

		Weed Density (No./10 ft^2)	
	Treatment	No Herbicide	With Herbicide
1	Mulch desiccated March 16	36.1	16.6
2	Mulch desiccated April 20	22.9	17.5
	LSD .05	8.3	

COVER CROPS AS AN ELEMENT IN THE DEVELOPMENT OF EFFECTIVE PEST MANAGEMENT PROGRAMS FOR GRAPES

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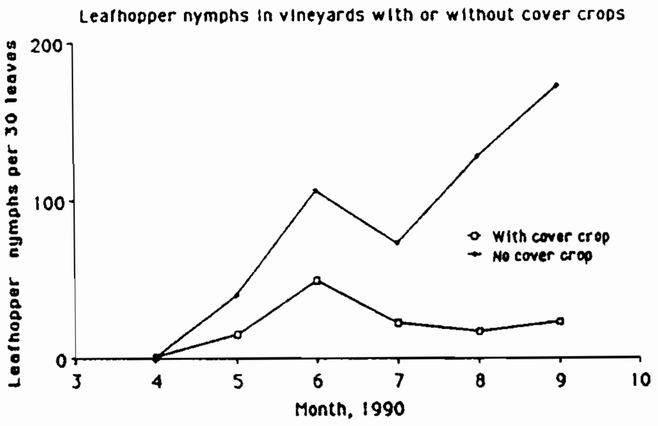
It is likely that traditional pesticide chemicals will continue to decrease in use in American agriculture, including in pest management programs in grapes. There are many alternative strategies that may prove to be excellent substitutes for these traditional chemicals. As an example, in the management of grape and variegated leafhoppers, effective strategies may include the following:

(1) Use of cover crops to build-up beneficial predator arthropods;
(2) Selective leaf pulling to remove first brood leafhopper eggs and nymphs; and,
(3) Preservation or planting of *Anagrus* parasite habitat.

Until recently, these strategies have not had great appeal to many growers, because the individual strategies may not provide the very high (greater than 90%) reduction in pest populations that is usually considered necessary in a traditional pesticide-based program. However, when effective cultural management techniques are used in combination with each other as parts of an integrated pest management program, a consistently high level of pest control may result. For example, if the three strategies listed above each provided 60% control of leafhoppers, in combination they would provide 94% leafhopper control.

There is no doubt that these strategies do work when effectively designed. This is attested to by the great movement during the last several years toward the use of cover crops as a major component in the management of many vineyards. These cover crops are intended by the growers not only to provide the usual agronomic functions of improvement of soil fertility and tilth, but also to provide a pest management function of reducing pest densities in the vines, presumably through the attraction or harboring of beneficial predator arthropods. However, we have observed great variability in the pest management advantage from cover cropping in various vineyards, and very little information is available to allow recommendation of the most effective way to manage cover crops or other cultural manipulations in vineyards so as to achieve the most effective pest management.

During the period from March through October, 1990 we surveyed plant-feeding and beneficial arthropods in 40 different blocks of grapes within 14 different vineyards. About half of the blocks had cover crops on the vineyard floor, and the other half were kept clean by cultivation. Each field was visited at 2- to 4-week intervals, and insects and other arthropods in both the cover crops and the vines in each block were sampled by the use of D-vac suction sampling machine. Berlese funnel separation of living organisms from the plant debris resulted in samples of collected insects and arthropods in ethanol. In addition, counts of numbers of insects and spiders were made on 30 grape leaves per block, and many of the leaves were brought back to Kearney Agricultural Center for microscopic identification of parasitized leafhopper eggs and for determination of the emergence of *Anagrus* egg parasites. Also, yellow sticky cards were placed in two locations per block as an additional means for sampling small flying insects. Much of the collected material is still waiting our identification and counting. However, clear trends have emerged, showing that vineyards having cover crops developed only about half as high a leafhopper population as did vineyards without cover crops. An example from one ranch is shown in the following figure, based on four blocks without cover crops and five blocks having cover crops.



We observed a great diversity of management techniques for the cover crops. These techniques included: (a) the use of many different individual or blended plant species or the use of resident grasses and "weeds" as cover crops; (b) different irrigation approaches, with the cover crops in some cases being maintained in a lush state and in others in a state of moisture stress during much of the time; and, (c) different periods during which the cover was very low or absent as caused by mowing or tillage operations. More research is needed to assess what impact these and other variables have on the number and diversity of beneficial arthropods that build-up in the cover crops and the degree of success of pest management in the associated vines.

ISSUES IN THE BENEFICIAL INSECT INDUSTRY

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Biological control is an important component of Integrated Pest Management. The proper release of mass produced predators and parasites (insects and mites) can provide adequate control of target pests. Current problems associated with chemical pesticides (resistance, secondary pests, safety concerns) have increased the demand for alternatives such as predators and parasites commercially produced and distributed.

Several issues are now being addressed by the industry. The need to organize became apparent to enough industry members that The Association of Natural Bio-Control Producers was formed. The Association is a non profit corporation created to provide a unified approach for the protection and improvement of the natural enemy production industry on a regional, national and international basis. The Association's objectives address current issues.

1 - Work at the federal and state levels to develop regulatory legislation appropriate to the safety and ecological soundness of our products. (Current legislation, especially in California, requires our industry to comply with standards and safety requirements expected of chemical pesticides such as liability insurance for chemical spills and drift).

2 - Develop a quality monitoring and certification program for producers and distributors. (A quality control committee has been established and guidelines are being submitted from

producer members, distributors, end-users, and University researchers. Our highest priority is proper identification. Due to varying degrees of difficulty, some species in culture can be routinely monitored at very low cost while others will be very costly to properly monitor. While "in-house" techniques may be appropriate and accurate, outside confirmation can lead to excessive costs in a certification program. Individual issues within the quality control program include, but are not limited to, emergence rates, sex-ratios, lab performance, field performance, beneficial/pest ratio).

3 - Provide a clearinghouse of information on natural enemies, their use and availability. (Much research is yet required in this area. However, "Fact Sheets" will be made available on known results and continuously up-dated as new information is provided through government and University research as well as practical application results).

4 - Hold annual meetings to exchange information and develop our professional contacts. ("Educating" the producer, distributor, the end-user and the researcher can better take place when information is exchanged in a mutually beneficial manner). Bridging the "gap" between profit motivated business and research is especially important for this industry. Much funding will be needed for proper research. Yet, the industry must be allowed to function while the answers are being sought. This industry has provided alternative approaches to pest control at the practical application level. We are eager to continue to improve and to provide quality products and service.

The commercial insectary industry faces a tremendous challenge. The industry is not new, only the interest in the industry is new. This is a relatively small industry which is now rapidly expanding. We look to all of you for input and patience in helping us meet the challenge.

WATER USE OF TREES IN THE LANDSCAPE

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Most landscape tree species in California require irrigation, especially throughout the establishment period. In the past, various estimates of water requirements have been made using parameters such as tree geometry, size, and leaf area. While these methods are useful, the California Irrigation Management Information System (CIMIS) offers additional information helpful for scheduling irrigations.

CIMIS is a state-wide weather station network of over 70 stations throughout California. Solar radiation, wind speed, temperature, and relative humidity measurements are collected and used in an empirical formula to estimate water requirements of 4-6" tall fescue. The following equation can then be used to estimate water requirements of crops or turfgrass species planted in large areas:

$$ET\ (Crop) = ETo \times Kc$$

ETo denotes reference ET, a measurement of maximum water use of tall fescue; Kc stands for crop coefficient, a decimal below 1.0 representing the relative water use of the crop or species in question as compared to ETo.

In the last decade, the late Dr. Victor Youngner, Dr. Victor Gibeault, J.L. Meyer and other researchers from University of California at Riverside, determined Kc's for warm and cool season turfgrass species through a number of experiments using both historical and CIMIS Eto measurements. Warm-season turfgrasses were found to be more water-efficient than cool-season varieties, with crop coefficients of 0.6 and 0.8, respectively.

While Kc's cannot be determined for singularly-planted landscape trees, relative differences among tree species can be investigated using the CIMIS network, based on the irrigated surface area around the trees.

In Spring 1988 the author, with assistance from UCCE Specialists J.L. Meyer and Dennis Pittenger, began a research project to determine minimum irrigation requirements of four species of commonly-planted landscape trees (_Liquidambar styraciflua, Cupaniopsis anacarioides, Quercus ilex, Ficus microcarpa nitida_ 'Green Gem').

Fifteen-gallon specimen trees were planted in a completely randomized field plot on 20-foot centers at South Coast Field Station (SCFS) in Irvine, California. No mulch material was applied.

All trees received 100% ETo as measured by real-time CIMIS for three months, at which time they were randomly assigned one of four treatments: 100, 80, 60, or 40% ETo, based on a 63.6 square foot irrigated area. The following formula is used to calculate length of each irrigation:

$$\frac{\text{Eto (in. from prev. wk)} \times 60 \text{ (min/hr)} \times 63.6 \text{ ft}^2. \times 7.48 \text{ (g/ft}^3\text{)}}{12 \text{ (in/ft)} \times 7 \text{ (gal/hr sprinkler output)}}$$

Quarterly, tree circumference at 6 in. above soil level, average breadth at widest point, and height data were recorded. Statistical analyses between summer 1988 - spring 1990 showed no significant differences among any species across any of the four treatments. Therefore, in summer 1990, each treatment was reduced by 20%.

Tensiometer readings at three depths, as well as water meter readings, are recorded weekly.

The following tables show relative comparisons of gallonage and inches at various locations in Southern California based on ETo levels used in the SCFS experiment:

HISTORICAL ANNUAL ET_0 BY LOCATION IN SAN BERNARDINO COUNTY

	100% In.	40% In.	40% Gal.	20% In.	20% Gal.
Crestline	50.8	20.3	805.7	10.2	402.8
Chino	54.6	21.8	866.0	10.9	433.0
San Bernardino	55.6	22.2	881.8	11.1	440.9
29 Palms	82.9	33.2	1314.8	16.6	657.4
Barstow	83.6	33.4	1325.9	16.7	663.0

HISTORICAL ANNUAL ET_0 BY LOCATION IN SOUTHERN CALIFORNIA

	100% In.	40% In.	40% Gal.	20% In.	20% Gal.
San Diego	44.0	17.6	697.8	8.8	348.9
Santa Ana	48.2	19.3	764.5	9.6	382.2
Los Angeles	50.1	22.0	794.6	10.0	397.3
San Bernardino	55.6	22.2	881.8	11.1	440.9
Palm Springs	71.1	28.4	1127.7	14.2	563.8

HISTORICAL ET_0 (INCHES) BY MONTH IN SOUTHERN CALIFORNIA

	L.A. Basin	UCR	San Bernardino	Irvine	San Diego
Jan.	2.2	2.7	2.4	2.3	2.2
Feb.	2.8	3.1	2.8	2.7	2.5
Mar.	4.0	4.4	3.9	4.0	3.3
Apr.	4.8	6.0	5.0	4.6	3.4
May	5.4	5.9	6.0	5.4	4.4
June	5.7	7.0	7.0	5.8	4.0
July	6.5	7.8	8.0	6.8	4.6
Aug.	5.9	6.7	7.0	6.4	4.6
Sep.	5.0	5.2	5.8	5.2	3.9
Oct.	3.8	3.5	4.1	3.8	3.3
Nov.	2.2	2.2	2.2	1.8	1.9
Dec.	2.6	2.7	2.9	2.6	2.2
TOTAL	50.9	57.2	57.1	51.4	40.3

It is important to emphasize that additional experiments at other CIMIS locations are necessary before final recommendations can be made. Also, small landscaped areas are affected by surrounding buildings, concrete and microclimates. Use the above tables only as general guidelines in combination with soil water-holding capacity tables that follow.

Soils differ widely in their ability to hold water and make it available to landscape trees. The water-holding capacity of a soil determines largely when to irrigate, while an estimation of ET indicates how much water to apply.

The following table compares the water-holding capacities of various soil textures:

Soil Texture	In. of available water per foot of soil depth*	Gallons per cubic foot of soil
Sand	0.5 - 1.0"	0.33 - 0.67 g
Sandy loam	1.0 - 1.5"	0.67 - 1.00 g
Clay loam	1.5 - 2.0"	1.00 - 1.33 g
Clay	1.5 - 2.5"	1.00 - 1.67 g

* One inch of water covers the soil surface one inch deep. One gallon of water covers one square foot of soil 1.5" deep.

Most trees can be sustained in a three-foot soil depth in non-layered, homogeneous soil. To determine a water budget, follow these guidelines:

1. Determine the water-holding capacity of the soil per foot.
2. Determine the ultimate rooting-depth of the tree at maturity (at least 3-feet).
3. Multiply (1) x (2) above.

For instance, if the soil is a sandy loam texture, and the tree requires a 3-foot rooting depth, multiply 1 in/foot x 3 feet. Three inches of water can be held in this soil. The soil should be filled to capacity, and refilled at a reasonable soil-moisture depletion level, usually about 50%. Use of methods to estimate soil water content or plant water content are also useful.

PROBLEMS IN AN URBAN WEED MANAGEMENT PROGRAM

By Richard Molinar, Horticultural Advisor
University of California Cooperative Extension in Alameda County

The problems or situations that arise in an urban weed management program are quite different than similar weed programs in a rural agricultural setting. "Different" does not imply worse or better, just unique. Unlike agricultural and farming areas, an urban area involves parks and recreation districts, public works, schools, and other agencies.

The areas of concern in an urban setting fall into at least three distinct categories:

1.DIVERSITY

In an urban area, there will be a wider variety of plants (species and genera) on or near the treated area. This makes the weed management measure utilized a critical choice for the safety of these plants; whether it be chemical control or some other measure.

> In one instance, the soil residual herbicide atrazine was used in a non-crop situation at 8 lbs. A.I. per acre. It was applied in the winter on a slope within 3' of a condominium turfgrass. The sycamore trees growing near the turf edge were overlooked. The following spring, damage on the tree side adjacent to the application was evident, however, not severe enough to cause death.

Eliminating wild blackberry vines in a drainage ditch between two neighborhoods disallows any kind of chemical residual control and even makes systemic foliar applications of glyphosate or trichlopyr questionable. The most practical solution is mechanical removal.

Chemical weed control in landscape areas is also difficult in many situations because there are a half dozen or more ornamentals interspersed, some of which may be on a oryzalin or oxadiazon label and others may not. A planting with birch, Pittosporum, Agapanthas, Liquidamber, Baccharis and pansies may present a problem with registrations.

2. PUBLIC SCRUTINY

"What a person doesn't know won't hurt them" is true 99.9% of the time. Given the suggestion that chemical exposure did occur, some people will develop symtoms whether or not they were in fact exposed. It is simply common sense that you do not generally announce a pesticide application, except to those customers involved, because you will undoubtedly find someone who is against that idea.

Communication is vital and informs customers/clientele what to expect, what will be used, for how long, etc. This should be done on a regular basis. However, involving other people who have nothing to do with the situation and are in no way affected, invites trouble. This is graphically illustrated in the following case history:

> Several years ago a company was contacted to control weeds in vacant lots with the herbicide oxyfluorfen. The company used a non-crop labeled rate with a red dye to help the applicators see where they had sprayed (it also allowed the absentee customers to confirm that the work was being done). On the fourth day, three representatives from the community confronted one of the applicators. They threatened him with pipes, spit on his truck, and informed him that they were tired of their pets and kids being killed. The applicator left to finish another day; and stopped using the red dye.
>
> U.C. Berkeley is well-known for its radical policies and student demonstrations. You would think any kind of herbicide applications would be unthinkable, however, they are in fact used, but as night applications. These types of applications are much less obvious to the masses and helps avoid public confrontations. Night applications are becoming much more popular for obvious reasons.
>
> A 80,000 acre park district in the Bay Area has been using a 600 head goat herd to eliminate weeds in park areas which are overgrown with blackberry, poison oak, fennel and Baccharis. This has been very well received by the public and environmentally conscious organizations. It is very effective, although not always economical.

3. MURPHY'S LAW NUMBER 13

"If Anything Can Go Wrong, It Will" - I believe the exact wording of this law states that "during a methyl bromide-chloropicrin fumigation (properly used), gas will still escape and force the evacuation of 1,400 residents."

Gladiola fields are routinely fumigated for the control of fusarium and verticillium wilts as well as for weed seeds. Put this practice in an urban area such as Fremont, and eventually you have a problem. On this particular day in October of 1987, there happened to be an inversion layer, the wind died down, and temperatures were in the 90's. The fumigant, some of which escapes normally anyway, was trapped under the inversion layer, and as a result the neighborhood adjacent to this 10 acre field had to be evacuated. Similar situations occur in rural-agriculture as well, but go unnoticed since housing tracts are not nearby.

In rural agriculture, the farmer and PCO does not have a great deal of contact with the public, except in situations where watermelons are contaminated with aldicarb or groundwater is found contaminated with simazine. However, in urban weed management, dealing with the public is an ongoing and almost daily occurrence. Communication <u>is</u> critical between applicator and customer, as well as within public agencies such as public works and parks/recration districts where jurisdiction may overlap.

USING A PORTABLE CHLOROPHYLL METER TO DETERMINE LEAF N CONTENT OF GRAIN CROPS

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The Minolta chlorophyll meter (SPAD Model 502) is a handheld, battery-operated device which can be used to determine the amount of chlorophyll present in plant leaves. Chlorophyll and nitrogen content are closely related. Several researchers have shown that the meter can be used to estimate leaf N content in the field with adequate accuracy. Schepers, et al. have shown that on corn leaves, the meter reading is correlated with total N content and can be used to diagnose N status of the crop. They found, however, that the relationship between chlorophyll meter reading and leaf N content differed among hybrid corn varieties enough to require a separate calibration for each variety tested. Turner and Jund (1989) in rice field trials were able to identify a nitrogen topdressing response threshold with the meter. In two rice field experiments and one wheat greenhouse experiment, we have observed a close correlation between leaf N content and chlorophyll meter reading on leaves. In the rice experiments, the relationship was similar at two sites at which different rice cultivars were used. The leaf N - chlorophyll meter reading relationship was affected by stage of growth, but a generalized calibration across growth stages gave nearly the same estimated critical levels as growth-stage specific calibrations.

Measuring Principle

Chlorophyll absorbs light strongly in the blue (450 nm wavelength) and red (650 nm) regions. The chlorophyll meter has a 650-nm light-emitting diode and a second LED that provides a reference beam with a wavelength of 940 nm (infrared region) at which absorption by chlorophyll is extremely low. A leaf blade (excised or still attached to plant) is inserted into the meter. When the measuring head is closed, the two LEDs emit in sequence. The light passing through the leaf strikes a receptor and is converted into an analog electrical signal. The meter reading represents the ratio of the intensities of the red (chlorophyll) and infrared (reference) light transmitted through the leaf.

Rice Field Experiment

We took meter readings in two N fertilizer rate studies conducted in growers' fields in Sutter and Butte Counties during 1990. In both experiments, N fertilizer was applied as subsurface bands of urea about a week before flooding in April or May 1990 at rates ranging from 0 to 180 lb N/acre in 30-lb increments. Normal grower rate of fertilizer N is between 75 and 150 lb N/acre. N rate plots (10 x 30 ft) were arranged as subplots within larger main plots that are part of a multi-year investigation of cover cropping and rice straw management alternatives. Medium grained, early varieties of rice were sown into water: In Butte Co., M-201 was planted May 10, and in Sutter Co., M-202 was planted May 25. Both fields had uniform, nearly weed-free stands.

Both locations were sampled at 50 and 60 days after seeding, approximately at mid-tillering and maximum tillering. A third sampling was conducted at panicle differentiation at 67 days (Butte) and 71 days (Sutter) after seeding. In each of the 10 ft x 30 ft N-rate plots that were sampled, two meter readings were collected on each of fifteen "Y-leaves". The Y-leaf is the most recently unfurled leaf. The two readings on each leaf were made about one-third the distance from the base of the leaf and one-third the distance from the tip of the leaf. In all plots the average value of the 30 readings was recorded and in selected plots, all 30 values were recorded. In selected plots, additional readings were made on each leaf to see if readings would be uniform along the length of leaves. The 15 leaves used for chlorophyll meter measurement were collected for N content determination using the Orange-G dye binding method of Hafez and Mikkelsen.

Wheat Greenhouse Experiment

During April and May, 1990, hard red spring wheat, cultivar 'Serra', was grown in pots in the greenhouse and fertilized at N rates ranging from zero to 300 kg N/ha (268 lb/acre). On three dates, meter readings were made on two most recently matured leaves from each of two pots. On each leaf, five readings were taken along its length. Total Kjeldahl nitrogen was determined on the two leaves from each pot. The sample dates were at four fully mature leaves (Haun Growth Stage 4.2), six fully mature leaves (HGS 6.1), and flag leaf (HGS 9).

Results and Discussion

In Sutter County, on plots that had been fallowed during the winter, maximum rice grain yield was obtained with 90-120 lb N/acre (Figure 1). On plots with purple vetch grown as a green manure and disced under in late April, only 30 lb N/acre was required for maximum growth. Yield declines were observed at higher N rates, although lodging was absent until very close to harvest.

At the Butte County location, maximum yields were obtained with 60 lb N/acre preplant fertilizer (Figure 2). Yields were normal for the area. Above 60-90 lb N/acre, yields declined with increasing nitrogen in part due to lodging. A small, possibly real N contribution was observed on plots that had been planted to purple vetch green manure during the 1988-89 winter.

The chlorophyll meter was easy to use and readings collected on leaves still attached to the plant appeared to fall within a narrow range at a given spot in the field. Chlorophyll readings were not consistently higher or lower at any position along the length of rice leaves. An example of this is shown in Table 1. In low and high fertilizer N plots at both locations, no significant effect of leaf position was found.

At both sites, grain yield was correlated with Y-leaf N content and chlorophyll meter reading. At both locations on each of the sampling dates, it was possible to identify a "critical level" range, i.e., a narrow range of values that was associated with maximum yield (Figures 4 - 6). The mid-point of the critical value range for measured Y-leaf total N was in fairly good agreement with values developed by Mikkelsen and widely used in the Sacramento Valley (Table 2). Uncertainty in the stage of growth of the rice plants in our experiments may have contributed to the small discrepancies observed.

