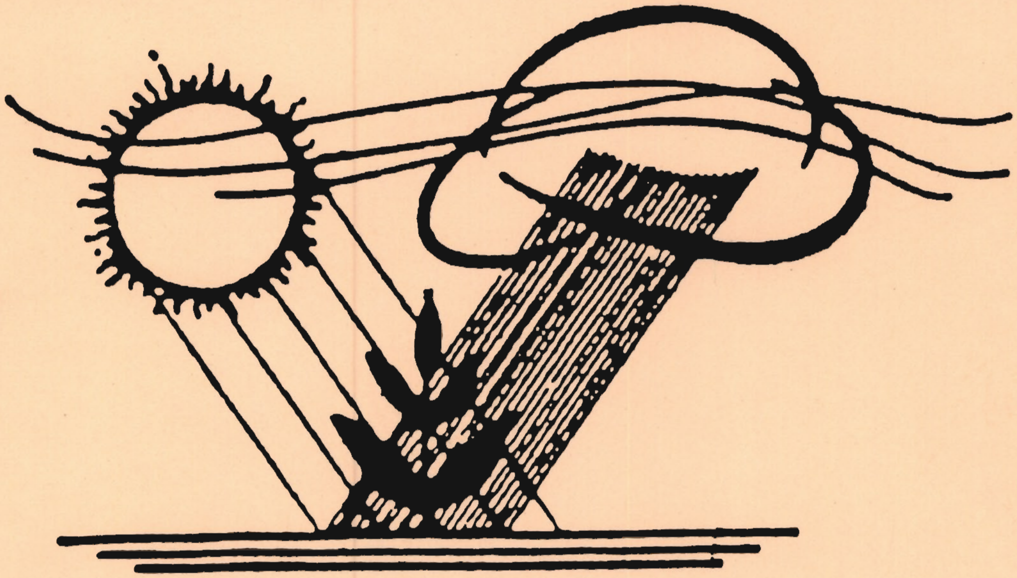
Proceedings

1996

California Plant and Soil Conference

Integrating Resources for Agricultural Production



California Chapter of American Society of Agronomy
and
California Fertilizer Association

January 17 and 18, 1996

Red Lion Hotel
1150 Ninth Street
Modesto CA 95354

PROCEEDINGS
1996
CALIFORNIA PLANT
AND
SOIL CONFERENCE

INTEGRATING RESOURCES FOR AGRICULTURAL PRODUCTION

CALIFORNIA CHAPTER
OF
AMERICAN SOCIETY OF AGRONOMY
AND
CALIFORNIA FERTILIZER ASSOCIATION

JANUARY 17 & 18, 1996

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THE LAND GRANT COLLEGE OF AGRICULTURE—NOTHING FAILS LIKE SUCCESS

James H. Meyer
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Massive changes occurring in the agricultural industries and expanding social interest in environmental quality, food safety and competition for natural resources, along with population pressures, are making it evident that Land Grant colleges of agriculture must reorganize to address a broader interface of both agriculture-related issues and others relevant to society in general. The Land Grant college of agriculture, whose past successes in serving the public interest have been so remarkable, faces a dilemma as it attempts to respond to changing directions, eliminating programs and adding new ones. This presentation addresses how the Land Grant college of agriculture might face these challenges.

Why does such a dilemma exist for these colleges? Farming has changed. Farmers, who are now a small minority in this nation, stand at one end of a continuous food and fiber system. Consumers occupy the other end. A large cadre of in-between businesses and industries provides inputs into the system and processes and distributes food to the consumer. Furthermore, farmers are responsible for managing a very large proportion of the natural resources of this country—land and water in particular. Mistakenly, the general public does not seem to appreciate the bountiful and healthful food supply available to them. Rather, the urban public tends to see farmers and ranchers primarily as competitors for natural resources, not as competent managers and stewards of them.

I have recently interviewed 23 deans of colleges of agriculture across the country as representatives of what is going on. The deans report a greater emphasis on consumer and urban issues and consider the clientele of their colleges to be the farmers, agribusiness and industry, environmental interests, governmental agencies, financial institutions, food processors and retailers, urban interests and the general public. Regrettably, few external advisory committees contain members who represent groups other than the first two. Many deans avow greater interest and efforts in environmental problems, a relatively new phenomenon.