Excellent agreement was obtained between chlorophyll meter reading and total N content (as estimated by the Orange G dye method) across both sites and sampling dates (Figure 7). When critical values extracted from the meter readings graphically from Figures 5 and 6 were converted to percent leaf N by using the equations in Figure 7, good agreement was obtained with the critical values derived from leaf N analysis and with the published critical values (Table 2). The slope of the relationship between meter reading and leaf N content changed with stage of growth. Good agreement was also obtained when a generalized equation across all the data in Figure 7 was used (equation shown in footnote of Table 2).

The critical values for the chlorophyll meter, from which the values in Table 2 were derived, were in the range of 44-45 at mid-tillering, 37-42 at maximum tillering, and 35-38 for panicle differentiation. Turner and Jund, in a rice field study in Texas, found that a meter reading of 39 "during the two weeks prior to and at the panicle differentiation stage" was the threshold separating response and no response to N fertilizer topdressing. This is in good agreement with the critical values identified in our study during the same period, that is, at maximum tillering and panicle differentiation. Further testing over a wider range of varieties and environments would be useful.

In the wheat greenhouse study, the chlorophyll meter readings increased with increasing total N content of leaves, but the correlation was not as good as in the rice study. This probably was due to the small sample size (four leaves) in the wheat study, but could also be due to a less consistent relationship between chlorophyll and nitrogen in the reduced light environment of the greenhouse.

Acknowledgments

We are grateful for financial assistance from the California Rice Research Board. Mssrs. Scott McCarthy, Liu Changshou, and Rick Miller assisted in data collection, and Dr. Marlon Brandon made the chlorophyll meter available for our use. For their assistance we are thankful.

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Turner, F.T. and M.F. Jund. 1989. A chlorophyll meter's potential to predict topdress N requirement of semidwarf rice. Agronomy Abstracts. Amer. Soc. Agron., Madison WI.

Table 1. Chlorophyll meter reading at different positions along length of rice leaves. Samples taken at mid-tillering, 50 days after planting.

Leaf position	Butte	Sutter
<u>High N rate</u>		
Base	47.7 (2.4)	46.4 (1.9)
Middle	48.8 (1.9)	--
Tip	48.0 (1.7)	47.7 (1.9)
<u>Low N rate</u>		
Base	44.0 (2.3)	44.4 (2.2)
Middle	44.4 (2.1)	--
Tip	44.2 (2.0)	44.8 (1.9)

Values are means of readings taken on 15 leaves within a plot. Standard deviations are shown in parentheses.

Table 2. Critical N level of rice leaves estimated by chlorophyll meter and by leaf N analysis.

	Meter			
	Growth stage specific[a]	All data[b]	Direct leaf N	U.C. (Mikkelsen)
	----------- Percent N in leaf -------------			
<u>Butte Co.</u>				
Mid-tillering	4.72	4.56	4.75	4.6
Max. tillering	3.64	3.66	3.50	3.3 - 4.0
Panicle differ.	2.97	2.99	3.22	< 3.3
<u>Sutter Co.</u>				
Mid-tillering	4.63	4.45	4.60	4.6
Max. tillering	3.34	3.31	3.25	3.3 - 4.0
Panicle differ.	3.15	3.19	3.10	< 3.3

[a] Equation from Fig. 7, specific for each sampling date.

[b] One equation from all data in Fig. 7, $Y = 2.33 - 0.117X + 0.0037X^2$, $R^2 = 0.92$.

Figure 1 Rice Grain Yield vs Nitrogen Fertilizer Rate
(Sutter County, 1990)

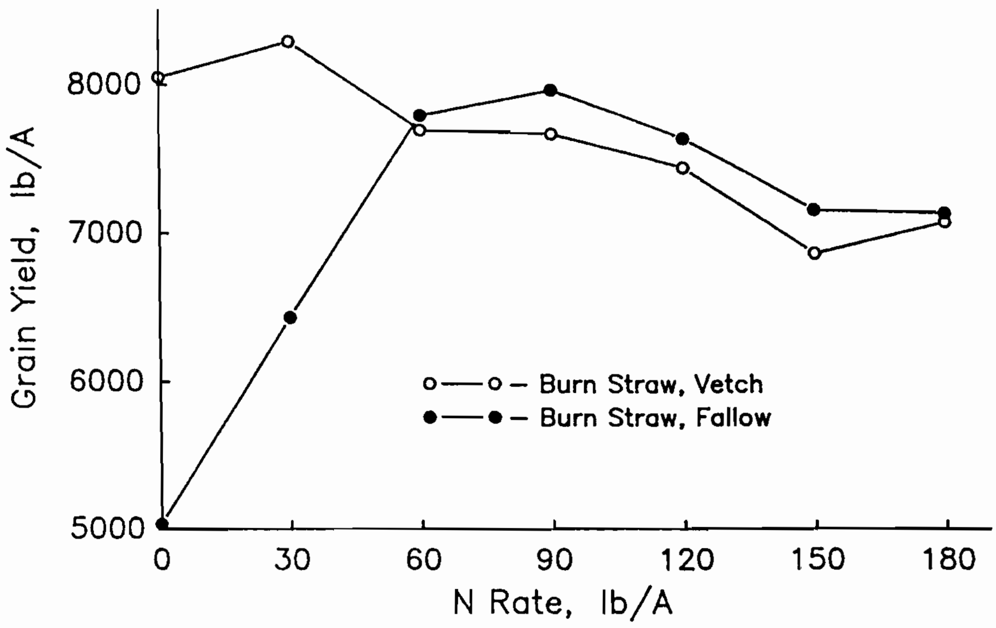
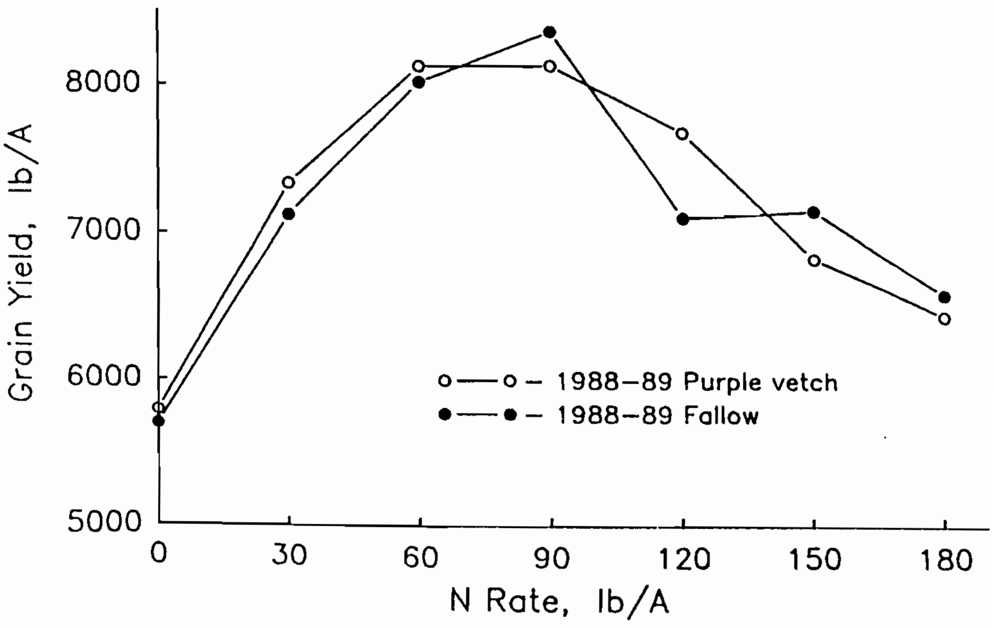
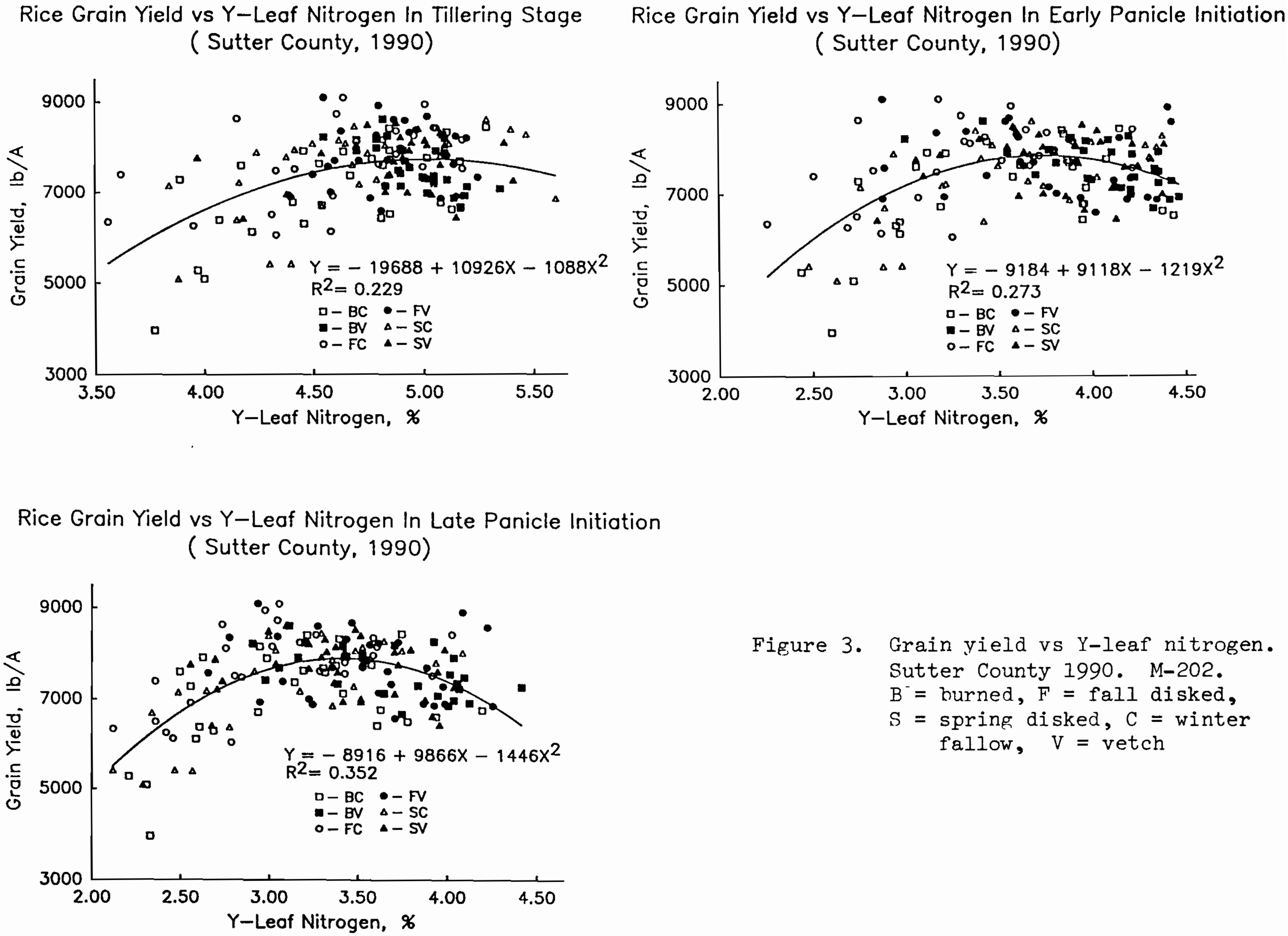


Figure 2 Rice Grain Yield vs Nitrogen Fertilizer Rate
(Butte County, 1990)





Rice Grain Yield vs Y–Leaf Nitrogen In Tillering Stage
(Sutter County, 1990)

Rice Grain Yield vs Y–Leaf Nitrogen In Early Panicle Initiation
(Sutter County, 1990)

Rice Grain Yield vs Y–Leaf Nitrogen In Late Panicle Initiation
(Sutter County, 1990)

Figure 3. Grain yield vs Y-leaf nitrogen.
Sutter County 1990. M-202.
B = burned, F = fall disked,
S = spring disked, C = winter
fallow, V = vetch

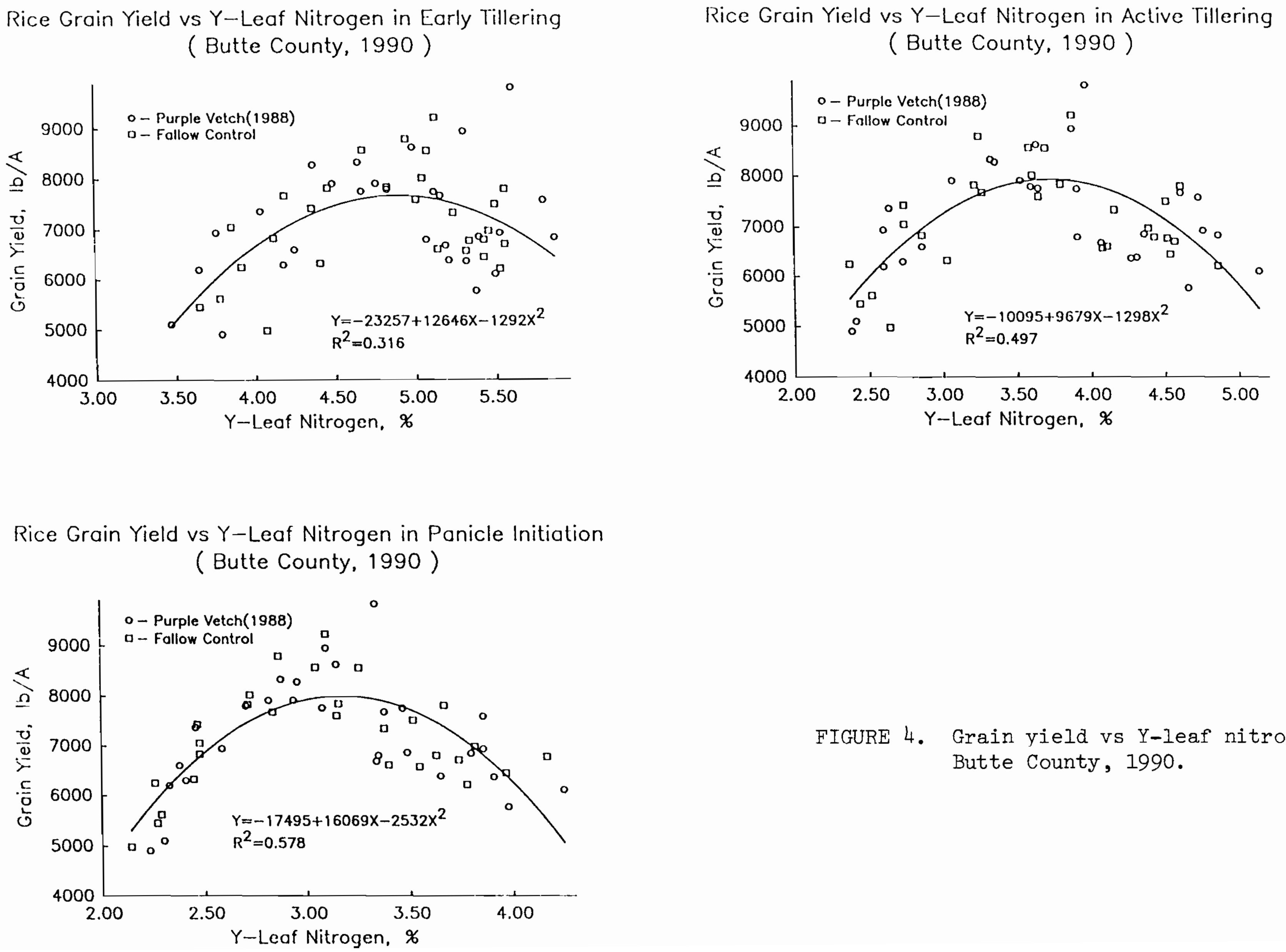
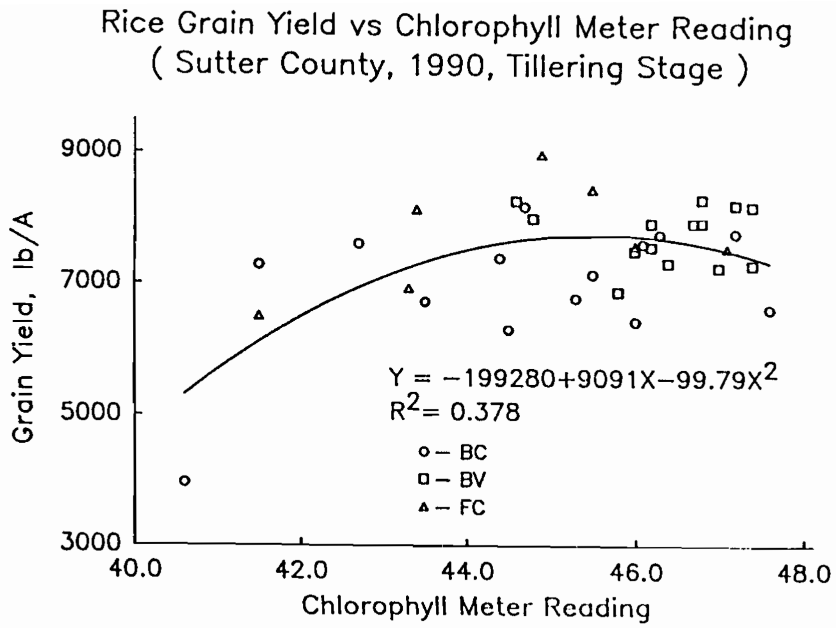
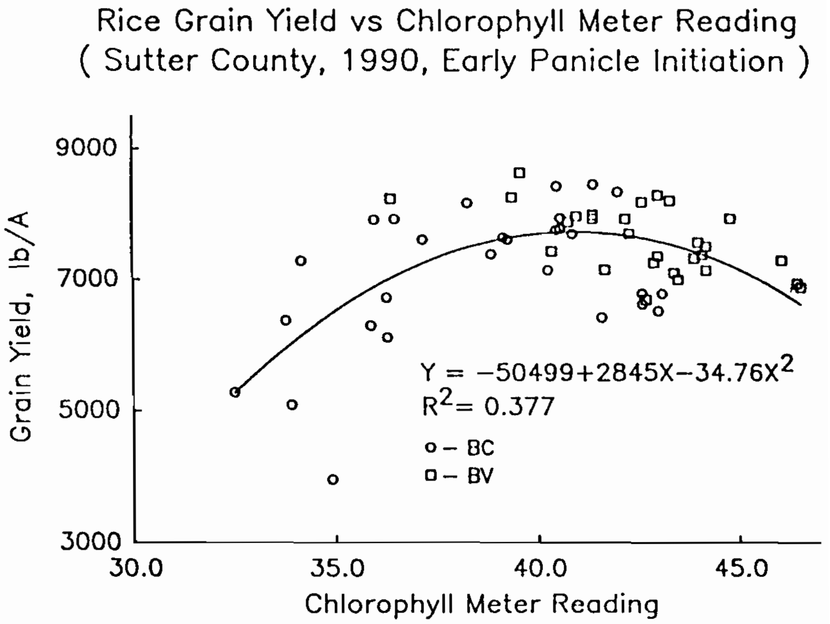


FIGURE 4. Grain yield vs Y-leaf nitrogen. Butte County, 1990.


Rice Grain Yield vs Chlorophyll Meter Reading
(Sutter County, 1990, Tillering Stage)


Rice Grain Yield vs Chlorophyll Meter Reading
(Sutter County, 1990, Early Panicle Initiation)

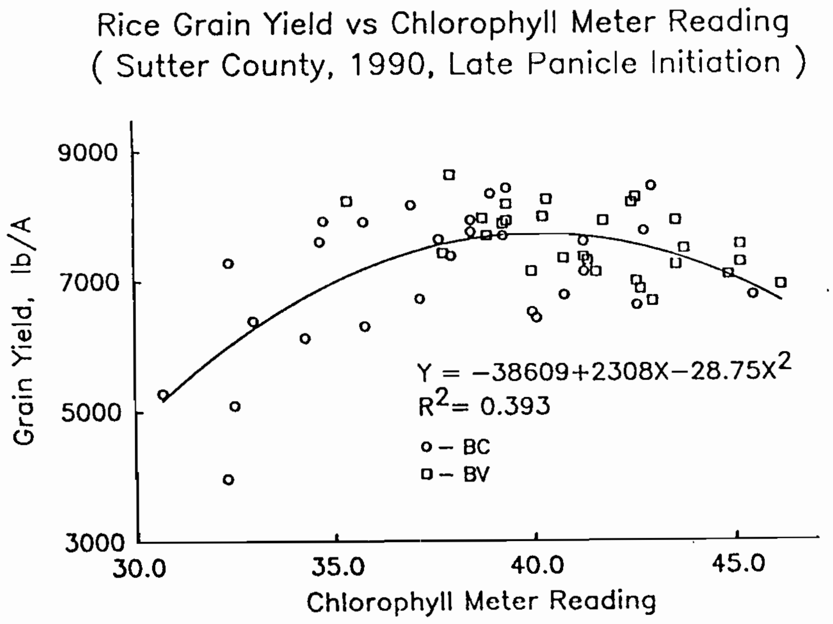
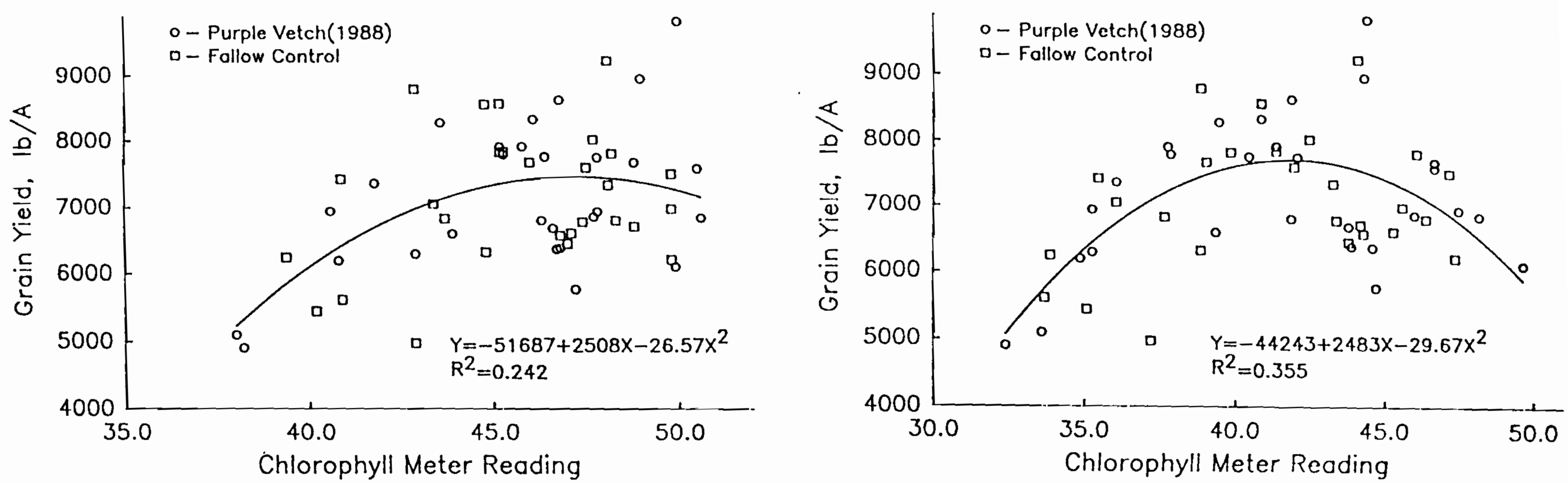

Rice Grain Yield vs Chlorophyll Meter Reading
(Sutter County, 1990, Late Panicle Initiation)

Figure 5. Sutter County Rice Grain Yield vs chlorophyll water reading. BC = Burned straw, winter fallow control. BV = Burned straw, purple vetch. FC = fall disked, winter fallow control.