Meanwhile, fewer personnel are doing teaching, research and outreach in agriculture-related disciplines. There are other important trends, too: in teaching, fewer and fewer students are majoring in agriculture because of the decreasing rural and farm population and little interest shown by urban students. In research, a relatively recent trend is towards more fundamental and adaptive research by industry and extension. In extension, farmers and agricultural industries are relying less on Cooperative Extension and instead get much of their information from the media, consultants, commercial organizations and professional journals.

What is the remedy? These colleges need to escape from old ideas, which means escaping from old organizations built on the past, and develop brand new policies, goals, missions and organizations. A learning organization, under competent leadership, can renew the organization by determining the clientele's and patrons' interests and concerns in the specific region or state and aligning the college's mission to serve those needs. The domain of the Land Grant college of agriculture includes the system of land custodians; that is, the custodian farmer and the agribusinesses that supply the inputs, consumers, community services, food safety interests, water quality, economics, energy consumption, biotechnology and environmental concerns are all part of this domain. The challenge is to organize to address these areas.

INTEGRATING STAR WARS TECHNOLOGIES INTO AGRICULTURAL PRODUCTION SYSTEMS

Stephen L. Rawlins, Chief Consultant
Appropriate Systems, Richland, WA[1]

INTRODUCTION:

For both economic and environmental reasons, farmers try to reduce the use of chemicals, water and other inputs to cropped fields to the bare minimum. Over the years, farm equipment has been perfected to uniformly apply inputs to entire fields, but the productive capacity within fields is not uniform. The goal of *precision farming* is to apply chemicals, water, seeds or other inputs to fields in quantities sufficient to meet the demands of the crop growing on each square meter of the field in a timely manner, with no excess. The lack of position sensing technology has seriously hampered progress.

The same technology that gives the military the precision targeting capability to guide missiles down the air vents of enemy buildings, global positioning systems (GPS)[2], is now making precision targeting of inputs to and accurate mapping of yields within a field possible.

The concept of precision farming is neither new nor complicated. For years dairy farmers have weighed each cow's daily milk production to determine how much grain to feed her. Initially the decision process was rudimentary. If a cow produced a full bucket of milk, she got a full scoop of grain. For a half bucket of milk, she got half a scoop of grain. Today's dairies are highly automated with sensors to identify individual cows and to measure milk production, computers to keep track of production and to compute appropriate rations, and automated machines to deliver the prescribed ration to each cow while she is being milked. Matching inputs to production capability is what precision farming is all about.

BASIC CONCEPTS:

While serving as National Program Director for Natural Resources on the USDA-ARS Headquarters National Program Staff in 1983, I developed a concept paper entitled "The Use of Computers and Sensor Technology to Build Systems that Close the Gap Between Science Information and Farm Application." Many of the basic concepts underlying site-specific

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[1] Former Research Scientist and member of USDA's Agricultural Research Service. National Program Staff .

[2] The global positioning system (GPS), developed by the Department of Defense, uses radio signals from (currently) twenty five satellites circling the earth to determine latitude, longitude and elevation of any point on the Earth's surface with a precision approaching one centimeter. Developed by the Department of Defense, this technology is now commercially available for civilian use at a cost that now makes yield mapping and variable rate application possible.

farming were developed in that paper, which is quoted in its entirety in Rawlins and Reep (In Press). Here are a few excerpts from that paper to illustrate these concepts as seen from a 1983 perspective:

- "The basic idea . . . is that soil and crop information sensed on-the-go would be stored in a computer on the tractor which is programmed to make real-time decisions based on this information to control cultural practices. Such practices might include fertilizer, herbicide and pesticide application, as well as tillage operations and planting depth and density."

- "The primary missing link now is remote position-sensing technology to indicate where the tractor is in the field. Once it is developed, site specific data can be sensed and logged into the two-dimensional computer map."

- "When position-sensing technology becomes available, existing computer software will permit automatic guidance of the tractor. This will permit the tractor to follow the same tracks exactly without operator control. The operator's primary function can therefore be observation of conditions within the field and logging them into the computer data base. For example, he could key in the location of specific weed, insect, disease, or other infestations in the field simply by holding down a particular key on his keyboard as the tractor passes through these areas. Additional information such as soil water content with depth, canopy temperature, plant height, soil cover and a number of other variables could be sensed on the go with automatic sensors. Manually obtained data such as soil clay content, soil slope and aspect, soil organic matter, and other such variables could be logged into the computer map for the field as relatively permanent data. Sensors are now available to measure the rate at which grain flows from the cylinder of a combine. The addition of new sensors to measure the yield of other crops on the go can be envisioned if the demand is there."