Rice Grain Yield vs Chlorophyll Meter Reading
(Butte County, 1990, Early Tillering)

Rice Grain Yield vs Chlorophyll Meter Reading
(Butte County, 1990, Active Tillering)



Rice Grain Yield vs Chlorophyll Meter Reading
(Butte County, 1990, Panicle Initiation)

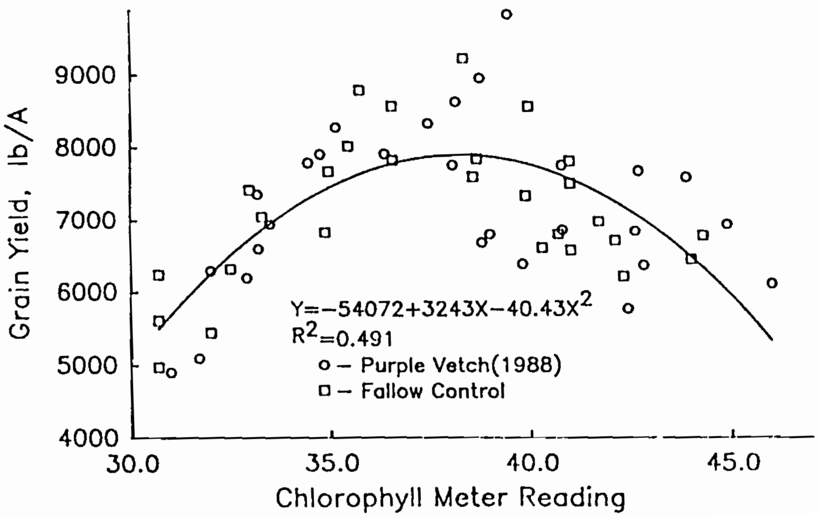


Figure 6. Butte County Rice Grain Yield vs chlorophyll meter reading.

Figure 7. Chlorophyll Meter Reading vs Rice Y-Leaf Nitrogen
(Sutter & Butte County, 1990)

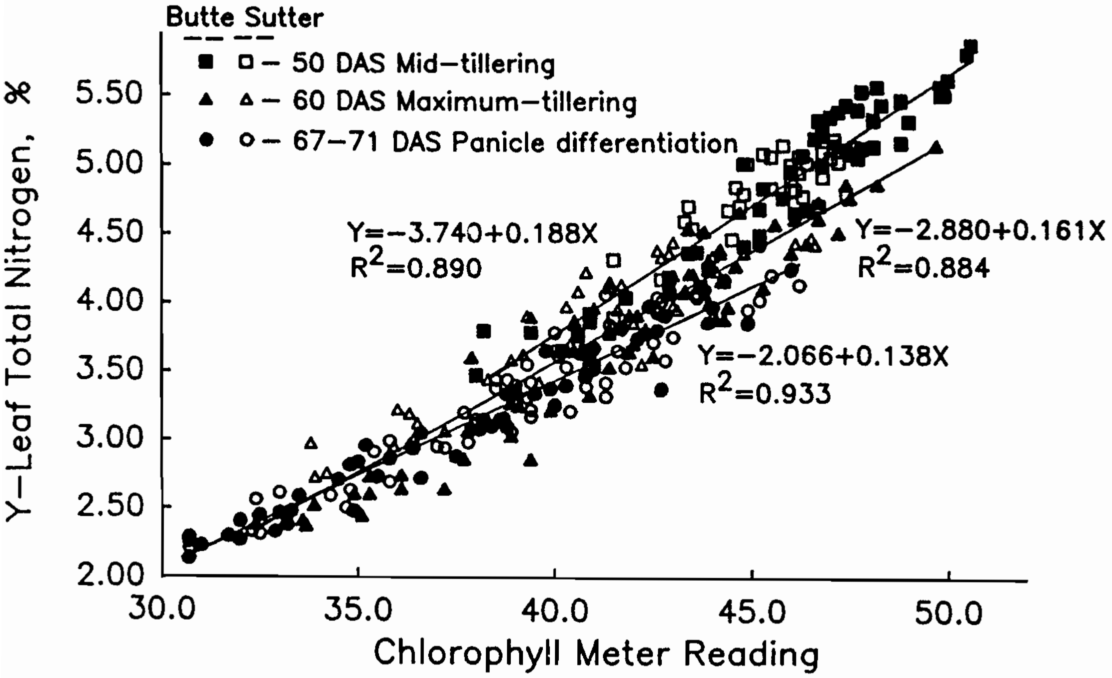
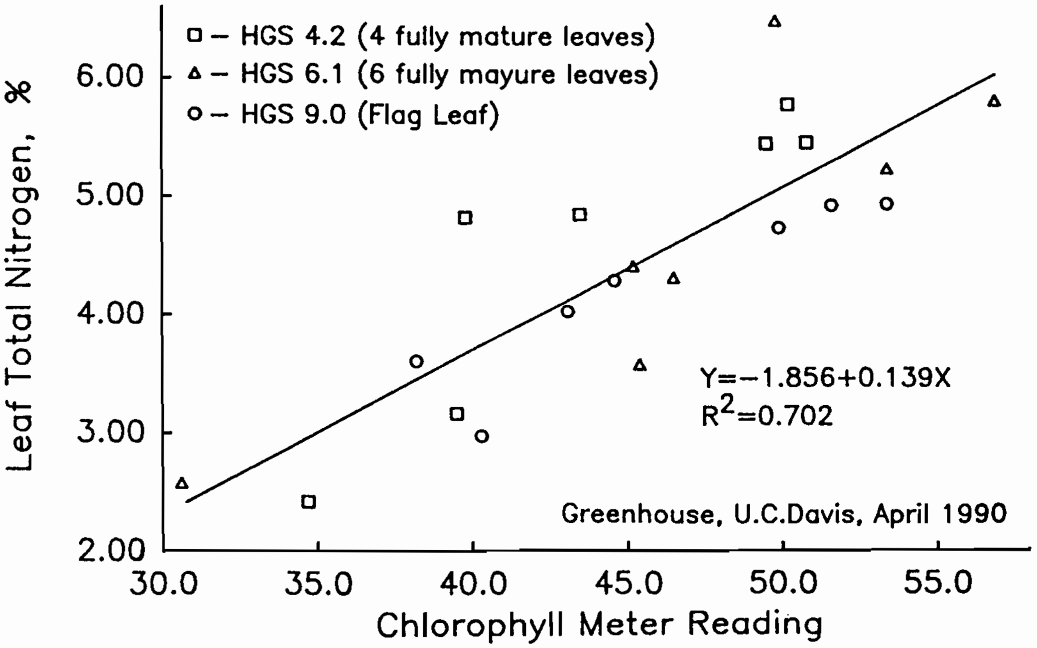


Figure 8. "Serra" Wheat
Chlorophyll Meter Reading vs Leaf Nitrogen



EFFECTS OF SOIL MOISTURE AND SOIL ORGANIC MATTER ON FIXATION AND RESIDUAL AVAILABILITY OF POTASSIUM APPLIED TO A VERMICULITIC SOIL IN THE SAN JOAQUIN VALLEY

D.C. Olk, Graduate Research Assistant and K.G. Cassman, Associate Professor, UC Davis

A late-season potassium (K) deficiency affects 15-20% of the cotton acreage in the San Joaquin Valley (Cassman 1986). Years of intensive cultivation without replenishing the K removal have apparently depleted K reserves in vermiculitic soils which dominate the East Side of the San Joaquin Valley.

In a fertilizer study conducted from 1985-1987 in a grower's field located near Lemoore, Kings County, a significant cumulative lint yield response to repeated annual K fertilization was obtained (Cassman et al. 1989). However, even the highest fertilizer rate (480 kg K ha^{-1} $year^{-1}$) did not completely alleviate the late-season deficiency. Over 80 percent of the applied K was fixed by soil minerals beyond recovery by 1M NH_4Cl extraction. This amount is 15 times the K removed by seed cotton harvest (27 kg K ha^{-1} $year^{-1}$). To simply maintain the labile K levels measured in 1985 required an annual input of approximately 120 kg ha^{-1}, fourfold more than the annual K removal by harvest.

In 1988, wheat was planted without K input. In the 1989 and 1990 summer seasons, cotton was grown with a uniform application of 112 kg K ha^{-1} (1989) and 158 kg K ha^{-1} (1990) applied over the residual treatments established from 1985-1987. When measured in August 1990, labile soil K levels were well below levels measured in 1987, despite the net K input of nearly 200 kg K ha^{-1} from 1989 to 1990 and regardless of the previous fertilizer-K input levels from 1985-1987. There was, however, a significant yield response to residual fertilizer-K treatments.

Multiple regression analysis identified two key factors of the labile K decreases in fertilizer plots from 1987-1990: solution-phase K (positive relationship) and organic carbon (negative). Thus, maximum K fixation occurred in those plots with the highest solution-phase K and lowest soil organic carbon levels.

In summary, an extremely large K fixation potential exists in the East Side soils. The fixation apparently continues for months and even years after inputs of K are applied. To identify the key factors that govern long-term fixation, studies were conducted to examine K fixation kinetics in relation to soil moisture regime and the influence of stable organic carbon compounds added to soil as humic acid.

Methods

Laboratory experiments were designed to simulate field conditions. To study long-term fixation under moisture conditions that characterize surface soils, K fixation was monitored in soil samples subjected to several wetting/drying cycles. To simulate fixation at subsurface depths where moisture fluctuations are attenuated, soil samples were incubated at constant moisture and temperature to follow K fixation. Soil in both types of moisture experiments was initially loaded with 12 mmoles K kg^{-1} soil, equivalent to approximately 1220 kgs K ha^{-1} applied to the surface plow layer. The effect of soil organic matter on K fixation was studied by extracting different humic acid (HA) fractions of organic matter from soil, freeze-drying these, and then adding various rates of the HA and K to soil in the moisture regimes described above.

All experiments presented here were done on the Grangeville sandy loam (Fluvaquentic Haploxeroll), taken from 20-40 cm. The soil was sampled at the site of the long-term fertilizer-K experiment. Similar laboratory experiments are underway on other East Side soils that display the potassium deficiency.

Other researchers have found that K fixation is adequately described by first-order rate kinetics. By graphing the natural logarithm (ln) of K concentration vs time (several minutes to hours), a linear relationship is obtained. The slope of the regression line is the rate constant, k. This parameter quantifies the rate of reaction, or K fixation. In contrast to our studies in which unsaturated soil conditions were simulated, soil in these previous experiments was either saturated or subjected to continually flowing solutions.

Results

Fixation under wetting/drying regimes

Potassium fixation occurred during wetting/drying cycles (Fig. 1). In contrast to previous reports, a bi-phasic fixation pattern was found. The greatest K fixation occurred rapidly, within 2-3 days of rewetting. In Cycle A, for example, the rate constant of fixation for this initial phase was sixty fold greater than the rate constant for the later phase of the drying cycle. While fixation was slower in the later phase, it continued until the final stages of drying.

Although the K was added in an initial wetting/drying cycle (not shown), total K extracted by 1M NH_4Cl decreased by 18% over the two cycles depicted. An even greater decrease of 36% occurred in the solution-phase K concentration. For cotton, it is this solution-phase K concentration index that is the best predictor of soil K sufficiency and potential yield response to applied K (Cassman et al. 1990).

Longterm fixation at constant moisture

Soil was incubated for up to 64 days at moisture levels that characterize the range of moistures found at depth in irrigated soils. Long-term fixation occurred at all moistures throughout the 64 duration. (Fig. 2). The rate constant of fixation increased when soil moisture was maintained at lower matric potentials. These rate constants are on the same order of magnitude as the rate constant in the later stages of a wetting/drying cycle, and measured fixation rates can account for the loss of K observed over time in the long-term field experiment.

Soil organic matter and fixation

The addition of humic acid (HA) extracted via the standard HA extraction method ("tightly-bound HA") had no significant effect on reducing fixation of added K. However, omission of the initial decalcification step with HCl in the standard extraction method resulted in recovery of a more unique pool of humic acids ("loosely-bound HA"). This fraction is more soluble and has a slightly different elemental composition than the tightly-bound HA. Addition of this loosely-bound HA significantly reduced fixation of added K (Fig. 3).

Experiments that combine moisture and organic matter parameters would better simulate field conditions. In the presence of the two humic acid pools, a wetting/drying regime causes large K fixation throughout three cycles, where K addition occurs at the beginning of the first cycle (Fig. 4). Addition of the loosely-bound HA, however, maintains significantly higher total extractable K levels throughout three cycles than does addition of tightly-bound HA or no HA.

Summary

Potassium fixation occurs during repeated wetting/drying cycles and during longterm incubation at constant moisture. The amount of K fixed per cycle decreased over successive wetting/drying cycles. The magnitude of fixation during longterm incubation depended on the moisture level maintained. At least one type of soil organic matter can reduce K fixation, but its effect is secondary to that of moisture.

Demonstration of a large K fixation potential and its continuation over time should indicate the importance of adequate K fertilization for optimal seed cotton yields. Indeed, efficient K fertilizer recommendations in this situation depend on knowledge of the size and duration of the K fixation.

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FIG. 1 LN K FIXED VS TIME
WET/DRY CYCLE EXPERIMENT

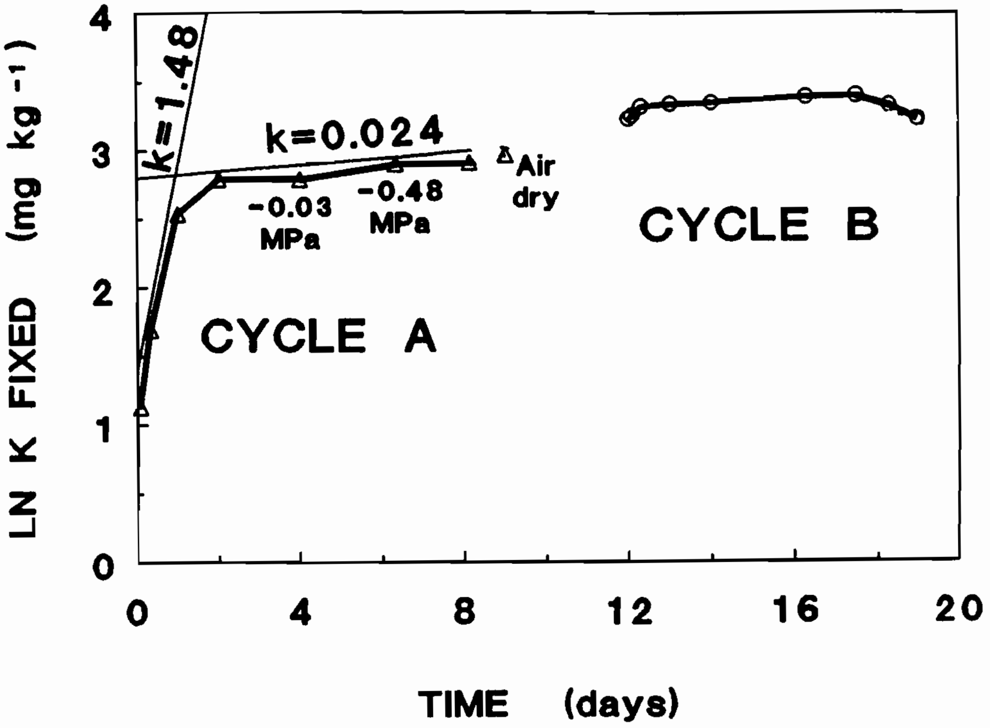


FIG. 2 LN K FIXED VS TIME
CONSTANT MOISTURE EXPERIMENT

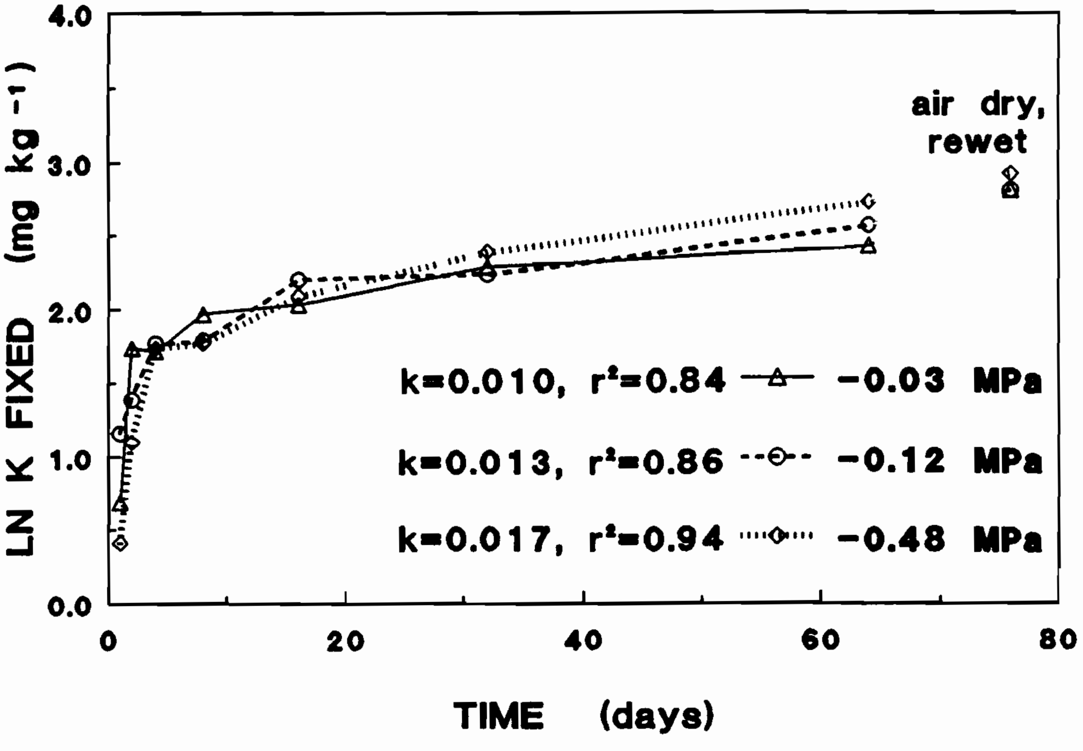


FIG.3 EXTRACTABLE K VS K ADDED
LOOSELY-BOUND HUMIC ACID EXPERIMENT

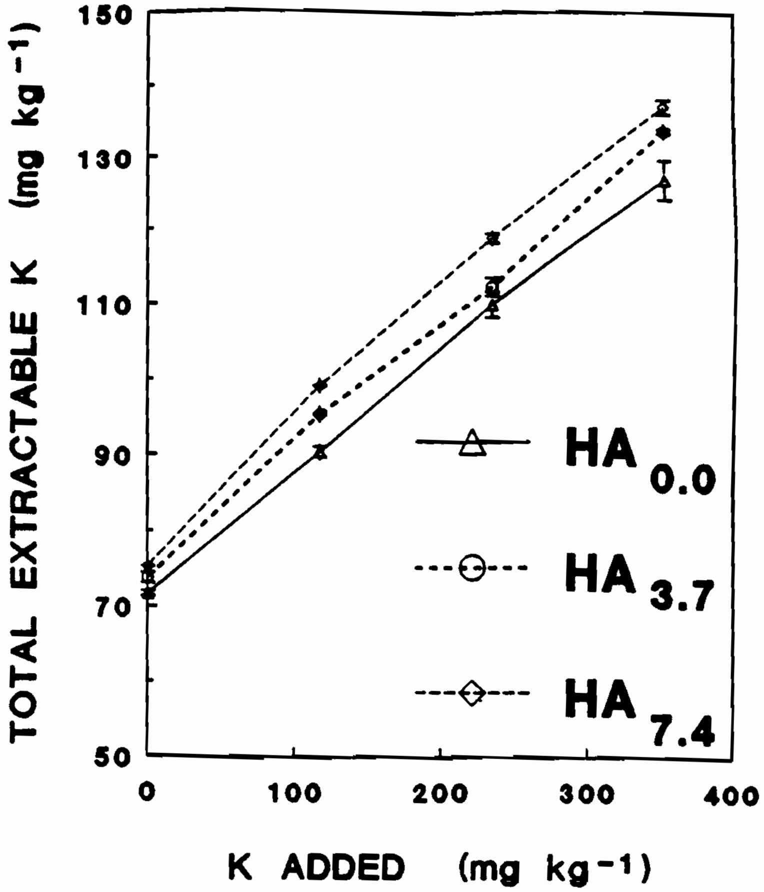
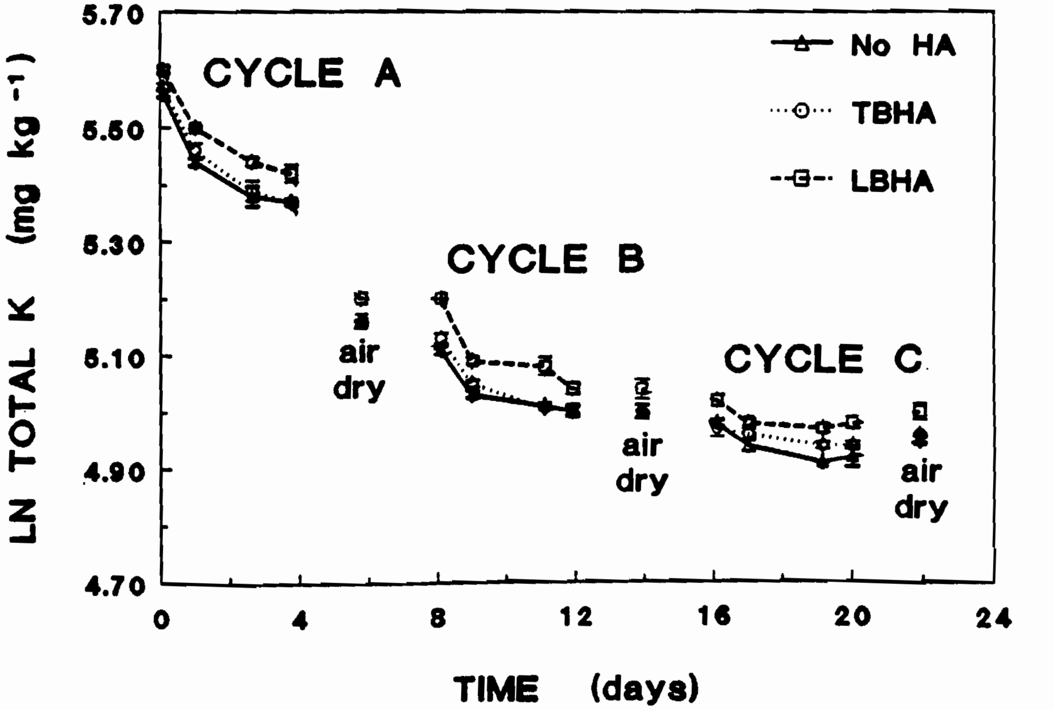


FIG. 4 LN EXTRACTABLE K VS TIME
WET/DRY CYCLES, HUMIC ACID EXPERIMENT



BORON DEFICIENCY EFFECTS ON FLOWERING

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Summary

In 1989-90 a series of field experiments were established to determine the effects of B nutrition on fruit set and yield in Pistachio. Results from these trials suggest a role for B in pollination and fruit set and suggest that B requirements for Pistachio are higher than previously thought. Positive responses to 'high' B applications (6 oz/tree soil applied or 5lbs/100gal foliar applied) included enhanced pollen germination, reduced flower drop, increased % split, increased yield and decreased blanking percentage. These responses occurred at tissue B concentrations well above those previously considered as 'sufficient'. Further studies to identify the physiological and biochemical role of B in the plant are being conducted. Boron applications in commercial orchards will be used determine optimum B levels and application techniques for a range of species.

Introduction

Boron is an essential element for plant growth and must be present in adequate amounts to ensure optimal plant growth and productivity. Boron is also a toxic element and in high concentrations will limit root growth, disrupt photosynthesis and in extreme cases cause tree defoliation. In contrast to most other essential elements the difference between an adequate B concentration in the plant and an excess of B is small, requiring particular care in the application of B to crops. This problem is complicated by the relative ease with which B can be taken up by the plant. In most soils (pH<8.5) boron is highly soluble and moves rapidly through the soil. Application of soluble B to the moist soil surrounding an actively transpiring tree can result in rapid uptake of the B into the tree and could result in expression of B toxicity symptoms. Boron is also rapidly taken up by leaves and care must be taken to avoid leaf burn following foliar applications of B.

Boron deficiency occurs widely in the fruit growing regions of California and is a limiting element in many *Pistachio* growing regions of the central valleys. Boron deficiency results in characteristic leaf symptoms that can be alleviated with the addition of boron fertilizers. Preliminary results lead us to believe that alleviation of foliar symptoms may not be sufficient to bring the plant to full yield. The flowering process may have a higher demand for boron than does leaf growth. Application of higher levels of boron however, has the potential to cause leaf burn. This results from difficulties in timing the application of B, and in the variable availability of B in soils.

Boron has long been recognized as an essential element for higher plants, its role and mode of action, however are unknown (Lewis, 1980; Marschner, 1986). It has been reported to be involved in such diverse processes as nucleic acid metabolism, cell division, sugar biosynthesis and translocation, membrane functions and is thought to interact with the function of hormones and phenolic compounds in the plant. Boron also has important effects on flowering in many species. The role boron plays in the flowering and fruiting process, however, is unclear. Possibly boron acts by altering the transport of sugars to the developing flower thereby reducing the sugar content of the nectar as well as decreasing pollen viability (Dickinson,1978). It has been suggested that high boron levels in the stigma and the style are required for the physiological inactivation of callose formed by the pollen tube walls thereby preventing the formation of phytoalexins which may inhibit pollen tube growth (Lewis, 1980). Observations in various fruit species (plum, cherry, hazelnut, soybean) suggest that the concentration of B in flower buds is a critical determinant of fruit set (Hanson et al., 1985 & 1990, Schon *et al,* 1987; Shresta *et al,* 1987)). In these same studies it was observed that there was a poor correlation between leaf B concentrations and flower bud B concentration. It is possible that a deficiency of boron influences fruit set by altering the transport of sugars to the developing flower thereby reducing the sugar content of the nectar (Marschner, 1986). Boron deficiency effects on the flowering process may also be due to a decrease pollen viability and pollen tube growth (Lewis, 1980).

This effect of boron deficiency is observed at concentrations in the tissue that would not normally be considered deficient, suggesting that the supply of boron required for seed and fruit production is higher than that needed for vegetative growth alone. There is an immediate need therefore, to understand how boron moves through the soil and plant and the role it plays in the flowering process.

Materials and Methods

In 1989-90 a large experimental site was established in Pistachio trees growing in B deficient sites (Arbuckle). Pistachio trees were chosen because of their high B requirement (>90 ppm), their high yield capacity and the frequent occurrence of B deficiency in commercial orchards. In total over 1000 trees were utilized in this experiment. Trees were divided into two groups and fertilized with either 0, 2, 4, 6 or 8 ounces Solubor per tree in November, or were treated with foliar sprays of 0, 2, 5, 10 lbs solubor/100gals in January and again in July. The experiment was designed as a randomized complete block with 50 replicate trees per block. Prior to bud burst several trees were also supplemented with ^{10}B applied to the soil. This procedure allowed us to estimate the proportion of B that is derived from soil applied fertilizer through the year and will allows us to determine the efficiency of B uptake from foliar sprays.

In an adjoining block, control trees-those receiving no B fertilization, were exposed to labelled B as follows:- Additions of a stable boron isotope (^{10}B) as a foliar spray were made in February (late dormant) and again in June (spray to drip). In addition, boron was injected directly into the stems of the plant using a stem infusion technique. This method appeared to be an effective method of controlling B applications so that movement and function on the element could be determined.

Leaf, flower and fruit B levels were monitored closely throughout the year (five sampling dates). At harvest a further estimate was made of the total B exported in the crop, lost as leaf fall and prunings and returned to the soil. In every tree a single limb of 8cm diameter and containing 30-100 flower clusters was identified and counted at three stages through the year. This data was used to establish the percentage of flowers lost during the season. The number of flowers produced, fertilized and fruit resulting has been determined in each treatment.

Total yield was determined on each of 600 trees and related to B application, % flower drop and nut quality parameters. Harvested nuts were sorted and the % blanks, non-splits and average kernel weights determined. Nutrient concentrations (N, P, K, Mg, P, Mn, Zn, Cu, B) in leaves, buds, flowers and nuts were determined for each tree at each of four harvest dates. This data will be used to establish seasonal nutrient budgets in these trees and to estimate B movement into the tree.

In a related experiment the effect of B on pollination was determined. Pollen from five male trees in each of the treatment blocks was collected at maturity and returned to the lab. In the laboratory in-vitro pollen germination tests were conducted by placing the sieved pollen on an agar medium at 25°C for 24 hours and scored for germination under the light microscope. Pollen was germinated either in the presence or absence of B in the germination medium, results are presented as the % of all pollen that germinated within 24 hours.

Results

Results are illustrated in Fig. 2-4. Application of foliar sprays of boron in the late dormant stage to both male and female trees resulted in a number of positive effects on pollination, flower set, yield and fruit quality.

Pollination

In male trees receiving supplemental B the growth and germination of pollen was enhanced (Table 1). Increases in foliar B application resulted in progressively greater pollination. Highest pollination values (+45%) were obtained at a B application rate of 5 lbs solubor/100 gals sprayed in late dormant. Higher levels of applied B (in this case 10 lbs/100 gal) resulted in a depression of pollen germination. Addition of B to the germination medium also resulted in enhanced germination at all B levels. In this case there was no depression of germination at the highest B application rate.

Flower Drop

The effect of B on pollination may have resulted in the decrease in flower drop observed in fig. 2 and on % splits and blanks. As with pollination, application of B (either soil or foliar) resulted in reduced flower drop during the season. Boron applications resulted in a reduction in the number of flowers lost (fig. 2) between March and July from 20% (no added B) to 12% (5lbs/100 gal Solubor). As with pollen germination high levels of B resulted in enhanced flower loss. A significant (+10%) positive effect of B application on the number of split nuts (fig 3.) was also observed. As with flower set and pollination excessive levels of B were deleterious and resulted in an increased percentage of non-splits. Total tree yield was also enhanced by the application of foliar boron (fig. 4), however in this instance high B did not have a negative effect.

Boron Concentrations

In these experiments none of the trees used displayed signs of B deficiency, and none of the trees had B concentrations below the 60-80 ppm that is usually cited as adequate. Positive responses to added Boron applied either foliarly or to the soil (results not shown), occurred at leaf tissue levels of between 100 and 300 ppm B (Fig 5). Apparently B continues to influence plant yield even when tissue B is in excess of that required for optimum vegetative growth. From this preliminary data we would recommend a mid-summer B concentration of **150-200ppm** for pistachio. Levels of B either higher or lower than this should be avoided.

The effects of B on Pistachio and other fruit crops clearly suggests a role of B in flowering. Whether B effects all species equally is unknown, current results would suggest a need to reevaluate B optimums for other crops, particularly those species in which the amount of viable pollen is a limitation to yield.

Discussion

The positive effects of B application on pollination, flower drop, yield and % splits indicate that we must reconsider our estimates of optimum B levels in Pistachio. This observation that B requirements for flowering are higher than those required for vegetative growth has been observed before (K. Uriu *pers comm.*) and has been suggested from the results of others (Hansen *et al.* 1986,1990). This is significant in that it demonstrates the importance of including yield in determinations of critical nutrient concentrations for plant growth. In the case of B deficiency leaf symptoms are not suitable indicators of a B deficiency.

As mentioned earlier, B deficiency has been implicated in flowering and fruit production in a number of species. Explanations of this effect include B effects on auxin metabolism, sugar transport, nectar production and pollen viability. The results presented here would suggest that B deficiency effects yield primarily through its effect on pollen viability.

In all characters measured, the highest level of B application (foliar) resulted in negative effects (yield and quality loss, leaf symptoms). Interestingly this response was not observed with high levels of soil applied B even where tissue B concentrations were very high. It is possible therefore that these effects were not due to high B concentrations *per se* but to the burning effect of the concentrated spray solution itself.

The responsiveness of pollen to late dormant B sprays suggests that B concentration in the flower buds may be of critical importance to the pistachio tree. Estimates of B uptake from this spray suggest that a small amount of applied B penetrated into the buds and was responsible for the marked increase in pollen germination (results not shown). If this is a real effect then B application strategies should be targeted at increasing bud B levels. It is unclear at this stage how and when B gets to the developing bud under normal conditions. Further research in this area will be necessary to optimize B applications.

Unfortunately, our current knowledge is inadequate to explain the physiology behind the observed effects of B on pistachio. We do not understand the relationship between pollination, flower drop and fruit quality and we do not adequately understand the movement of B in the plant to be able to manage B applications. It is clear that B deficiency has a significant influence on the flowering process in a number of crops and warrants further investigation.

POLLEN GERMINATION IN PISTACHIO

Treatment	- B	+B
Control	50.90^{a}	62.00^{a}
2 lbs/100 gal	71.90^{b}	90.10^{b}
5 lbs/100gal	95.80^{c}	98.00^{c}
10 lbs/100gal	65.50^{b}	89.50^{c}

TABLE 1 Effect of foliar applied B on germination of Pistachio pollen in-vitro. Pollen was collected from trees that had been sprayed in late-dormant phase (Jan) with a range of B sprays. Pollen was then sieved to 100micron and placed on agar medium at 25 °C for 24 hours. Values are % germination. 100 µM B was added to a second set of germination assays and the experiment repeated (+B).

[a] Numbers with different superscripts within one column differ significantly (5%).

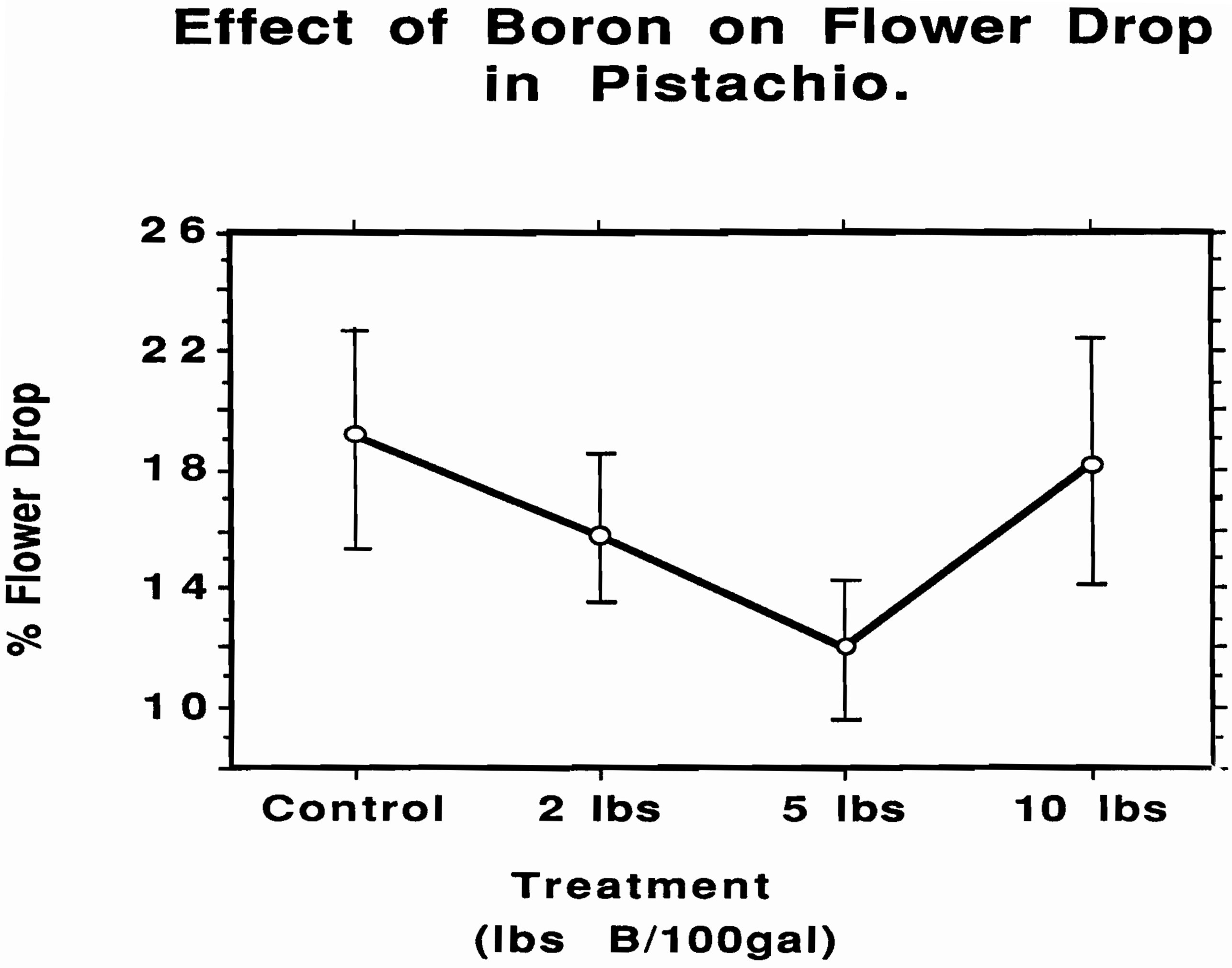


FIGURE 2. Effect of foliar B spray on flower drop in Pistachio. Total flower number was counted on 5cm diameter branches in each of 600 trees. Percent difference in flower count between March and July is plotted for each of the B application rates.

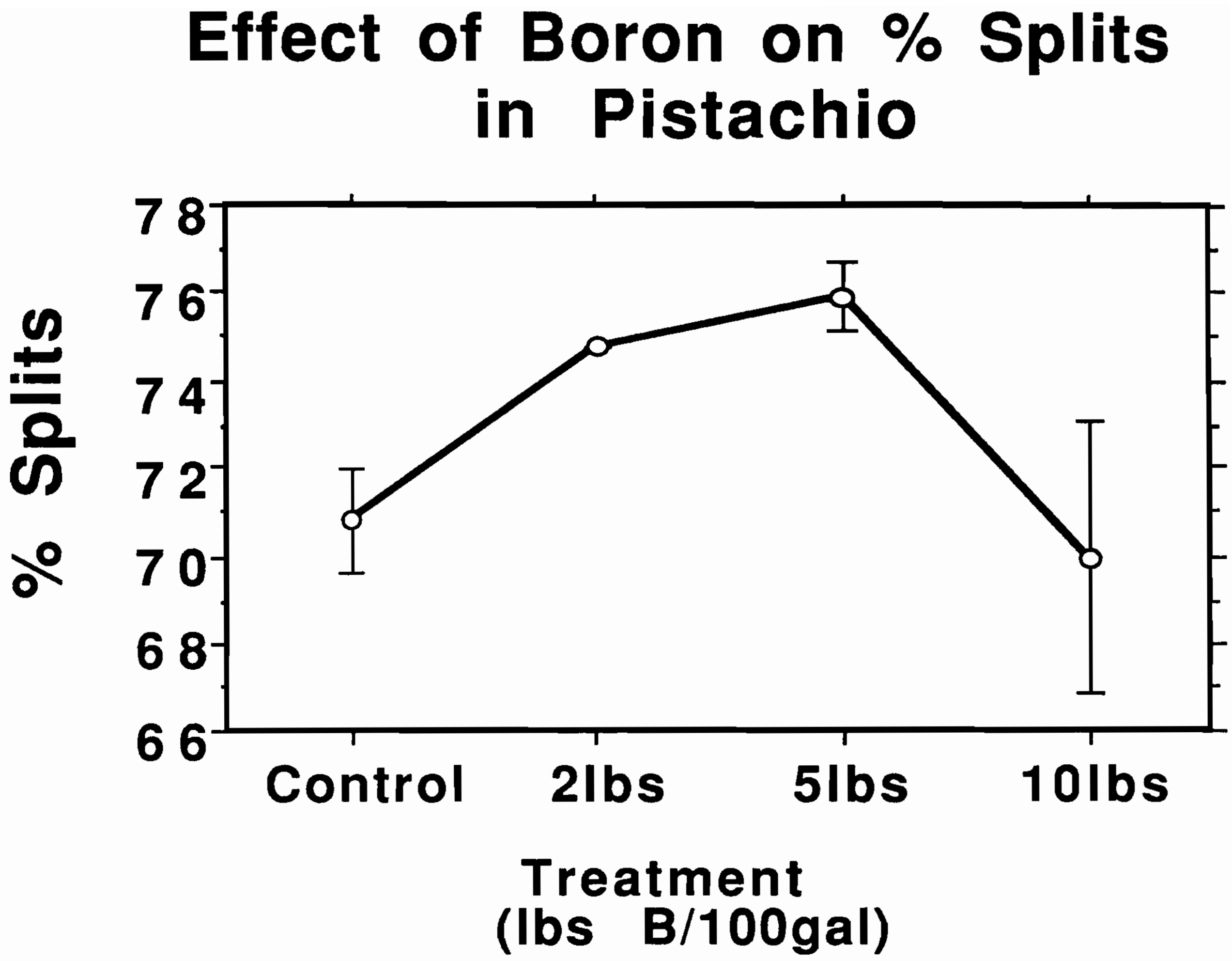


Figure 3. Effect of Foliar B application rate on % of split nuts in Pistachio.