- "Having such information available would make it possible to optimize the treatment of each square meter of the field rather than broadcast treating the entire field. For example, the yield map will make it possible to separate areas of the field with high yield potential from those with low yield potential. Rather than broadcasting fertilizer over the entire field, automatic feedback to the fertilizer spreader would make it possible to fertilize each square meter of the field according to its yield potential. The same is true for planting density. The weed map would make it possible to spot treat with a range of specific herbicides rather than broadcast treating the entire field. The possibility of treating small patches of weeds or insects before they grow to the point that it is economically feasible to broadcast treat the entire field would make it possible to contain and eradicate weeds and other pests that now get out of control. On-the-go soil moisture sensing, the technology for which is under development now, would make it possible to automatically control the depth of the planter to make sure that seeds are placed in moist soil. This soil moisture content information, in addition to base data such as soil organic matter and clay content, would make it possible to automatically control the amount of herbicide that is applied to gain weed control without causing damage to the growing crop. Sensor technology to remotely sense residue cover would make it possible to control the tillage operation to make certain that sufficient cover remained on the soil to control erosion. It would also contribute toward determining appropriate herbicide rates."

- "Such a system would also make it possible to conduct field experiments far more efficiently than is now possible. Fertilizer treatments for example could simply be programmed into the computer so that a series of different rates are applied at various places within the field. When the crop is harvested yields can be compared with fertilizer rates to generate response functions. Once such systems became practical for actual on-farm operation, yield trials could be automatically programmed into the computer each season and the response functions could be used in conjunction with the projected cost of fertilizer and price for the crop to determine the most profitable fertilizer rate to apply."

PROGRESS ON KEY CONCEPTS:

Technology for variable rate application of dry chemicals has been marketed since about 1986 by SOIL TEQ, Inc. of Minnetonka, MN. Variable rate application machines for both dry and liquid materials as well as yield monitoring hardware, mapping software and other technologies are now commercially available from a number of companies[3].

No instances of on-the-go sensing of information for real-time control of tillage, herbicide and insecticide application rate, or planting depth and density have been demonstrated. Automatic guidance of the tractor requires more accurate position sensing than differential GPS provides, but the availability of real-time kinematic (RTK) GPS with centimeter-level accuracy should make this possible in the very near future. Until automatic guidance is available, observation of conditions such as the location of specific weed, insect, disease, or other infestations within the field and logging them into the computer database will usually require an additional person on the field machine. Automatic guidance of field machines to allow them to follow the same tracks exactly without operator control could have significant additional benefits. By limiting soil compaction to narrowly defined bands, other strips of the field could be optimally tilled for a seed bed, or as a zone of enhanced water infiltration. All-weather access to fields on these

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[3] Jim Van Winkle ("Precision Agriculture: Will it Change the Way You Market?", Ag Retailer, March 1995) lists the names and products of some of these companies in a number of product areas. The number of companies listed in each area are: 9 for navigation/location systems, 3 for communication systems, 6 for metering application equipment, 3 for yield monitors, 7 for computer mapping software, and 4 for soil testing (or other) apparatus. Several other companies not identified in Van Winkle's list can be found in articles and advertisements in the publication "ag/INNOVATOR" (a monthly newsletter published since September, 1993 by the Agricultural Information Management Network, 7014 West Highway C-13, Linn Grove, IA 51033), which is, perhaps, the best source of commercial site-specific farming technology information.

compacted "roadbeds" could also permit fields to be planted early, even during a wet Spring.

On-the-go sensing and logging of information such as soil water content with depth, canopy temperature, plant height, soil cover and a number of other variables with automatic sensors, although possible, has not yet been implemented in a practical site-specific farming application. Manually obtained data such as soil clay content, soil organic matter, and other such variables are used extensively to develop application maps. Field slope and aspect need not be measured manually, as anticipated in 1983, but can be generated from longitude, latitude and elevation data logged by GPS.

Although prototype sensors were available in 1983 to measure the rate at which grain flows from the cylinder of a combine, considerable improvement has been made, and several are now available commercially. During the past two years Rawlins et al., 1995, and Campbell et al., 1994 have developed sensors to measure the yield of potato or other bulk crops that can be moved over a weighing conveyor on the harvester. This technology, now commercially available from HarvestMaster, Logan, UT, is being tested on several fields this year.