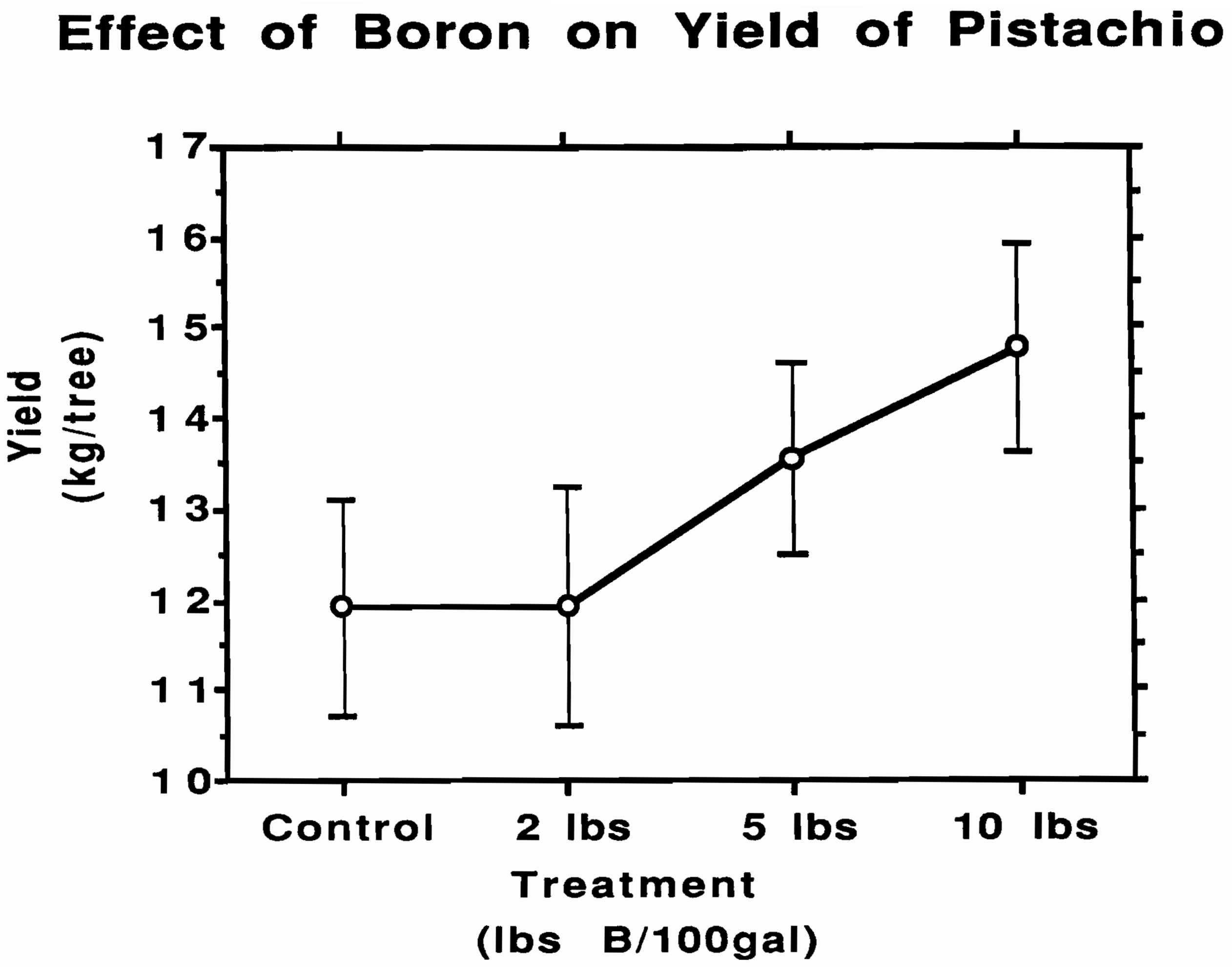
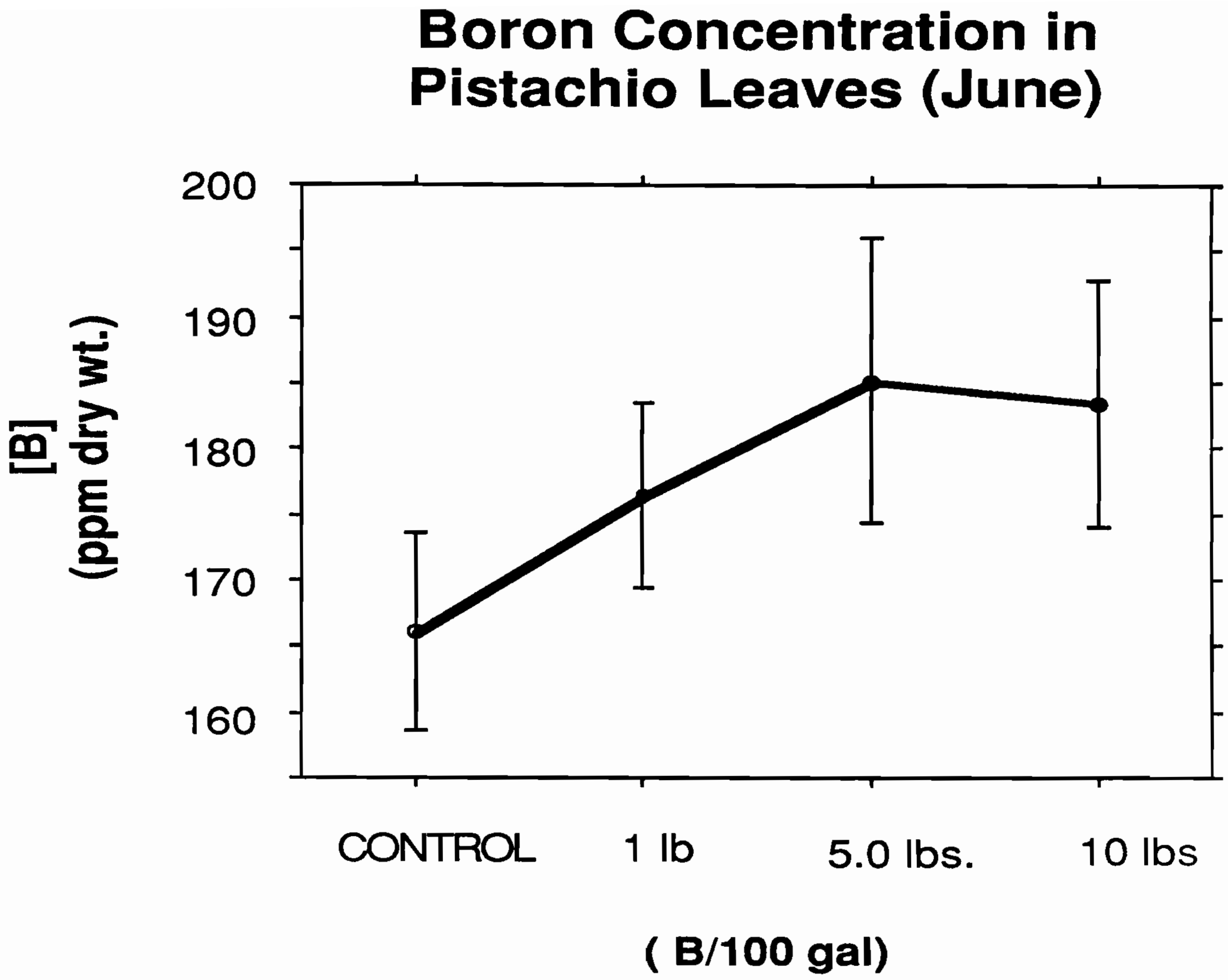


Figure 4. Effect of foliar B application rate on yield of Pistachio.


Boron Concentration in Pistachio Leaves (June)
200
190
180
170
160
[B]
(ppm dry wt.)
CONTROL
1 lb
5.0 lbs.
10 lbs
(B/100 gal)

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Winter Cover Crops to Improve Nitrogen Cycling in the Salinas Valley

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Louise Jackson, Assistant Professor/C.E. Specialist, Department of Vegetable Crops,
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Introduction

Winter cover crops are currently used infrequently in the Salinas Valley, yet green manures were once considered indispensable for lettuce production in this region (Knott and Tavernetti, 1944). Cover crops have the potential to improve soil texture and water infiltration (Williams, 1966; Flocker *et al.*, 1959) and increase organic matter and microbial activity (Tisdall and Oades, 1982; Miller *et al.*, 1989). Cover crops can also reduce nitrate leaching to groundwater, a serious problem in the Salinas Valley, by taking up excess nitrate and water in the soil during an otherwise fallow winter period (Muller *et al.*, 1987). Mineralized nitrogen from incorporated cover crop residues can then become available to the subsequent crop, thus contributing to more efficient nitrogen cycling.

Our research has focused on finding appropriate cover crop species that are well adapted to Salinas Valley growing conditions, exhibit good characteristics for nitrogen accumulation, and will fit into current production schedules. Of the number of native and European cultivars tested so far, phacelia (*Phacelia tanacetifolia*) seems the most promising for recapturing leachable nitrate and making it available to the following lettuce crop.

Methods

A trial comparing eight non-leguminous winter cover crops was established in Salinas on a slightly alkaline, loamy soil of granitic parent material. The design was a randomized complete block, and the species used included oilseed radish (*Raphanus sativus* cv. "Renova"), white senf mustard (*Brassica hirta* cv. "Martigena"), white mustard (*Brassica alba*), phacelia (*Phacelia tanacetifolia* cv. "Phaci"), rye (*Secale cereale* cv. "Merced"), barley (*Hordeum vulgare* cv. "Arivat"), annual ryegrass (*Lolium multiflorum*), and perennial ryegrass (*Lolium perenne*). A fallow plot was added to each block as a control, and treatments were replicated three times. Cover crops were planted on November 15, 1989, in two 12 meter rows on beds 1 m on center.

Soil samples were taken on January 7 and March 8, 1990, at depths of 0-15, 15-30, and 30-60 cm, extracted in 2 M KCl, and analyzed for mineral ammonium and nitrate with an ammonium analyzer, using a reduction process to measure nitrate (Carlson, 1986). In March, a separate set of soil samples was taken at 0-30 and 30-60 cm depths directly in the cover crop plant row and midway between the plant rows. Roots were washed free of these cores, and root length was measured on a Comair root scanner (Hawker de Haviland, Victoria, Australia). Samples of aboveground cover crop material were also taken in January and March. Both aboveground and root samples were dried, weighed, and analyzed for total N by the Kjeldahl method.

Cover crops were incorporated with a rotary tiller on March 20, ammonium sulfate fertilizer was applied at a rate of 85 kg ha^{-1} of nitrogen as ammonium sulfate on April 5, and 'Salinas' lettuce was direct seeded on April 10. Soil samples (0-15 cm) were taken weekly between March 20 (just prior to incorporation) and the end of June, and analyzed for mineral ammonium and nitrate. Potentially mineralizable nitrogen was measured in these soil samples using a seven-day anaerobic incubation procedure (Waring and Bremner, 1964).

Results and Discussion

Winter cover crops took up 10-20 kg ha^{-1} of soil N between planting in November and January (Figure 1a). By March 9, the cover crops produced 2000-6000 kg ha^{-1} of aboveground biomass, which contained 100-175 kg ha^{-1} of soil-derived N. Total root length and weight to a depth of 60 cm showed no significant differences between cover crops, and averaged 6600 m of root length m^{-2} of soil and 530 kg of root ha^{-1} across all species. An average of 11% of total cover crop biomass was located belowground in roots, and roots contained approximately 7% of total cover crop nitrogen.

Soil nitrate levels in the 0-15 cm depth at the time of planting the cover crops averaged 83 μg nitrate-N g^{-1} soil and decreased to an average of 27 μg g^{-1} soil by January, although treatment differences were not significant at this date (Figure 1b). By March 9, all of the cover crops had depleted soil nitrate pools significantly compared to the bare soil control and had brought nitrate concentrations below 5 μg nitrate-N g^{-1} soil. Concentrations of nitrate were somewhat higher in the 15-30 and 30-60 cm depths, but the bare soil control had significantly higher concentrations than all of the cover crops in both lower depths (data not shown).

Much of the seasonal decrease in nitrate concentration shown in the bare soil plots was likely due to leaching, although losses by denitrification and microbial immobilization were also possible. Decreases in the cover crop plots may be partially due to leaching, but considering the amount of N in the cover crop standing biomass and their extensive root systems, much of this soil N was probably captured by the cover crop.

Following incorporation of the cover crops on March 20th, and the addition of N fertilizer approximately two weeks later, the phacelia and rye plots exhibited similar patterns in soil ammonium concentrations in the 0-15 cm depth, but both cover crop plots showed lower and more constant ammonium concentrations than the bare soil (Figure 2, a and b). Significant immobilization of fertilizer ammonium may have occurred in the cover cropped plots compared to the bare soil plots. Phacelia plots maintained higher concentrations of soil nitrate than either the rye or the bare soil plots through most of the lettuce season (Figure 2, c and d). In addition, rates of potentially mineralizable N during the first week following cover crop incorporation are highest in phacelia plots (Figure 3, a and b). After the first week, phacelia and rye had very similar rates of mineralizable N, which were both higher than in the bare soil.

These results indicate that, given moderate amounts of applied fertilizer shortly after incorporation, the phacelia residues may break down and become mineralized rapidly enough to become sufficiently available to the following lettuce crop. Both cover cropped treatments appear to have immobilized significant amounts of ammonium fertilizer application. Inorganic N concentrations during the lettuce growth period, however, were typically higher in the phacelia plots than in the bare soil plots. This suggests that soils with readily mineralizable organic residues may improve fertilizer N availability and crop utilization. Higher rates of potentially mineralizable N in the cover cropped soils also indicate higher microbial activity, which has been linked to improved soil structure (Tisdall and Oades, 1982).

Conclusions

Phacelia is a promising winter cover crop species for use in the Salinas Valley lettuce production systems for several reasons. Its succulent top growth and non-fibrous root system makes incorporation of residues easier than grass residues, and thus allow incorporation of residues directly on beds without needing to disc. Phacelia accumulates significant amounts of potentially leachable soil N in its top growth, and our results suggest that with proper management, this captured N may be made available to the subsequent lettuce crop. The brassicas tested in this experiement were also promising in their N uptake capacities and relative ease of incorporation, but unlike phacelia, they harbored diseases such as turnip mosaic virus (Koike, S., pers.

comm., 1990) which could threaten the large acreages of broccoli and cauliflower production in the valley.

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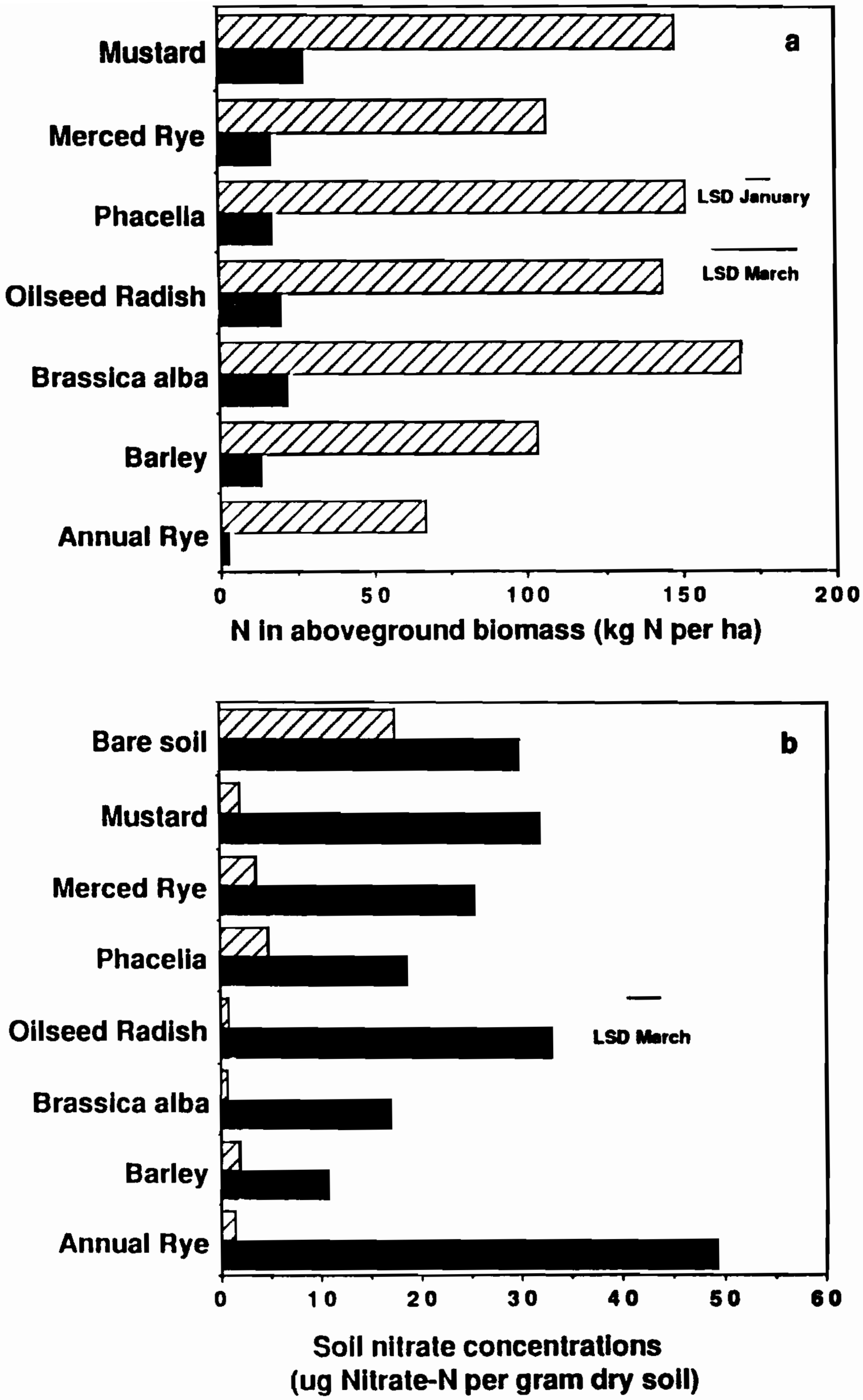

Figure 1. Cover crop N (kg N ha^{-1}) in aboveground biomass (a), and soil nitrate concentrations (b), 0-15 cm depth. Salinas lettuce experiment, January (■) and March (▨), 1990. Soil nitrate concentrations are expressed as μg nitrate-N g^{-1} soil. Bars represent lengths of LSDs at P=0.05; nitrate concentrations in January (b) were not significantly different.

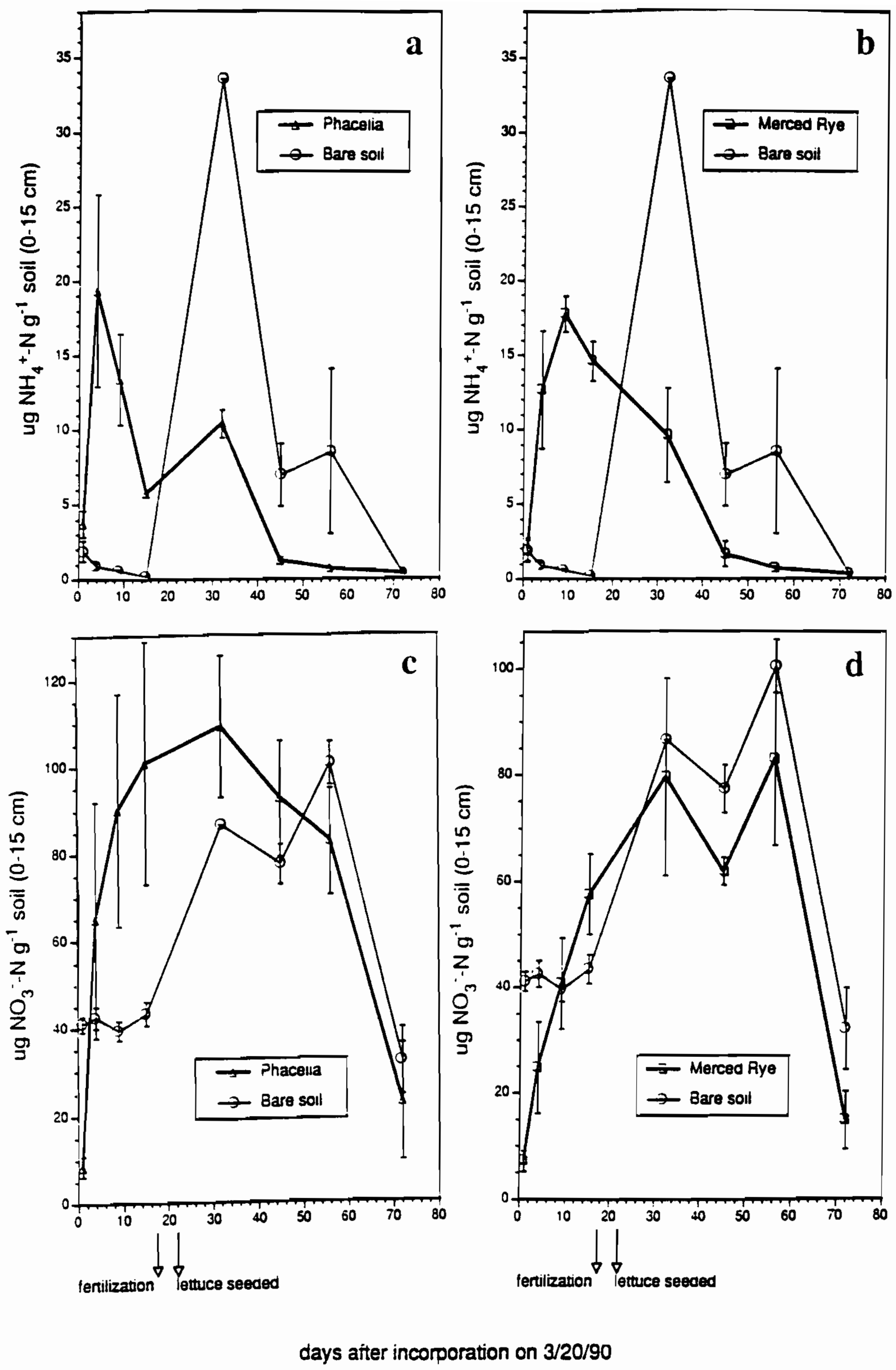

Figure 2. Soil ammonium (a and b) and nitrate (c and d) concentrations in the 0-15 cm depth following incorporation of cover crops in phacelia , Merced rye and bare soil plots. Mineral nitrogen concentrations are expressed as μg NH_4^+-N or NO_3^--N g^{-1} dry soil. Bars represent standard errors. Note differences in units in the various graphs.

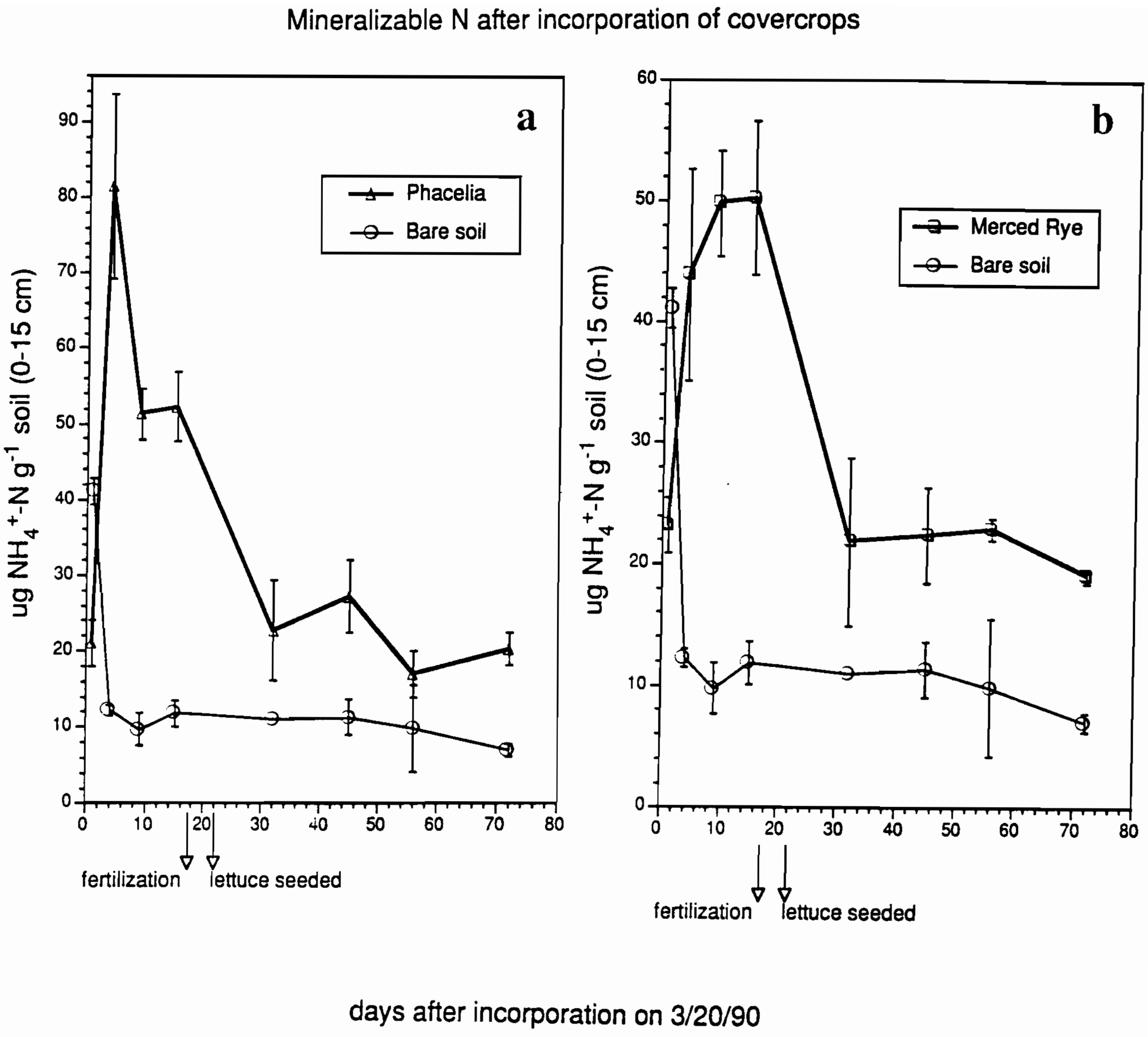

Figure 3. Potentially mineralizable N in phacelia , Merced rye , and bare soil plots in the 0-15 cm depth following incorporation of cover crops. Mineralizable N is expressed as net μg NH$_4^+$-N g^{-1} dry soil produced after seven days incubation. Bars represent standard errors. Note difference in units in the two graphs.

IRON CHLOROSIS IN SAN JOAQUIN VALLEY DECIDUOUS ORCHARDS

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Deciduous orchards in the San Joaquin Valley commonly experience problems with iron chlorosis. Although the causes can include both a deficient amount of iron present and lime-induced chlorosis, the latter is by far the most significant factor in this valley.

Soil pH readings above 8.0 are not uncommon in some of the severe iron problem areas. Planting trees into these soils containing high amounts of free lime results in iron chlorosis problems that persist throughout the life of the orchard. Because of the magnitude of the soils buffering capability and the depth of some of the chalky lime soils, postplant amendments are marginally successful. This situation is most prevalent on the loam and clay soils on the valley's Westside.

A different yet related problem occurs on the sandier Eastside soils. Here it is not uncommon to see surface soil pH readings of 5.0 or less. Underlying these topsoils, layers of high pH lime-based strata can occur. This presents even a more complex postplant problem when treating with amendments since further aggravating the acidic surface soils is undesirable.

In either of the above discussed situations there is no substitute for a good pre-plant amending of these soils. This is the one opportunity the grower has to radically treat soil pH problems at a depth and location that would be unattainable once trees are present (i.e., deep injection of acidifying amendments directly down the tree rows). Unfortunately most observed field problems are those identified after an orchard has been established.

Local attempts to treat lime-induced chlorosis problems in orchards include a range of products from ammonium fertilizers to sulfuric acid. The use of topical soil sulfur treatments is the most common practice.

Relying exclusively on ammonium sources of nitrogen is an inherently limited and slow process that rarely affects below the surface few inches. Soil sulfurs offer great potential but are also slow to react and are usually not incorporated to a depth where they can benefit enough of the deep roots of perennial crops. Sulfuric acid offers the best opportunity to create rapid changes in high pH soils. It however, possesses the greatest limitations when the logistics of handling, application and initial cost are considered. Those who have opted to use this treatment, whether shanked or surface applied, report rapid and favorable results.

There are a host of other materials on the market that have been tried in the battle against iron chlorosis. Sulfur based products like N-Phuric (15-0-0-16) and Nitro-Sul (20-0-0-45) have had some successes. Humic acids, iron foliar sprays, and soil chelates have also been tried with mixed results.

Iron soil chelates present an interesting situation. Good success has been achieved with these products by the turf and landscape industries, and with shallow rooted annuals. With deep rooted perennials local results have not been as encouraging. When we are dealing with soil pH's in excess of 8.0, only the EDDHA chelate formulation is stable. Treatments in mature orchards with this material can exceed costs of $12 per tree without significant benefit. Less costly chelate formulations such as DTPA chelate are available, but its stability degrades at a pH of 7.6 or higher. The commonly available EDTA chelate is even less stable in alkaline soils and does not correct lime-induced chlorosis. This EDTA, as well as lignosulfonated chelates are sometimes used as foliar treatments. Generally enough iron cannot be absorbed to eliminate the problem without multiple applications that often lead to phytotoxicity.

Iron Chlorosis Trials:

The following data represents trials in Stanislaus County where soil applications of iron were used in an attempt to correct iron chlorosis problems.

Cherries: (Soil applied/water incorporated)

Treatment	Chlorosis Rating[1]
Zn EDTA	1.80 a[2]
Untreated Check	1.75 ab
Fe EDDHA	0.90 bc
Fe EDDHA + Zn EDTA	0.20 c

Peaches: (Soil applied/water incorporated)

Treatment	Chlorosis Rating[1]
Untreated Check	2.07 a[2]
Gypsum	1.86 a
Ferric Sulfate	1.86 a
Fe EDDHA	1.79 a

[1] Chlorosis Rating: 0= No Chlorosis; 1= Mild; 2= Moderate; 3= Severe.

[2] Means followed by the same letter are not significantly different (0.05 Duncan's Multiple Range)

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N Timing in Furrow and Drip-irrigated Vineyards

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Summary

It has been shown that rapid shoot elongation in the spring for both grapevines and deciduous fruit trees is heavily dependent on the redistribution of nitrogen (N) previously stored in roots, trunk, canes, or limbs. Since the grapevines need for N is greatest in the spring it can be inferred that N fertilizer should be applied when the vine can best absorb and incorporate it as part of the N reserve while minimizing N loss from the soil. This information has prompted continuing studies on N fertilizer timing under drip and furrow (flood) irrigation utilizing isotopically labeled ^{15}N-depleted. Under furrow irrigation, winter and spring applications of N were found to be inefficient in vine N uptake and very susceptible to leaching by irrigation and rainfall. In contrast, late spring, summer, and postharvest fall treatments provided for considerably more N storage in the roots and trunk to support early shoot growth the following year. These findings have been substantiated in subsequent studies in raisin, table, and wine grape vineyards. They have demonstrated postharvest and fruitset stage N applications to be the most efficient, budbreak the least efficient, and veraison intermediate in N utilization. No adverse effects on vine growth and bud fruitfulness due to N fertilizer timing have been found. However, N fertilizer, regardless of timing, tends to delay fruit soluble solids accumulation as compared to no N fertilizer. These studies are enabling us to further refine vine tissue analysis in diagnosing vine N requirements in different cultivars, with bloom petiole analysis for nitrate being the most sensitive indicator. Drip irrigation offers a very efficient and convenient method to apply fertilizer directly to vine's root systems. N timing and rate studies under drip have shown very high efficiencies in vine uptake, provided that water application rates do not exceed plant water use (evapotranspiration). Thus, N fertilization under drip irrigation can be timed according to the vine's immediate needs and with less concern of timing to avoid leaching losses from the soil. Knowledge of N fertilizer efficiencies through improved timing is enabling growers to use reduced fertilizer rates, thereby reducing costs and the potential for nitrate contamination of ground water.

The traditional timing of N fertilization in vineyards has been during winter to early-spring. This timing was chosen to enable winter rainfall to move the N into the root zone by the beginning of new spring growth. Thus, N would be available to support the rapid shoot, leaf, and cluster development in the spring and early summer. However, current N timing research is modifying this practice.

Studies with Furrow Irrigated Vineyards

Studies were initiated by Bill Peacock, Farm Advisor, Tulare County, CA, in 1980 comparing water and spring N application timing. It was found that winter application in November was highly inefficient due to excessive leaching from rainfall and spring irrigations. Early spring application in March was more efficient in providing vine uptake but was still quite susceptible to leaching from irrigation. Subsequent work with ^{15}N-labeled fertilizer demonstrated vine N distribution in various vine parts over time as influenced by fertilizer timing. It was found that, as with other deciduous crops, the grapevine relies heavily on reserve N during the stage from budbreak to the end of bloom. During this period root uptake of N is limited and provides minimal amounts of N for growth. From the end of bloom to harvest the grapevine is capable of absorbing large quantities of N but the major share of this newly acquired N is utilized by the bunches, leaves, and shoots. The fastest rate of N uptake is from the end of rapid shoot growth to veraison at a time when the requirement of developing clusters is high.

From veraison (berry softening) to harvest the rate of N uptake decreases with the ripening fruit still being the largest sink.

The postharvest period shows another stage of rapid N uptake. It provides the greatest amount of stored N to support new growth the following spring, as the permanent vine parts, including the roots, are the dominant sink. As the N cycle continues into the following spring, this storage N is utilized in substantial amounts to support new growth. This relationship is shown in figure 1 where four dates of fertilization are compared: 4 April, 24 July, and 22 September 1983, and 15 March 1984. Isotopic ^{15}N under furrow irrigation was used in this study. Leaf blades were analyzed for labeled N on five dates subsequent to the initiation of the study. The data clearly shows the large amount of post harvest-applied N available to support growth from budbreak through bloom in the following year, 1984. Budbreak timing was the poorest in supplying N by bloom of the years of application and of contributing to carryover N in the following year. Summer application was intermediate.

We are now refining our knowledge of timing and vine use efficiency with field studies under a variety of conditions. This includes studies of N timing with various rates over multiple years, different cultivars, and varying vineyard conditions and irrigation practices. Studies are centered on comparing timing treatments at different phenological stages of vine development--budbreak, fruit set, veraison, and post harvest--plus a split-timing treatment with the N rate divided between fruit set and post harvest applications.

One study involved 4 commercial vineyards of Thompson Seedless and Flame Seedless over 3 years. The results showed the budbreak treatment to be least effective in supplying inorganic N (NO_3 + NH_4 in petioles) during the period of rapid shoot growth. Fertilizer N uptake and incorporation into leaf tissue was more rapid from fruit set to veraison than from budbreak to fruit set. The timing treatments of fruit set, veraison, and post harvest were fairly equal in N supply over 3 years. The exception was a Thompson Seedless raisin vineyard on sandy soil which showed benefit from split application (fruit set + post harvest). The advantages of split application on sandy soils is understandable considering the potential for leaching from irrigation. Also, the budbreak treatment produced the lowest yield response in sandy soil, again demonstrating poorer N use efficiency with this timing.

There are concerns about possible detrimental effects of some timing treatments such as a delay of fruit maturation from veraison treatment and late stimulation of shoot growth from post harvest application. Generally, it has been found that all N treatments, regardless of timing, tends to delay fruit maturation as compared to control, unfertilized. This has been demonstrated in our raisin, table grape, and winegrape trials. Additionally, there is a tendency for higher N rates to delay fruit ripening and produce more vegetative growth regardless of timing. Poorer raisin quality from veraison N timing in Thompson Seedless also suggests that this timing may not be desirable in some vineyard situations. To date, late season vine vegetative growth due to N timing has not been a problem.

Information provided by this work is rapidly changing grower practice. Many growers are avoiding N fertilizer applications during winter dormancy through budbreak in irrigated vineyards. Many are waiting until berry set when fertilizer uptake and efficiency of use improves. Post harvest timing is an increasing practice, recognizing its potential for vine N storage. However, it is only recommended where there will be at least 4 to 6 weeks of an intact, functioning leaf area in the fall to provide N uptake, assimilation, and storage by the grapevine. Veraison applications are presently not recommended because of the potential to adversely influence fruit ripening. Also, N applied at that time would tend to accumulate in the fruit, of no benefit to the grower and of questionable value to wine quality.

Because of improved N fertilizer efficiency with berry set and/or post harvest timing, growers are now using rates of 20 to 40 lbs. N/acre. This compares with the previously used rates of 40 to 80 lbs. N/acre in late winter, early spring. Reduced N rates and improved N efficiency of vine use are lowering grower costs and possible NO_3 contamination of ground water.

Studies with Drip Irrigation

Nitrogen fertilizer timing under drip irrigation has also been studied. In a Thompson Seedless vineyard trial conducted by Bill Peacock, Farm Advisor, Tulare County it was found that spring N applications are just as efficient as summer applications under drip. This is shown in table 1 where single and split applications in spring 27 April (27 April + 21 May) are compared with summer 12 June (12 June + 7 July) totaling 40 lbs N/acre. Spring applications increased vine leaf N to greater concentrations by harvest on 20 September 1984. However, the summer applications ultimately provided comparable concentrations of stored N in permanent vine parts at dormancy and in leaf tissue the following spring, 5 May 1985.

Drip irrigation provides the capability of supplying nutrients in small increments during periods of peak demand. Also, fertilizer efficiency may be improved by partitioning application over an extended period to minimize losses due to leaching. This was evaluated in the drip N timing study by comparing a single application of 40 lbs N/acre, split applications of 20 lbs N/acre 2 weeks apart, and partitioning 40 lbs N/acre into 8 weekly applications. The results in table 2 show no differences due to N partitioning in leaf and dormant vine tissues over a 10-month period.

Varying rates of total N have also been studied under drip irrigation to determine fertilizer efficiencies. 0, 20, and 40 lbs N/acre rates were compared in a spring to summer treatment period over 8 weeks. The results in table 3 show tissue fertilizer N levels over 2 years, 1984 and 1985, to be in proportion to N fertilizer rate. This would indicate equal efficiency of fertilizer application and vine N uptake regardless of N rate.

These results may be explained by method of fertilizer application and efficiency of irrigation under drip. Fertilizer is applied directly to areas of root concentration with drip irrigation. Water applications through drip can also be easily managed so as to not exceed the evapotranspirational demand of the vineyard. Thus N is not readily leached below the root zone as is experienced with furrow irrigation.

Because of the high potential for water and N fertilizer efficiency under drip we are recommending that growers apply N according to vine crop demand. Studies by Dr. Larry Williams at the Kearney Agricultural Center remove about 20 to 30 lbs N/acre under San Joaquin Valley conditions. Thus growers are utilizing these values to form the basis of annual fertilizer rates of application. Timing of N is largely based on their judgement of vine vigor, fertilizer history, and petiole analysis for NO_3.

Table 1
Drip Irrigated N Trial
% N derived from ^{15}N-depleted labeled fertilizer in leaves sampled
20 Sept 84 and 7 May 85; and roots, trunk and canes sampled in dormancy

	Total N	% Fertilizer N		Time
of	Applied	Leaves		Roots/Trunk/Canes[2]
Fertilizer Application	lbs/acre	20 Sept 84	7 May 85	Dormant
Check	0	0 c	0 b	0 b
Applied 27 Apr	40	9.26 a	4.17 a	5.19 a
Applied 12 June	40	4.94 b	6.42 a	4.22 a
Applied 27 Apr and 21 May	40	9.55 a	5.01 a	4.51 a
Applied 12 June and 10 July	40	6.46 b	6.82 a	5.00 a

Mean separation within columns by LSD, 5% level.

[1] Fertilizer applied 1984; indicates total N applied for year.
[2] Values represent means for root, trunk and cane samples.

Table 2
Drip Irrigation N Trial
% N derived from ^{15}N-depleted labeled fertilizer in leaves sampled 18 July 84, 20 Sept 84 and 7 May 85; and root, trunk and canes sampled in dormancy

Fertilizer Portioning Treatments	Total N[1] Applied lbs/acre	% Fertilizer N Leaves 18 July 84	2 Sept 84	7 May 85	Roots/Trunk/Canes[2] Dormant
Check	0	0 b	0 b	0 a	0 b
1 application (27 Apr)	40	8.48 a	9.26 a	4.17 a	5.19 a
2 applications (27 Apr, 11 May)	40	8.53 a	9.55 a	5.01 a	4.51 a
8 applications (weekly, 27 Apr to 19 June)	40	8.68 a	9.10 a	5.80 a	4.78 a

Mean separation within columns by LSD, 5% level.

[1] Fertilizer applied 1984; indicates total N applied for year.

[2] Values represent means for root, trunk and cane samples.

Table 3
Drip Irrigation N Trial
% N derived from ^{15}N-depleted labeled fertilizer in leaves Sampled 20 Sept 84 and 7 May 85; and roots, trunk and canes sampled in dormancy

Time of Fertilizer Application	Total N[1] Applied lbs/acre	% Fertilizer N Leaves 20 Sept 84	7 May 85	Roots/Trunk/Canes[2] Dormant
Check	0	0 c	0 c	0 c
27 Apr to 19 June (weekly)	20	5.79 b	3.24 b	2.62 b
27 Apr to 19 June (weekly)	40	9.10 a	7.18 a	4.78 a

Mean separation within columns by LSD, 5% level.

[1] Fertilizer applied 1984; indicates total N applied for year.

[2] Values represent means for root, trunk and cane samples.

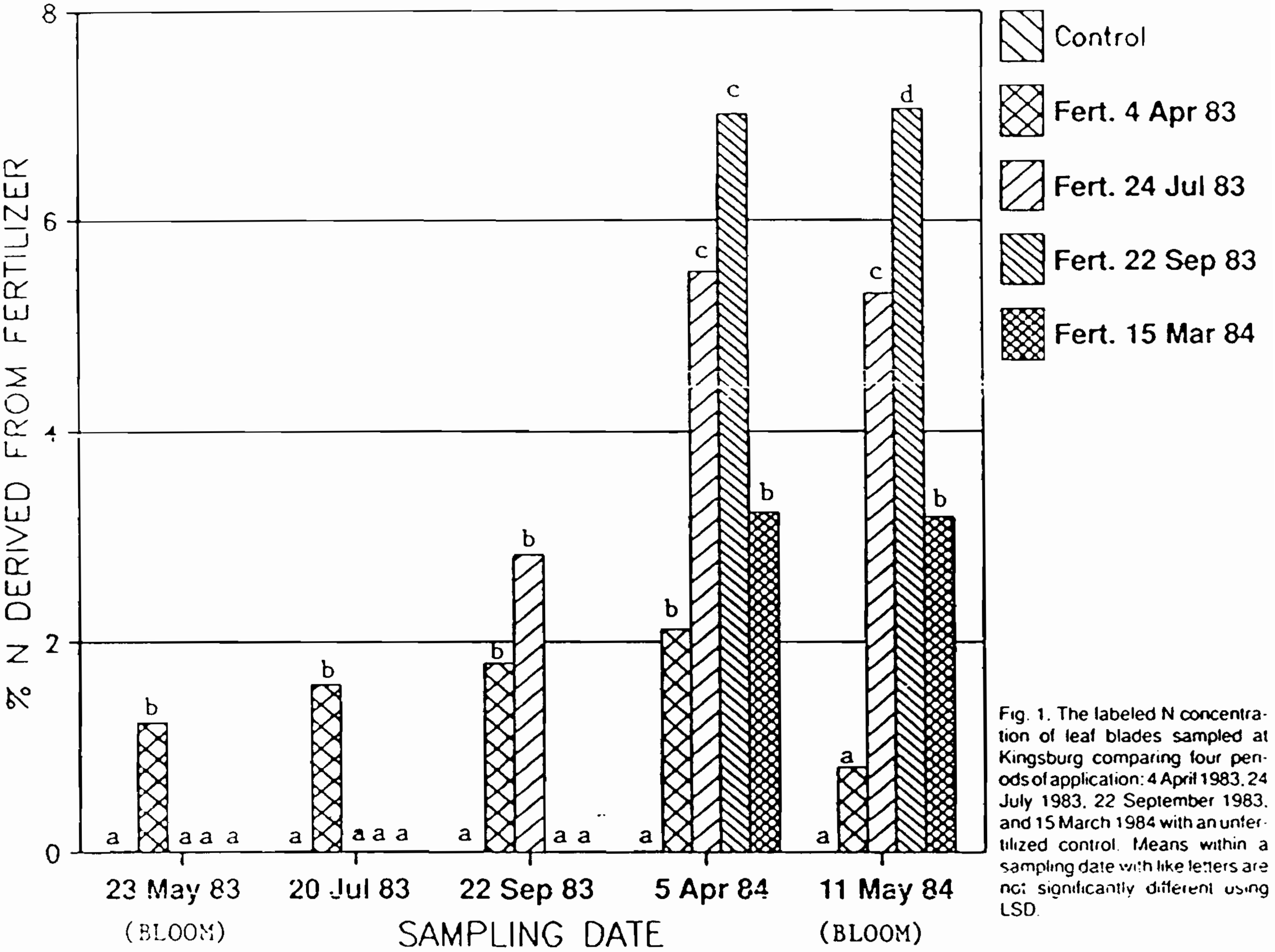

Fig. 1. The labeled N concentration of leaf blades sampled at Kingsburg comparing four periods of application: 4 April 1983, 24 July 1983, 22 September 1983, and 15 March 1984 with an unfertilized control. Means within a sampling date with like letters are not significantly different using LSD.

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LAND APPLICATION OF MUNICIPAL SLUDGE - BENEFITS AND CONSTRAINTS

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In 1975, a municipal sludge land application field experiment was initiated at the Moreno Field Station of the University of California located approximately 17 km south of Riverside, CA. In this experiment, a composted sludge and two liquid sludges were applied on a Greenfield sandy loam soil and a Domino silty loam soil at various solid loading rates. Following each application of sludge, crops were planted. At the third and eighth year of the experiment, sludge application at selected sections of the experimental field was terminated but the cropping on all the experimental plots continued to the present. Throughout the experment, the soil and the plants were sampled and assayed for potential contamination by the sludges. The purpose of this experiment was to assess the long term effects of municipal sludge land application on crop yields, soil properties, and accumulation of potentially hazardous heavy metals in the plant tissue.