Yield maps constructed by on-the-go monitoring of harvester output as a function of position are ideal for validating computer-based crop simulation models. Developed by ARS scientists and others for many years, these models could form the basis for prescribing temporal and spatial inputs for crops.

Because many of the input data for crop simulation models are spatially referenced, geographic information systems (GIS) are effective tools to provide input, manipulation, query, and output of the large amount of spatial data required for this process. In an initial study Han et al., 1995b used a commercial GIS system, and linked it with a potato crop simulation model. Data layers were set up to hold the spatially distributed data for each of the primary input variables required by the simulator. The simulator was then run for each area of the field that was significantly different, and new layer was created containing the predicted spatial yield, as well as nitrogen and water leaching distribution for the field. Data for a sample potato field irrigated with a center-pivot system showed that the distributions of water and nitrogen were the most important variables controlling yield.

Although these simulations point out the possibilities of performing "what If" analyses if model-based prescriptions were available, validation is required by comparing predicted with actual yield maps. This validation process will allow us to identify which processes controlling yield in the field are not accurately represented by the simulator, helping us set priorities for directing fundamental research to fill these information gaps. But once perfected, the GIS-simulation model system should provide a useful tool for site-specific farm management.

Software to construct yield maps from yield monitoring data must correct for swath width as well as eliminate areas already harvested or outside the cropped area from being counted in the acreage accumulation. Han et al. (1995) have developed a recording system that uses the GPS position to keep track of cut and uncut areas, and records yield data only once over any given area. Existing commercial mapping software does not automatically account for these factors.

CONCLUSIONS:

The development of site-specific farming technology, impeded for many years by the lack of cost effective position-sensing technology, is now at the threshold of a revolution. All of the components required to make it effective exist. It's now a matter of integrating these components into cost effective systems that farmers can use.

Although decreased costs can be expected by eliminating over or under application of inputs to all areas of the field, perhaps the greatest benefit will be reduced environmental damage. One of the most effective strategies for managing insects and diseases in agriculture is biological control. Biocontrol requires the introduction and protection of beneficial organisms that act either as predators or competitors with the organisms to be controlled. Because broadcast chemical spraying often kills these beneficial organisms, during the initial stages of biocontrol establishment, farmers are faced with the dilemma of spraying to save his crop, or not spraying to allow the beneficial organisms to grow. Site-specific application of chemicals would allow the farmer to spot treat areas where disease or insect outbreaks first occur, without treating the whole field. Particularly with a chemical spray boom on a center pivot irrigation system, access to any part of the field is available throughout the growing season. Site-specific farming is eco-friendly.

Industry is quickly developing the smart machines required to deliver prescribed inputs to fields on a site-specific basis. The barriers for future progress lie more in the area of developing rather than delivering site-specific prescriptions. Much remains to be done by scientists to fill this gap.

Research by ARS and University scientists and engineers has contributed substantially to the development of these technologies. One of the most serious problems remaining is that unlike cows, the productive capacity of each area of a field can vary considerably from year to year. For example, an area that has low yields during a dry year because it has sandy soil that doesn't hold much water, may have high yield during a wet year because it has good drainage. Water is the most important factor causing yield variation from year to year. It can be both a curse as well as a blessing. Because of this, last year's yield map may not be a good guide for the productive capacity of each area of the field this year.

To predict the productive capacity, and therefore, the inputs required to each area of a field, we have to be able to take the rainfall, as well as other factors that differ from year to year, into account. One of the most promising ways of doing this is with computer models that simulate the response of a crop to these. Remote sensing from satellites can help us measure the variable conditions at each site in a field required as inputs to these computer models.

Because the soil water holding capacity is such a dominant factor in predicting the yield variability of fields, we need to find ways to measure it directly.

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IN WHAT FORM WILL CALIFORNIA AGRICULTURE SURVIVE?

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INTRODUCTION

California agriculture faces more threats to its present status than at practically any other time in history. These threats are varied and different. I shall discuss most of them in the following discussion.

I. International Competition

The new NAFTA treaty has the effect of changing the very way California agriculture performs. In the past the lower labor costs in Mexico were offset by the duties on U.S. equipment entering Mexico, by the duties levied on agricultural products entering the United States, and by costs of transportation. This is all changing and the changes will be very difficult for the farmers of our state. There are probably no more efficient farmers in the world than California farmers, but it is more difficult in the produce business to compete with labor costs that are as much as one-tenth the cost of our labor. While our labor costs are high *vis a vis* the Latin American countries, our wages do not adequately reflect the true value received. There is no reason for a young high school graduate to earn more money as a check-out person on the counter for a chain store than the technical operators of our spray rigs, cultivators, and other mechanized equipment. The labor unions recognize that fact, and are trying once again to unionize agriculture. That is all well and good, but in the face of international competition, it seems unlikely that the farmers of this state could withstand substantial wage increases at this time.

II. Environmentalism

A. Water

Water has been put into clear and present danger by the emphasis of environmentalists on fish and wildlife. In the great San Joaquin Valley, water contracts have been invalidated and it would appear as though water use will be greatly restricted into the future. The same may be true for the users of the Colorado River, where the courts have ruled that four ancient fish be returned to the river. These include the bony-tailed Chub, and the razorback sucker. All of these fish are equally as lovely as their names and are of no commercial value. But already plans are being made to eliminate the game fish from the river, and to regulate the dams in order to take care of the fish that presently do not exist in most reaches of the river. Farmers will have to make Herculean efforts to make sure that any of the protected fish do not enter their irrigation ditches and canals. This will have the effect of reducing the amount of water available for farmers, as well as the cost thereof. Not only farmers will be involved in this fiasco, for it will also limit power production, and water for the citizens of Southern California.

California has developed many giant shipping and importing firms. During the debate about the Treaty, most farmers were opposed, while the large shippers were strongly in favor. To the large shipper it makes no difference whether a product comes from Costa Rica or California, but it is of great importance to land owning California farmers.

B. Farm Chemicals

I have just returned from an extended trip to Bulgaria, and it is more clear to me than ever how difficult it is to farm without fertilizers, insecticides, hormones, and all of the other full array of chemicals that it takes to maintain modern agriculture. Farmland is outstanding in Bulgaria, but agricultural production is miniscule because of their failure to use farm chemicals.

It is transparent that there should be strong and uniform regulations regarding the use of farm chemicals world-wide. Instead of thinking globally, California has seen fit to set up its own standards for the use of chemicals. This results in strange happenings. My company, for example, grows fall melons in Arizona only because Arizona permits the use of insecticides prohibited in California. These rules accrue to the benefit of imported foodstuffs for those producers are not bound by the California regulations. Somehow everyone really needs to compete on a level playing field, while maintaining exacting safety levels.

C. Air

While air quality has not yet become a major limiting factor, its time is not far away. When the PM10 regulations (regulations concerning particle size of dust and other contaminants in the air) are vigorously enforced, there may be periods during which farm tillage cannot take place. Time is all important in agricultural production. If crops are not planted in a timely manner, sever losses can take place. This is particularly true in produce, where two days differential in planting can amount to a week's difference in harvest.

Too little attention for too long has been paid to the environment, but the time has come to level the playing field for each state and nation. If not, California farmers cannot be competitive on world markets, and the whole shape of agriculture will change in this state.

III. Research

There are many farmers who still think that all academics have pointy heads. In California, however, present day farmers eagerly leap upon new developments in agriculture. Many years ago I co-founded the Lettuce Research Advisory Board in this state. It was and is designed to pay for agricultural research out of the pockets of the shippers of lettuce within the state. While it is a bit unbelievable, these very same shippers are paying a pretty penny to establish a full fledged lettuce genome. This is pretty far out stuff, but these firms are aware that such knowledge may pay untold dividends for the industry over the long run. Not only is the payout assured, but the work is most exciting to both farmers and researchers.

How the farmers of the State of California could successfully farm without inputs of research, particularly from the University of California, is difficult to conceive. Cutbacks in the research facilities of the University and with U.S.D.A. have put agriculture in clear and present danger. While no one will support the thesis that there was no fat to be cut in the various research organizations, the present state of affairs is very threatening.

IV. Future

California is probably the most progressive agricultural region in the world, with the possible exception of Israel. It therefore has the most to lose if it cannot compete with other nations of the world on a relatively equal footing.

The farmers of this state have become what they are by being innovative, intelligent, and quick to adapt to almost any circumstances. It is to be hoped that these virtues, coupled with the work of scientists of the same ilk will keep California in the forefront of world agriculture for many years to come.