As the residue of municipal wastewater treatment process, the sludge catches almost all of the potential pollutants removed from the sewage. These constituents may be categorized in the following manner:

biodegradable organic matter,

pathogenic organisms,

essential plant nutrients,
potentially toxic organic and inorganic substances, and
dissolved minerals

Any of the above categories of potential pollutants may limit the land application of municipal sludges. Results of the study indicated that:

1. Total biomass production from the sludge-treated soils is equal to or better than that of experimental control where chemical fertilizers were used for crop production.
2. Organic solids added into the soil through the sludge application significantly increase the soils' water holding capacity, and hydraulic conductivity and decrease the soils' bulk density and modulus of rupture.
3. Sludge application which introduces N in excess of the plant nutritional requirement always causes leaching of nitrate below the root zone.
4. Bacterial pathogens and virus present in the municipal sludges die off quickly in the soil and are no longer detected at the time of crop harvest. Ova of parasites, however, are detectable three months after the application of sludge
5. Through the sludge application, large amounts of heavy metals (Cd, Cr, Cu, Ni, Pb, and Zn) may accumulate in the surface layer of the soil where the sludge has been applied. Plants grown on sludge-treated soils usually contain greater amounts of Cd and Zn. The extent of Cd and Zn accumulation in the plant tissue is proportional

to amounts of sludge metal present in the soil and varies with the plant species. There is no indication, however, that the other industrial metals commonly appearing in the municipal sludges are accumulating in the plant tissue.

As other sludge constituents are readily assimilated by the soil, it appears that the heavy metal present in the sludge may limit the amounts of sludge applied to cropland.

RECLAIMED WATER REUSE IN SANTA ROSA

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Successful reclaimed water reuse in practice is exemplified by the Santa Rosa Subregional Water Reclamation System. The City of Santa Rosa, California, operates a subregional water reclamation system that reclaims wastewater from the Cities of Santa Rosa, Rohnert Park, Cotati, Sebastopol, and the South Park County Sanitation District. Advanced wastewater treatment is provided at the Laguna Subregional Wastewater Treatment Plant through the use of chemical addition and effluent filtration. The reclaimed water consistently meets California Title 22 Wastewater Reclamation Criteria for unrestricted reuse. The reuse options currently in place include pasture and hayland irrigation on City-owned and privately owned land, irrigation of privately owned vineyards and orchards, landscape irrigation of golf courses and commercial developments, and use of reclaimed water on demonstration-level created wetlands.

The Santa Rosa Subregional Water Reclamation System has a long history of successful reuse. The initial facilities were constructed in the mid-1970s and included the Laguna Treatment Plant, storage ponds, an extensive pipeline distribution system, and approximately 3,000 acres of agricultural reuse. The reclamation system has been expanded since initial construction to provide capacity for growth in the service area. The storage and distribution system consists of a series of 13 storage ponds, ranging in surface area from approximately 2 to 80 acres with a total storage capacity of about 4,600 acre-feet and a 15-mile delivery pipeline with outlets for each farm. The area receiving reclaimed water now consists of approximately 4,700 acres of agricultural land and two 18-hole golf courses.

The Santa Rosa Subregional Water Reclamation System is truly a cooperative-users agricultural system. The agricultural component of the current reclamation system consists of approximately 1,200 acres of city-owned and about 3,500 acres of privately owned land. The privately owned land is operated by over 35 individual cooperating farmers, each of whom has a contract with the city to receive reclaimed water. The cooperating farmers use reclaimed water for the production of pasture, legume silage, corn silage, grass hay, apples, and wine grapes. The city-owned land is leased to farmers who farm the site for production of annual bean/grass silage and grass hay. This combination of city-owned and privately owned land has provided a good mix for successful implementation of a reuse project.

In addition to the agricultural component of the subregional reclamation system, reuse is accomplished with the Mountain Shadows Golf Course reuse project in Rohnert Park. In this project, reclaimed water is used to irrigate two 18-hole golf courses, thus reducing the demands on the domestic water supply from both the Sonoma County Water Agency and the local groundwater basin.

The Subregional System is also pursuing the implementation of reuse through constructed wetlands. A demonstration wetlands has been constructed to document the wildlife habitat benefits and reclaimed water quality enhancement (polishing) achieved with wetlands reuse in the Laguna de Santa Rosa watershed. Also, another demonstration wetland has been established to document the capacity of a habitat enhancement wetland to treat liquid dairy waste.

Continued reclamation is the theme of the future for the Santa Rosa Subregional Water Reclamation System. The recommended alternative for the long-term improvements (providing capacity for 2010 design conditions) is to expand the reclamation system by adding more agricultural land (about 7,500 acres), implementing more landscape irrigation projects, and constructing wetlands in both the Laguna de Santa Rosa and Americano Creek watersheds for wildlife habitat enhancement. The long-term improvements are the subject of continued investigations through 1990, which will lead to facility implementation by 1995.

LAND TREATMENT OF HIGH-STRENGTH FOOD PROCESSING WASTEWATERS

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INTRODUCTION

Land treatment of wastewater is a long-practiced technology for pollution control. Since its infancy, much has been learned about the "science" of land treatment. As the critical interrelationships of the soil-plant system became better understood, it became clear that careful management of all elements of the system is necessary to effectively treat the wastewater. Systems that treat high-strength food processing wastewaters are especially subject to the need for site-specific design and a high level of wastewater and site management. Typical high values for BOD, suspended solids, total nitrogen, and sodium and a broad range of pH values in food processing wastes are critical factors that must be addressed in developing a site and the corresponding site management plan.

Effective site management and development is critical to the successful land treatment of high-strength food processing wastewaters. An effective site management plan can many times overcome the constraints of an otherwise unacceptable land treatment site.

Some of the special management techniques that may need to be addressed to develop a successful land treatment system for food processing wastes include the following:

- Physical modifications of the soil profile
- Modification of soil chemistry through soil amendments
- Pretreatment of the wastewater stream
- Special cropping programs
- Special site-specific wastewater application systems

Two case studies of successful land treatment systems are presented in the sections that follow to illustrate the implementation of these special management techniques.

CASE STUDIES

TOMATO PROCESSING--MERCED

Background

Using food processing wastewater for preseason irrigation of city-owned cropland has relieved seasonal overloading of the municipal system in Merced, California. During the noncanning season, Merced's wastewater flows are similar in volume and quality to what might be expected from a residential community of comparable size. However, during the peak canning season from mid-August to mid-October, the city generates waste loads that in some respects are equivalent to wastes of a city of more than five times its size. During the 1975 canning season, for example, flows to the city's wastewater treatment plant were more than double the 5.8 mgd (254 l/s) average daily flow, 5-day biochemical oxygen demand (BOD) increased more than seven times, and suspended solids increased more than four times over levels during the noncanning season.

CH2M HILL's facilities planning and environmental studies report identified three major grant-eligible alternatives for treating city wastewater. The treatment alternative selected was to treat the city's domestic flow prior to direct discharge and to exclude the food processing wastewater from the treatment plant. This seasonal food processing wastewater would then be applied to cropland, utilizing the soil and crops to provide the necessary nutrient removal. This alternative was chosen primarily because it minimized the need for adding costly and energy-intensive facilities to meet the revised discharge standards. The potential for further reducing the city's operations costs through revenues generated by the sale of crops irrigated with the wastewater was also an important consideration in the screening of alternatives. The elected plan was analyzed to show that it had the lowest total annual cost of the three choices.

Special Site Constraints

A 985-acre (398 ha) parcel adjacent to the city's treatment plant was chosen for the land application project. This site was selected on the basis of its development potential, its size and capacity to accommodate anticipated flows of up to 2.6 mgd (113 l/s), and its proximity to the treatment plant, which would simplify supervision of the operation and maintenance of the site.

A site-specific soils investigation was performed on the selected site. The site soils were poorly drained, and the surface soils were saline-alkali in nature. In addition, the presence of an undulating hardpan underlying the surface soils restricted the vertical movement of water in the profile.

Another major design consideration with the construction of the site was to protect the site and facilities from storm flooding by a creek bordering the site. In addition, the development of the site for crop production would remove an area of wetland habitat. Removal of the wetland habitat was a major environmental concern of the project.

Management Options for Mitigating Constraints

To mitigate the effect of the poor soil conditions on the site, the entire site was deep-plowed to a depth of 3-1/2 feet (1 m). Gypsum was added to improve the chemical balance of the soils. The deep-plowing operation was carefully controlled to avoid penetrating the underlying hardpan, thus minimizing the possibility of groundwater rising to the surface soil and becoming contaminated by the wastewater applied to the land. Significant earthmoving and regrading was required to that the wastewater could be distributed evenly on the site with a surface irrigation system.

The site was protected from storm flooding by grading contours and constructing drainage control structures to retain flood flows at the lower end of the site. The high flows are slowly released to the creek as the storm ends and the stream recedes. In this manner, flood conditions downstream can be regulated to they will not be more severe than conditions existing prior to the construction.

A 385-acre (155 ha) wetlands area was also constructed adjacent to the 600-acre (243 ha) land application site. The new wetlands replaced similar terrain that was developed for crop production. Secondary treated wastewater is supplied to the wetlands area by periodic pumping from the effluent channel at the city's wastewater treatment plant. The wetlands area is operated to enhance waterfowl and other indigenous wildlife. The design and management of the wetlands were in accordance with the planning efforts involving the U.S. Fish and Wildlife Service and the California Department of Fish and Game.

A grain or hay crop is planted each fall on the site for nutrient removal. The crop utilizes the applied nutrients from the previous summer's wastewater application. The land application facilities have been operational since 1979, and the city estimates that the annual gross operating costs of the land application program have been reduced by at least 40 percent through the sale of crops from the site.

WINE PRODUCTION--SALINAS VALLEY

Background

A winery in the Salinas Valley was producing a high-strength process wastewater and discharging the wastewater to the city sewer for ultimate treatment at the municipal treatment plant. Due to the high strength of the wastewater (BOD ranging from 3,000 to 5,300 mg/l and suspended solids ranging from 400 to 12,000 mg/l), an activated sludge pretreatment facility was operated by the winery to reduce the loadings to the municipal treatment plant. However, even with the pretreatment facility, overload conditions occurred at the municipal treatment plant during the crush season. In addition, the pretreatment facility required near 24-hour operation during the crush season, which presented significant operating costs and reductions in system reliability.

Growth projections by the winery indicated that the capacity of the pretreatment facility would be exceeded in 1984. Therefore, a land treatment system was selected to provide complete treatment and disposal of the winery process wastewater.

Special Site Constraints

The winery did not own sufficient land onsite to treat the process wastewater. In addition, it was desirable to locate the land treatment site in the surrounding agricultural area away from residential development of the city. A 110-acre (45 ha) site was identified approximately 2 miles (3.2 km) from the winery for use as the land treatment system.

The soils investigation identified four major soil types on the site. One of the major soil types consisted of enough clayey soil to significantly reduce the surface infiltration rate. In addition, approximately 40 percent of the site was underlain by a slowly permeable, hard, massive layer at depths ranging from 30 to 100 inches (76 to 254 cm).

This massive layer was a silica-indurated duripan, which was originally formed near the surface and was subsequently buried by alluvial deposition.

Management Options for Mitigating Constraints

Based on the field evaluation and discussions with local farm managers, the site has been ripped in three directions prior to establishment of a vineyard approximately 5 years previously. The investigation indicated that ripping the site did not significantly improve the filtration characteristics. To improve the soil infiltration characteristics, slip-plowing was recommended to modify the soil profile of the Danville and Placentia series soils. The slip-plowing was done on 6- to 8-foot (1.8 to 2.4 m) centers to a depth of at least 6 feet (1.8 m) unless limited by the duripan. The slip-plowing operation effectively mixed the clay subsoil with the more sandy substratum, creating uniform drainage channels within the profile.

To provide flexibility in the remote site operations and backup reliability for the system, approximately 90 days of storage was provided at the site. Floating mechanical aerators are used in the storage facilities to maintain dissolved oxygen levels.

The existing solid set irrigation system for the previous vineyard was retrofitted for use in the land treatment system. The sprinkler nozzle diameter was increased and screening capability was provided to reduce the chance of nozzle plugging.

The land treatment system has been successfully operating since 1982. Operation costs for the land treatment system are significantly less than the previous activated sludge pretreatment facility and subsequent treatment by the municipal treatment plant. Sufficient capacity is available at the site to provide for projected growth by the winery.

RECYCLING WOOD FUELED CO-GENERATION FLY ASH ON AGRICULTURAL LANDS

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Since the advent of wood-fueled electrical power generation plants in California nearly ten years ago, plant operators, potential users, and regulatory agencies have been concerned about the use of fly ash and other by-products. This presentation will give characteristics of several types of ash products and describe the soil-plant locations as well as the methods and rates of application to achieve increased crop growth in an environmentally sound manner.

It is important that wood-fueled power plant fly ash be distinguished from ash produced from other fuel sources, in particular, coal, sewage sludge or urban-waste fueled. The distinction is important because of the variety of chemical ingredients these other fuels introduce into the ash, chemicals which might not be present in wood-fueled power plant ash or present in substantially lower concentrations. For example, ash from coal, sludge or urban-waste may contain lead from paint and other heavy metals or toxic organics from plastics or petroleum products. Thus, the ash referred to herein will be wood-fueled power plant ash.

Wood ash is collected at various points in a boiler furnace system--from bottom ash collected beneath the fire box to multi-clone ash and fly ash cleansed from the flue gases escaping into the atmosphere. Depending upon the furnace type, its efficiency, and whether the collected ash is reinjected into the furnace for recombustion, the final ash waste product can be a gray to white colored, low carbon (<3% by weight) ash or a black, light weight, high carbon (30% or more by weight) ash.

The chemical composition of the two types of ash including the total elemental analysis is presented in Table 1. Two types of chemical analyses are performed on ash. Total element analysis, or total threshold limit concentration (TTLC), will characterize and help to determine the fertilizer value of a material. Soluble element analysis, or soluble threshold limit concentration (STLC), determines the soluble compounds in a material and is used to characterize what might leach out of the ash into streams, lakes, or ground water. Power plant operators routinely conduct STLC tests on their ash to

Table 1. Chemical composition of the two types of ash. All concentrations except moisture content are expressed on a 100% basis.

Element or Constituent	High carbon black ash Concentration, %			Low carbon gray ash Concentration, %		
	Range		Typical	Range		Typical
	Low	High		Low	High	
Moisture	22	66	45			
Inorganic	45	86	60	96.5	97.1	97.0
Organic**	9	65	40	2.9	3.5	3.0
pH (STLC)	10.5	13.5	12.0			
pH (Sat. paste)	7.9	10.0	9.5	9.6	9.9	9.8
Nitrogen (N)	0.03	0.43	0.20	.002	.004	trace
Phosphorus (P)	0.14	0.94	0.35	0.28	3.04	1.50
(P_2O_5)	0.32	2.14	0.80	2.18	6.91	3.41
Potassium (K)	0.31	5.04	1.50	5.70	22.00	10.00
(K_2O)	0.77	6.07	1.81	6.87	26.51	12.05
Calcium (Ca)	1.61	8.60*	3.00	5.00	17.70*	8.00
Magnesium (Mg)	0.10	2.20*	0.50	1.95	4.23*	3.00
Sulfur (S)	0.03	0.65	0.15	0.08	0.39	0.20
Iron (Fe)	0.08	1.60	0.50	0.59	3.52	2.00
Manganese (Mn)	0.06	1.47	0.30	0.20	2.10	1.00
Sodium (Na)	0.10	0.42	0.30	0.22	0.63	0.35
Chloride (Cl)	0.06	0.15	0.09			
Silicon (Si)				1.20	12.66	8.00
Aluminum (Al)				0.82	3.20	2.00
	Concentration, ppm			Concentration, ppm		
Zinc (Zn)	30	340	150	162	1220	400
Copper (Cu)	29	112	35	25	380	150
Boron (B)	35	190	100	120	1950	200
Selenium (Se)	--	<.5	<.5			
Lead (Pb)	<5	105	35	10	539	150
Arsenic (As)	<.5	35	<2	0.6	20	
Cadmium (Cd)	0.8	4.8	2	1.2	3.4	
Chromium (Cr)	7.0	35	20	10	92	
Molybdenum (Mo)	5.2	18.4	<5			

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* Calcium and magnesium concentrations are more variable depending on whether lime or other calcium and magnesium materials are injected into the combustion chamber.

**The organic fraction is determined by loss on combustion at 800-900° C.

satisfy Water Quality Control Board requirements. Concentrations are given as milligrams per liter (mg/l). Few routinely conduct total element analyses which are necessary to determine fertilizer value. TTLC concentrations are given as percentages for the major elements or parts per million for the minor elements.

The physical characteristics of ash affect the storage, handling, transport, and spreading of ash. Moisture content greatly affects the weight being transported and ease of handling and spreading. As the material becomes dry, the fine particles are easily picked up by the wind and/or moved by water. Herein lies several of the more serious and potentially undesirable environmental problems; the contamination of our air and water. Table 2 gives the particle size distribution of the high carbon black ash after it has been dried and sieved. In some cases, the bottom ash will have a significant amount of wood and bark, which may be several inches to a foot or more in length, and rocks several inches in diameter. These particles, larger than one inch in diameter, must be removed before application to agricultural land. Insufficient number of samples at this time makes it difficult to adequately characterize the low carbon gray ash other than to say it might be somewhat similar to agricultural lime.

One might ask about the quantities of ash being produced. A voluntary survey of several power plants in California in 1989 determined that 8,434 cubic yards of ash were being produced monthly from 208,000 bone dry tons (bdt) of fuel, approximately one cubic yard of ash per 24 bdt of fuel (4.17%). Perhaps as much as 95% or more of this ash is of the high carbon black nature with only 5% of the total being low carbon gray material. The California Energy Commission (1987) estimates biomass (largely wood) fueled power plant fuel consumption to be 5.28 million bdt/year. At 24 bdt/cubic yard ash, 220,000 cubic yards of ash would be produced every year in California.

Before farmers, ranchers, farm advisors, and consultants can determine the possible benefits from the application of ash to agricultural lands, several items should be evaluated. First is the fertilizer value and whether the soils to which the ash is to be applied are deficient in one or more plant nutrients. Second is the value that might accrue from the addition of organic matter to the soil. Third, if the ash has a very low carbon or organic content (<10%) it may have ability to serve as a potassium fertilizer and liming material.

One of the principal benefits of the black ash is its phosphorus, potassium, and other nutrient content. However, the breakdown of the material and release rate of the nutrients is very slow. Although the total concentrations are very low (<1-5%), applied at several tons per acre the ash does support or enhance plant growth when these nutrients are not adequately supplied by the soil. If the fertilizer value of the typical ash were to be calculated using the following prices; nitrogen (N) $.30/lb., phosphorus ($P_2O_5$) $.30/lb., and potassium ($K_2O$) $.20/lb., it would be worth $7.28/wet ton. Unfortunately, the organic fraction is usually so high and the nitrogen and other nutrient content so low that soil microorganisms generally will need to acquire nitrogen and perhaps other nutrients from the soil to decompose the ash. This results in reduced supplies of soil nitrogen being available to a growing crop and additional nitrogen will be required to support plant growth. Legumes which biologically fix atmospheric nitrogen or fertilizer nitrogen sources can be used to supply the needed nitrogen for crop growth and microbial decomposition of the ash. The fly ash can also be applied a number of months before planting the crop to allow sufficient time for its partial decomposition. Based on the chemical composition, ash products should be applied to the more acidic soils which are low in potassium and perhaps phosphorus and sulfur. Acid forest and range as well as acidic cultivated soils are the most suitable sites on which to apply ash.

Table 2. Physical composition of the high carbon black ash.

	Range		Typical
Characteristic	Low	High	
Moisture, %	22	66	45
Inorganic, %	45	86	60
Organic, %	9	65	40
Particle size:			
>5 mm	1	28	16
2-5 mm	5	27	13
1-2 mm	4	11	6
<1 mm	45	87	65

Forage yield results following the application of high carbon black fly ash are given in Table 3. The two locations in Mendocino County are rangeland sites having native species of grasses, forbes and legumes along with some introduced species, primarily subterranean and rose clovers. The locations in Plumas and

Sierra Counties are irrigated pastures having largely native grasses and forbes with very few legumes. It can be noted that at some locations rather large yield responses were observed, whereas at others little or no forage yield increases occurred. Where a response was observed, several ingredients are usually present: (1) the presence of legumes to fix nitrogen for the grasses and forbes to utilize, and (2) a location where additional and more readily available supplies of phosphorus, sulfur, potassium, and perhaps other nutrients are being supplied to growing plants than the soil might provide.

Table 3. Forage yield responses in tons dry matter per acre (DM/A) to soil surface applications of high carbon black wood fuel-fly ash at several locations in northern California counties.

	Mendocino		Plumas, 1990**			Sierra, 1990**		
			Meadow Valley			Sierra Valley		
Ash applied (tons/acre)	Springs	Little Valley	1984	1990	89 & 90	1989	1990	89 & 90
0	1.39	4.34	1.04	1.04	1.04	.78	.78	.78
4	1.88							
8	2.24							
16	2.42		1.44	1.41			.77	
24						.78		
32	2.17		1.76	1.43	1.77		.79	
40								.85
48						.71		
64	2.11	5.29			1.80			
80								.82
128		5.91						
256		5.72						
512		6.12						
1024		6.19						
		(25)*	(57)	(35)		(63)	(36)	

* Ash moisture content at time of application.

** Yields are for 1990 from ash applications made in 1989, 1990 or 1989 plus 1990.

The addition of organic matter to soils often improves several physical characteristics such as tilth or ease of tillage, water infiltration, increased microbial population which usually aids in soil aggregation and improves soil structure, increased cation exchange capacity and greater nutrient cycling. Even though these improvements in the soil physical and chemical properties are sometimes dramatic and increase the ease of tillage and management, they often result in little or no increase in crop productivity. Unfortunately, the cost and difficulty of transporting, handling, and spreading bulky materials like fly ash result in a small or even negative return on the investment for a farmer or rancher.

Some experimental work has been done to evaluate the black high carbon ash alone as a "soil" material. When applied on land to a depth of 18 to 20 inches, allowed to be leached by rainfall to remove the soluble alkaline (sodium, potassium, calcium, magnesium) oxides, and then seeded to clovers and grasses, the ash produced a large forage yield increase of about two tons per acre (Table 3, Little Valley site). In this situation, the soluble phosphorus, potassium, sulfur, and other nutrients from the ash were taken up by the subterranean clovers which, in turn, fixed large amounts of nitrogen for both the clovers and grasses to grow. At another site, the clover-grass seed mix was placed in contact with the unleached ash and the soluble toxic alkaline oxides killed the germinating seedlings.