BIOSOLIDS AND FOOD PROCESSORS:
DEFINING THE DISCORD

Steven S. Balling
Director, Environmental and Analytical Services
Del Monte Foods

Food processors, like any other business, must answer to their customers. Customer perception of the quality and safety of our product is our reality, regardless of its basis in fact. Unfortunately, the application of biosolids, like pesticides, to agricultural lands presents us with significant perception problems. Because of that perception, Del Monte grower contracts clearly state that no municipal sludge, sewage, or wastewater shall be applied to land on which a Del Monte crop is being grown.

Because of this perception problem, consumers, farmers, and processors are asking tough questions about the use of biosolids on food crops. Until our their questions are answered clearly and publicly, ill maintain that position. The questions involve science, regulation, irony, and responsibility.

Questions of Science:

- *What do we know about differential uptake of heavy metals by different crops?* There are over 250 crops grown in California, what do we know about their ability to concentrate metals? We <u>do</u> know that spinach and other leafy greens concentrate cadmium, and that certain *Brassica* species are used specifically to remove metals from contaminated soils. Will processing crops do the same?

- *Is absence of fecal bacteria a reliable indicator of absence of other pathogens?* Most of the biosolids applied to croplands will be Class B material. Sampling for pathogens in this material will target fecal coliforms and streptococci only, apparently in the belief that they are good indicator organisms. Are they? What about organisms like hepatitis A, poliovirus, *Giardia*, and *Cryptosporidium* that require few units to cause disease?

- *Is one sample per month adequate?* The greatest frequency of sampling required by EPA's 503 regulations is for those appliers who receive ≥ 15,000 tons/year -- they must sample once per month. That works out to one sample for every 1250 tons, or one sample in an acre of biosolids eight inches deep. Is that statistically significant? What is the typical variance of pathogens and pollutants found in sludge?

Questions of Regulation

- *Who is enforcing the standards?* EPA isn't. They have no budget for enforcement. Local agencies can't. They have even less money. The burden of enforcement falls upon the farmers who receive the biosolids, and who typically don't have degrees in toxicology or microbiology. Who then protects us from the snake oil salesmen?

- *How do POTWs account for hazardous waste "slugs" in sewage sludge?* EPA relies on pretreatment of industrial sewage at the source to avoid contamination of the sludge. What happens when a mistake occurs and a slug of hazardous waste is released into the sewage system? Are spills of pollutants diluted or do they remain concentrated all the way out to the farm?

- *What happens if EPA changes allowable heavy metals concentrations on farmland?* In 503, EPA has established maximum loading capacities for heavy metals. What happens if new evidence is discovered that requires lowering of a loading capacity below the level already applied to the farm? Will the farmer be able to grow a crop on that land? Will his or her children be able to play on it? Will the bank let him sell it? Will it become a Superfund site?

Questions of Irony

- *Why does EPA regulate carcinogenic chemicals in biosolids at a risk level of 1 in 10,000 and pesticides at 1 in 1 million?* Has EPA determined that the benefits of biosolids applications are greater than the benefits of pesticide applications?

- *If flies must be kept out of treated fields, shouldn't workers and children?* Clearly, EPA is concerned about human exposure to pathogens in field-applied biosolids. For Class B biosolids, regulations require vector attraction reduction measures so that flies from a treated field won't land on your picnic lunch and, when applied to public areas, human access is restricted for one year. On farms access is restricted for 30 days. Why the difference?

- *Why is it unsafe to dump sludge on landfills and oceans, but safe to dump it on farmlands?* Sludge has been banned from oceans and landfills because of environmental impacts. Are farmlands less sensitive?

Questions of Responsibility

- *What's to be done with farmland during the 14 month preharvest interval?* For Class B sludge, above ground food crops that touch the soil (e.g., most vegetables) shall not be harvested for 14 months after application. Root crops cannot be harvested for 20 to 38 months. Farmers will have to plan their rotations (and their loan payments) carefully.

- *Who is liable if problems arise from the legal application of biosolids?* EPA regulations for sludge application emphasize the process, not the results. Liability is inherited with the product, from the applier to the farmer to the processor.

- *Why is it unsafe to dump biosolids on landfills, but safe to dump it on farmlands?* Biosolids have been banned from oceans and landfills because of potential environmental impacts. Are farmlands less sensitive?

While I believe there are good science-based answers to these questions. Unfortunately, they are not yet part of the public consciousness. Until they are, the use of biosolids for many food processors will remain a very simple equation: the benefits do not outweigh the risks.

BENEFICIAL USE OF BIOSOLIDS COMPARED TO OTHER RESIDUALS AND FERTILIZERS USED IN AGRICULTURE

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WATER ENVIRONMENT FEDERATION
ALEXANDRIA, VA

The Water Environment Federation (WEF) headquartered in Alexandria, Virginia, has a worldwide membership of over 40,000 water quality professionals dedicated to preserving and enhancing the global water environment. As such, WEF disseminates information on numerous water-related issues including the responsible management of solids produced by the treatment of wastewaters before these renovated waters are returned to the environment. The Residuals and Biosolids Committee of WEF has the goal of making biosolids recycling publicly acceptable throughout the globe by the year 2000. We call it *Biosolids 2000*! Biosolids is defined by WEF as a *primarily organic solid product produced by wastewater treatment processes that can be beneficially recycled. Biosolids 2000* may sound like an ambitious goal, but it is achievable and will represent a culmination of efforts that have been ongoing within WEF for almost 20 years.

Since the late 1970s, Congress and the United States Environmental Protection Agency have consistently maintained a policy of encouraging the recycling of various materials back into the environment through beneficial use programs. The Clean Water Acts of 1977 and 1987 have provisions that encourage the beneficial use of appropriately generated and treated materials such as biosolids. Congress clearly recognized that biosolids could be a valuable resource to increase crop production by supplying nutrients to plants and improving soil characteristics. Since 1972, the EPA and several other federal agencies such as the United States Department of Agriculture and the Food and Drug Administration have issued policy statements strongly supporting the beneficial use of biosolids in a variety of settings including its use on farms and in home gardens.

During the development of the 40 CFR Part 503 Regulation for the Use or Disposal of Biosolids, EPA reviewed thousands of pages of documents, data and findings from hundreds of field trials

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Taken from the "Guidance for Regulatory officials on the Beneficial Use of Biosolids as prepared by the Residuals and Biosolids Committee of the Water Environment Federation.

and laboratory experiments on the human health and environmental impacts from the use or disposal of biosolids. Field trials on biosolids have been conducted in the U.S. and in other countries for at least 40 years. Some biosolids sites have undergone repeated application with monitoring of biosolids for nearly 30 years. The vast amount of information gathered from these field trials and biosolids sites demonstrates no environmental degradation or human health impacts when used in accordance with federal criteria. Indeed, the only effects noted are that both the plant and animal ecosystem have been significantly improved via increased soil fertility due to biosolids applications. There have been macro and micro nutrient additions to the soil, increased organic matter content of the soil along with increased moisture delivery to the ecosystem. No documented negative human health or ecological impacts have been experienced when biosolids that meet all of the requirements of the federal Part 503 rule have been land applied for beneficial use under good agricultural management practices.

With this history and background, the WEF has developed a four part strategy for the implementation of *Biosolids 2000*. The four elements of this strategy are:

Promote Recycling

The WEF will continue to promote the recycling of residuals and biosolids throughout the globe. We will share recycling and cost saving experiences with our peers and encourage positive thinking away from the disposal mentality.

Provide Information

The WEF will act as a resource center and provide information on residuals and biosolids to the local, national and international communities. It is imperative that we have a common voice and that we give consistent and accurate information to our various publics.

Partnership

WEF will work diligently in partnership with other local, regional, national and international organizations. WEF will maximize the use of the best of all of our partnership organizations, because one organization cannot do it all. Working together we will achieve *Biosolids 2000*.

Become More Proactive

WEF will become more proactive on residuals and biosolids issues and encourage other partnership organizations to do the same. It is essential that we move out of the existing paradigms for gaining public acceptance.

Using these four strategic points as the basis for discussion, WEF is focusing its public acceptance program on seven gate keeper audiences: academic/agricultural scientists, water quality professionals, public health officials, agricultural groups (farming representatives), media, environmental groups, and regulatory officials. Therefore, WEF is encouraging regulatory officials to consider the following six items before implementing a biosolids regulatory program:

1. Use the term "biosolids" to replace all references to beneficial use of "sludge". WEF hired the firm of Powell Tate to provide advice on the name change. Their studies showed that the use of the term biosolids provides a significant advantage with respect to public perception. The advantage is augmented when regulatory officials use the term biosolids in laws, regulations and guidelines.