To minimize the undesirable aspects of fly ash being moved by wind or water, it should generally be applied at rates less than approximately 30 tons wet material per acre. This is assuming that growing plants or plant residues measure about 2-6 inches in height so that winds will not pick up and blow the dry ash to unwanted locations like streams, water courses or into the atmosphere. If the fly ash is applied to cultivated soils, rates up to 250 tons per acre or more (2-4 inches depth) may be spread and incorporated into the soil. Higher rates or greater depths of fly ash may be difficult to incorporate. This should be done several months prior to planting a crop since soil microorganisms will require nitrogen from the soil to initiate the decomposition process.

Perhaps the greatest challenge with fly ash handling is the transportation to and storage at the field site. Since the spreading rates are rather high, large amounts of material need to be stored on site before it becomes economical to bring in spreading equipment. During this time of several weeks or even months, the fly ash will dry and the fine particles be picked up by wind and possibly even result in "black clouds" being moved some distance from the point of storage. Locating the storage point where the fly ash will be protected from movement by wind or water is essential to prevent unwanted environmental contamination.

The low carbon (<3-5%) gray ash consists primarily of ash from the bottom of the furnace after near complete combustion of all organic matter. It will usually be quite high in calcium, potassium, magnesium, silicon and aluminum, primarily in the oxide form. Its principal use is as a potassium fertilizer and liming material. As such, it should be applied to acid soils having a pH below 6.5 which are also low in potassium for the greatest benefit in increasing crop growth response. Rates of application of liming materials are determined by use of a soil test and the calcium carbonate equivalent of the liming materials. For greatest crop growth benefit, lime and potassium fertilizers should be incorporated into the soil to a depth of at least 6 inches. Possible exception to the need for soil incorporation would be for the growth of some legumes, particularly the shallow rooted subterranean and rose clovers.

BIOREMEDIATION AS A TECHNOLOGY TO DECONTAMINATE WASTES

by
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Bioremediation of hazardous wastes is becoming a popular mitigation alternative in cleanup of pollution. This technology is simple to maintain, applicable to large areas, requires low costs for maintenance, and involves complete destruction of the contaminant. Other cleanup techniques often include immobilization, fixation or transport to Class II landfills. However, with the new enacted legislation ("Land Ban") prohibiting disposal of metals-, solvents-, and petroleum hydrocarbons-contaminated soil in landfills, bioremediation is becoming even more popular and now accepted by the regulatory agencies. This presentation will focus on bioremediation of petroleum hydrocarbons and the metalloid, selenium. Bioremediation of petroleum hydrocarbon-contaminated soil can be accomplished by adding biostimulating agents such as fertilizers (nitrogen and phosphorus), enhanced aeration, moisture, and high temperatures. In subsurface spills, hydrogen peroxide may also be added in providing an oxygen source for the oxidation and breakdown of long-chain aliphatic compounds and ring fission. Environmental conditions which promote bioremediation of seleniferous soils include selective carbon sources (e.g., proteins and pectin), aeration, moisture and high temperatures. Laboratory and field projects will be discussed as they pertain to bioremediation of these pollutants.

REDUCTION OF HERBICIDES IN RICE FIELD DRAIN WATERS OF THE SACRAMENTO VALLEY

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California rice is irrigated from rain and snowfed catchments of the Cascade, Klamath and Sierra Nevada mountain ranges. Irrigation water flows through a complex network of supply and drain canals and excess water is returned to the Sacramento River and its tributaries. Rice herbicides used for weed control have polluted downstream waters used for public consumption. The purpose of these studies was to monitor the levels of herbicides at various points in the irrigation network; and to establish voluntary and regulatory programs to mitigate off-site movement of these chemicals. From 1982 to 1989 herbicide levels were reduced by 95% or more.

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ALFALFA IRRIGATION FOR SEED PRODUCTION

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Relatively mild water stress can cause alfalfa (*Medicago sativa L.*) hay/forage production to decline. Controlled moisture stress is an important component for optimum alfalfa seed production, but little information is available to quantify the plant water status necessary to achieve this goal. This two-year large-scale field study was initiated in 1988 to establish an optimum water management for alfalfa seed production. Four contrasting irrigation treatments were imposed on a Tulare clay loam (fine-loamy, mixed [calcareous] thermic Typic Torriorthents) in the San Joaquin Valley, CA. Soil water content was measured with a neutron probe and plant water status was monitored with pressure chamber, diffusion porometer, and canopy temperature measurements. Actual crop evapotranspiration was occasionally measured with a Bowen ratio procedure. Maintaining high available soil moisture lowered seed production as did severe water stress. Allowing midday leaf water potential to drop to -2.7 MPa prior to irrigating resulted in the highest seed yield (0.93 Mg ha^{-1}). Plant-based water status measurements provided a good base for irrigation scheduling.

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GRAIN DISTRIBUTIONS IN MAIN SPIKES OF SALT-STRESSED WHEAT: A PROBABILISTIC MODELING APPROACH

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Mexican semi-dwarf wheat cultivars, 'Yecora Rojo' and 'Anza' were grown in greenhouse sand cultures under saline and non-saline conditions. This paper investigates the changing grain set and individual grain mass patterns occurring along the main spike between the control treatment (osmotic potential = -0.05 MPa, electrical conductivity of the irrigation water = 2.0 dS/m) and a saline treatment (O.P. = -0.65 MPa, EC_{iw} = 14.3 dS/m). Multiple linear regression models are used to describe the individual grain mass patterns; these grain mass patterns are shown to be highly deterministic once the grain locations along the spike, the grain locations within a spikelet, and the grain mass potential for the plant are specified. The grain occurrence patterns are also shown to be dependent on a similar set of variables through the use of logistic regression modeling. both types of statistical analyses are advantageous since changes in grain set and grain mass patterns can be easily detected and studied. Additionally, the above mentioned results can be incorporated into a probabilistic model which can stochastically simulate main spike grain set and grain mass development.

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YIELD COMPONENTS OF MAIN SPIKES IN SALT-STRESSED WHEAT

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The Mexican semi-dwarf wheat cultivars, 'Yecora Rojo' and 'Anza' were grown in greenhouse sand cultures. Two saline treatments (osmotic potentials = -0.65 and -0.85 MPa; electrical conductivities of the irrigation waters = 14.3 and 18.1 dS/m, respectively) were compared with a non-saline control (O.P = -0.05 MPa; EC_{iw} = 2.0 dS/m). Main stem yield components as well as patterns of grain set and individual grain weight, conditional on position along the spike and within the spikelet were determined. For both cultivars, the number of spikelets and grains per spike decreased with increasing salinity. However, at -0.65 MPa, main spike grain yield increased 20% over the control values. Increased grain set per spikelet together with increased grain size contributed to yield enhancement in Yecora Rojo. Yield increase in Anza (-0.65 MPa) occurred solely as a result of increased grain size. At -0.85 MPa, both grain set and grain size of Yecora Rojo were sharply depressed and grain yield was 47% of the controls. Anza was less sensitive; yield from the -0.85 MPa treatment was not significantly different from the controls.

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LEAF AND TILLER DEVELOPMENT ON SALT-STRESSED WHEAT GROWN IN THE GREENHOUSE

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Studies were conducted in greenhouse sand cultures using two semi-dwarf wheat (*Triticum aestivum L.*) cultivars, 'Yecora Rojo' and 'Anza' to determine the effect of salt stress on leaf and tiller development. Saline treatments were imposed by irrigating with water that contained NaCl and $CaCl_2$ (1:1 by wt). Electrical conductivities of the irrigation waters were 2.0 (control), 14.3, and 18.1 dS/m. Increasing levels of salinity significantly reduced the number of leaves on the main stems of both cultivars. However, the number of thermal units needed to produce each leaf (the phyllochron) increased with increasing salinity. tiller initiation and survival for both cultivars were severely affected by salinity. Data from this study will be compared with field plot data to evaluate their reliability for the development of wheat growth simulation models.

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LEAF AND TILLER DEVELOPMENT ON SALT-STRESSED WHEAT GROWN IN FIELD PLOTS

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Two semi-dwarf wheat (*Triticum aestivum L.*) cultivars, 'Yecora Rojo' and 'Anza', were grown in artificially salinized field plots to determine the effect of salt stress on leaf and tiller growth and development. Saline treatments were imposed by irrigating with municipal water salinized with NaCl and $CaCl_2$ (1:1 by wt.). Electrical conductivities of the irrigation waters were 0.9 (control), 11.3, and 17.5 dS/m. Increasing salt stress significantly decreased the rate of leaf growth but did not consistently decrease the number of leaves in either cultivar. However, salt stress markedly reduced the number of tillers that were initiated and the number of heads that developed and matured. The growth and developmental data derived from this study will be used in the development of a wheat growth simulation model (SWHEAT) that responds to soil salinity stress.

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AMMONIUM-POTASSIUM AND AMMONIUM-CALCIUM EXCHANGE IN RHIZOSPHERE AND BULK SOIL OF ARBUCKLE GRAVELLY LOAM

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Comparative studies of cation exchange equilibria involving ammonium in rhizosphere and bulk soil are important in order to understand the nutrient distribution and leaching phenomenon in a drip irrigation system where a large amount of ammonium fertilizer is applied. Peach (*Prunus persica* cv. Lovell) seedlings were grown in pots for 5 months in the greenhouse to obtain rhizosphere and bulk soil samples. Cation exchange equilibria were measured by leaching each soil with series of solution containing NH_{4+} and K^+, and NH_{4+} and Ca^{2+} in which the composition varied. Cation exchange isotherms and selectivity coefficients will be presented and the effects of rhizosphere soil conditions on cation exchange will be discussed.

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N-FORMS AND MYCORRHIZAL INOCULATION EFFECTS ON GROWTH AND NUTRIENT ACCUMULATION OF COFFEE SEEDLINGS

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A greenhouse experiment was conducted in an acid soil (ph 4.25) for four months to evaluate the effects of different N-sources, NH_4-N, NO_3-N and a mixed NO_3+NH_4-N, and mycorrhizal inoculation (*Glomus intraradices*) on the growth and nutrient content of young coffee seedlings (*Coffea Arabica L.* cv Guatemala). Shoot and root dry weights were significantly higher for mycorrhizal plants fed mixed N and NO_3 compared to non-inoculated counterparts (29% and 36% respectively). Ammonium and NO_3+NH_4-N fed coffee seedlings also grew significantly better than those fed NO_3-N (64.7% and 35.3% respectively). Mycorrhizal inoculation resulted in higher plant N, Ca and Mg accumulation but lower tissue Mn concentration. Mycorrhizal symbiosis was apparently established after 2 months. N sources and mycorrhizal inoculation significantly altered rhizosphere soil properties such as pH, exchangeable acidity and ext-Al.

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REVEGETATION OF DISTURBED SOILS WITH TOPSOIL AND FERTILIZER AMENDMENTS

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The variation in N and P pools, mycorrhizal infection and plant growth was evaluated following various fertilizer and/or topsoil applications to the unweathered geological material exposed during highway construction. Nutrient pools were defined operationally: total, mineralizable, extractable, and microbial N; total, inorganic, organic and total P; organic and total C. Treatments included O, 5, 20, 40, 60% vol/vol additions of topsoil to the unweathered geological material and/or o, 1, or 2 times the standard fertilizer application rate of 150 lb/ac of 10-20-0 and 200 lb/ac of 0-20-0. Plant biomass increased with percentage of topsoil added in all treatments. Mycorrhizal infection was depressed with higher fertilizer amendments, but the infected root weight was greatest in the single fertilizer treatment.

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MODIFIED INGROWTH CORES FOR EVALUATING ROOT RESPONSE TO ACID CONDITIONS

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High rates of urea application in a drip irrigated almond orchard has resulted in an acidic drip zone. The Arbuckle gravelly loam (fine-loamy, mixed, thermic Typic Haploxeralf) has pHs as low as 3.6. To evaluate the response of almond roots to low pH, a root ingrowth core technique was used. Moist soil acidified to pH 4.5 was packed in a polyethylene mesh (0.7mm) cylinder 10 cm in diameter and surrounded by a larger cylinder 15 cm in diameter and 20 cm high. Untreated soil was placed in the larger cylinder surrounding the treated soil and used as a spatial control on root growth and density. The cores were frozen (Henderson and Krstansky, 1989) and placed in the drip zone. Design and construction of the cores will be presented.

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HERBICIDE USE, IRRIGATION PRACTICES AND GROUND WATER CONTAMINATION IN A CALIFORNIA CITRUS GROWING REGION

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Widespread detection of herbicide residues in well water has been reported in a major citrus producing area of California. The California Department of Food and Agriculture conducted a mailing survey of citrus growers in Tulare to identify and characterize irrigation and herbicide practices that might be associated with reported well water contamination. Forty-one percent of the 1500 citrus growers responded to the survey. Ranking of herbicide importance to growers paralleled the frequency of detections in well water samples: simazine > diuron > bromacil. The relationship between use of irrigation and frost protection systems and ground water contamination was examined. A significant positive regression at $\alpha = 0.05$ was measured for citrus growers using irrigation water for frost protection. A low response rate to questions dealing with non-chemical weed control practices suggests that the citrus growers surveyed rely almost exclusively on chemicals for weed control.

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WATER MANAGEMENT EFFECTS ON WEED CONTROL AND CROP PERFORMANCE IN CALIFORNIA RICE PRODUCTION

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Several tools are in use or under development to mitigate offsite movement of rice herbicides in field drain waters. These include regulations on outflows, irrigation system design changes, and innovative cultural practices coupled with reduced herbicide use. Pilot field studies and follow-up demonstrations have shown that deep water (approx. .18m) gives a high degree of control of certain common rice paddy weeds, providing an opportunity to use less chemical herbicide. Rice yield in deeper water is, in most cases, equal to the yield of rice grown in shallower water (.10 to .13m) although deeper water may reduce stands. Weed species response, rice agronomic performance and cultivar tolerance to various water management strategies will be discussed. the importance of in-field water management for weed control and residue management and barriers to use of deep water will also be covered.

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TRAINING AND PRUNING HEDGEROW ALMONDS

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In 1979 a Nonpareil-Price almond orchard, was planted 2.2m x 6.7m (270 trees/acre). Four pruning treatments were imposed on the hedgerow planting at the end of the first year. 1. Interplanted: Trees trained to 3 scaffolds then standard pruned 2nd-6th years. Alternate trees were whisked back during 7th and 8th years and whisked trees removed after 9th year. 2. Permanent Hedge: Trees trained to 3 scaffolds and standard pruned throughout. 3. Two Scaffold Hedge: Heavy 2nd and 3rd year training required to form 2 main scaffolds growing into the row middles then standard pruned. 4. Unpruned Hedge: Trees trained to 3 scaffolds then no further pruning. Treatment with alternate trees whisked back had 15% reduced yield each year following whisking. Removing these heavily pruned alternate trees at the 9th year then reduced yields an additional 30%. Now, three years after removal, yield still lags by 18%. Accumulating six years yield data shows no differences between the three treatments maintained as hedgerows. However, whisking and removing alternate trees resulted in 2000 lbs less yield over the 6 year period.

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GROWTH HABIT TRAIT NOMENCLATURE IN ALMOND AND PEACH PHENOTYPES

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Almond (*Prunus dulcis* MIll) and peach (*Prunus persica* L.) are closely related species with many genetic traits in common. Variation in growth habit shows a consistent pattern among populations of peach, almond and their hybrid offspring. From this material a system of growth habit traits has been identified based upon genetically controlled processes of vegetative shoot elongation and flower bud initiation. All flowers are produced from lateral buds. The classification proposed for their characterization includes:

Class I. Growth from terminal buds on one year old shoots (six morphological groups),

Class II. Growth produced from lateral buds on 1-year old shoots (three morphological groups),

Class III. Combinations of Class I and II.

These classes cover the entire range of peach and almond phenotypes and probably all *Prunus*. Class I is precocious and produces flowers by the second year from growth initiation. Class II plants do not produce flowers until the third year. Expression is enhanced by increase in vigor.

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COPPER DEFICIENCY IN CALIFORNIA WALNUT

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Initial leaf tissue analysis indicated that the degree of distortion and dieback in a young walnut orchard was correlated with decreasing amounts of Cu in the leaf. Complete correction of Cu deficiency was obtained for two years when high rates of Kocide 101 were used or when low rates were applied repeatedly each year. Soil treatments gave partial correction; soil injected treatments showed continued improvement over time. Tissue analysis for Cu correlated well with the degree of distortion and dieback in the trees. Critical Cu levels in the walnut kernel were 4 ppm and 3 ppm in the leaf. Kernel and leaf tissue levels were highly correlated. Shriveling of the kernels was the main nut quality symptom associated with Cu deficiency. High rates of foliar or a combination of foliar and soil treatments may give the best results in young trees. Once trees are in production, the standard yearly Cu program for walnut blight control should provide adequate Cu deficiency correction.

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HORTICULTURAL AND ECONOMIC COMPARISON OF HAND VERSUS MECHANICAL PRUNING IN A HIGH DENSITY FRENCH PRUNE ORCHARD

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French prunes (*Prunus domestica* L.) on myrobalan seedling rootstock were planted in 1981 in an east-west direction with 4.9 m between rows and 2.7 m between trees on a poorly drained Class II soil in Glenn County, CA. A randomized complete block design was used with 8 trees per plot. Trees were pruned by hand to an open-center tree form or pruned by machine to a pyramid form in the dormant or summer season resulting in 6 pruning treatments. This high density system has led to high yields of good quality fruit (9.18 dry tons/acre in 1989, sized at 78 fruit per pond). Hand pruning led to higher yields, larger fruit, lower drying ratios and a greater dollar return per acre than any of the machine pruned trees. Dormant machine pruning led to larger fruit produced than those trees pruned in the summer by machine. Mechanical pruning may be possible for short time periods, but continued practice led to smaller fruit with lower yields than hand pruning. Certain locations within the tree canopy had smaller fruit size and it is within those lower locations where fruit size needs to be improved. These and additional experimental results obtained from 1987 through 1989 growing seasons will be presented.

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EFFECTS OF FIRE ON SOIL MORPHOLOGY AND MINERALOGY IN AN OAK WOODLAND

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Fires are a widespread phenomenon in wildlands of the western U.S. The objective of this study was to determine the effect of fire on soil color, pH, texture, and clay mineralogy. Samples were collected from the surface 10 cm of a loamy, mixed, thermic Lithic Haploxeroll derived from granitic parent material before and after prescribed burning in an oak (*Quercus* sp.) woodland in the Santa Rosa Plateau of southern California. The most striking effects were found in soils located under fallen logs that burned thoroughly, leaving 1 - 5 cm of white ash on the surface. Beneath this ash the initially dark brown soil (10YR3/3) had been reddened in the upper 5 cm to strong brown (7.5YR5/6) underlain by 4 15 cm of black (10YR2/1) less intensely burned soil. The pH incrased from 7.0 in the unburned soil to 10.2 in the reddened layer and 8.5 in the black layer. A significant ($p=0.05$) decrease in the clay content (from 13 to 6%) was measured for the reddened, most severely burned layer. The clay fraction of the unburned soil was dominated by biotite and kaolinite. In the reddened layer, the kaolinite decomposed, while biotite persisted. There were no detectable changes in soil morphology or mineralogy in the adjacent burned grassland soil.

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TRAFFIC TOLERANCE OF COOL SEASON GRASSES OVERSEEDED ON COMMON BERMUDAGRASS

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A study was conducted to identify traffic tolerant cool-season turf species suitable for use in winter overseeding of common bermudagrass, *Cynodon dactylon* (L) Pers. Mature bermudagrass was overseeded with 'Caliente' and 'Elka' perennial ryegrass (*Lolium perenne* L.). Annual ryegrass (L. *multiflorum* Lam.), 'Rebel II' tall fescue (*Festuca arundinacea* Schreb.), 'Shadow' Chewings fescue (*F. rubra* var. *commutata* Gaud.), 'Flyer' creeping red fescue (*F. rubra* L.), and rough bluegrass (*Poa trivialis* L.). Rough bluegrass was seeded at 1.46 kg/are and the others at 4.88 kg/are. Traffic was imposed with a Brinkman Traffic Simulator (BTS) during the winter and spring. Traffic tolerance was determined through periodic visual rating of turf quality. The ryegrasses exhibited excellent tolerance, particularly Caliente. Rebel II tall fescue had good tolerance, while the fine fescues were only fair. Rough bluegrass had virtually no tolerance.

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WINTER COLOR OF BERMUDAGRASSES IN SOUTHERN CALIFORNIA

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Common and hybrid bermudagrass (*Cynodon spp. L.*) are well adapted for turfgrass use in much of California. They are resource efficient grasses and resistant to most turfgrass pests. The lack of widespread use of bermudagrasses is in part due to their dormancy during winter months. Thirty-two cultivars and lines were examined for dormancy patterns and winter color at two locations in Southern California. Of the environmental parameters examined, a mean soil temperature at 10.2 cm was the most reliable predictor of dormancy. Below 10° C for more than one week, all grasses were dormant. Hybrid bermudagrasses retained color better than the common bermudagrasses. Of the hybrids, Santa Ana, Tifway, Tifway II and MSB10 gave best winter color.

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RELATIONSHIPS BETWEEN ENZYME ACTIVITIES AND SOIL TILTH IN ORGANIC AMENDED SOIL

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Soil enzymes involved in nutrient cycling have an important role in the formation of recalcitrant organic molecules which contribute to the chemical stability of the soil ecosystem. The activities of 10 soil enzymes involved in C, N, P and S cycling were assayed in an Arlington coarse-loamy soil which had received 100 Mg ha^{-1} of either poultry manure, sewage sludge, barley straw (*Hordeum vulgare*) or alfalfa (*Medicago sativa*) over a 31-month time period. Incorporation of the four amendments increased soil aggregate stability, respiration, water infiltration rates, moisture content, enzyme activities and decreased bulk density. Enzyme activity in the amended soil was increased 2x or 4x over the check plot. Correlation and multiple regression analyses showed that acid phosphatase, arylsulfatase, β-glucosidase and urease activities were significantly related to increased aggregate stability. The activity of the carbon-cycling enzymes was high in the plant material and may significantly contribute to the cycling of plant residues in soil.

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