2. Adopt as the sole basis for technical standards relative to the land application of biosolids, the federal requirements in the land application portion (Subpart B) of EPA's Part 503 Regulation for the Use or Disposal of Biosolids. Do not impose any additional or more stringent requirements above the Part 503 rule unless justified by site-specific documented data and information. This information would have to demonstrate that conditions exist at biosolids land application sites that create greater exposure, impacts and risks than those used in the very conservative risk assessment developed for the federal Part 503 land application requirements. If a regulator does have the reliable field documentation to support additional or more stringent requirements, WEF would then agree that these requirements should be imposed. Furthermore, additional and/or more stringent land application requirements above those contained in Part 503 should be imposed only after considering holistically the impacts of biosolids on human health and the environment compared to agricultural residuals that biosolids compete against such as chemical fertilizers (e.g., rock phosphates, anhydrous ammonia, urea) and the whole family of animal manures.

   One of the best selling points of this position is the fact that the 503 Regulation is based on the most detailed risk-assessment ever conducted by EPA. Therefore, the argument should be made that it is not prudent public policy to impose scientifically indefensible regulatory requirements on biosolids land application projects. Some agencies have actually imposed additional regulatory requirements based on perceived fears of nitrogen, heavy metals, organic chemicals or pathogen impacts on crops, soils, surface water and/or groundwater. These requirements have been imposed without considering the relative impacts of common agricultural materials if these materials were to replace the biosolids. These competing materials contain similar, and in many cases greater, amounts of these pollutants which in some cases are more mobile and available than biosolids to impact the environment. It is not equitable for the regulatory authority to have more restrictive limits on the argument that they do not have the statutory authority to regulate these competing agricultural residuals and the only material that can be regulated is biosolids. The regulatory authority should at least examine the scientific basis for evaluating the impact of land applying biosolids as compared to land applying the competing agricultural residuals. We must also not lose sight of the fact that many of these fears about biosolids are not merely perception, they are based on real concerns which have been addressed during the extended public comment and reevaluation of 40 CFR Part 503 from 1989-1992!

In addition, experience has shown that not all issues can be resolved based solely on the science of the risk assessment; it is one of many tools which can provide support for reasonable programs. Consequently, some regulatory requirements are, and probably will continue to be, developed based upon public opinion and public perception and will not be applied equally across the board to all practices (e.g., animal manures). Obviously, if states wish to impose additional management practices and other requirements based upon public policy decisions, that will remain their prerogative. WEF is hopeful that by being proactive, these types of decisions and associated controversies will disappear. In any event, states have the ethical obligation to document their reasons for being more restrictive and those reasons must be based upon good science.

3. Adopt the concept in the land application subpart of the 503 regulation that when biosolids meet certain requirements they should be treated like other fertilizers (e.g., commercial fertilizers). Do not modify this concept and do not add further regulatory requirements for these biosolids. The EPA considers biosolids that meet the pollutant concentrations in Tables 1 and 3 of 503.13, respectively, of Subpart B of the Part 503 rule, one of the Class A pathogen reduction alternatives in subpart D of Part 503, and one of the first eight vector attraction reduction options in subpart D of Part 503 to be as environmentally acceptable as agricultural fertilizers. For this reason, biosolids that meet those requirements are not subject to the Part 503 land application general requirements and management practices, nor to any site restrictions for pathogen reduction. Since the frequency of monitoring, recordkeeping and reporting requirements in the Part 503 land

application subpart still apply to those biosolids, the information and data needed to demonstrate that such biosolids continue to meet the pollutant, pathogen and vector attraction reduction requirements will be maintained.

The concept that biosolids that meet certain Part 503 requirements [cross-references of 503. 10(b) to (g)] should be treated like other fertilizers is vitally important to encourage the recycling of the nutrients and organic material in biosolids. Failure by regulatory officials to adopt this concept can only make recycling of biosolids less attractive by imposing unwarranted restrictions on such materials. It is also important, that the term EQ (exceptional quality), or any similar convenient short hand term, be eliminated and not used in regulations. No such term is used or referenced in the 503 regulation. In addition, the terms Class A and Class B for pathogen reduction alternatives should not be used; there should simply be nine alternatives for pathogen reduction. Regulatory officials should be extremely careful not to use Category 1 versus Category 2 or Class 1 versus Class 2, etc. The use of this type of terminology increases the possibilities that the public will envision one product to be better or safer than another. It is important for regulatory officials to avoid the use of any kind of negative or divisive terminology because the results will be counter productive to the goals of *Biosolids 2000.*

4. States are urged to request authority from EPA to manage biosolids and issue biosolids permits solely through a state program. This could be accomplished either through an NPDES mechanism (40 CFR Parts 122-124) or through an alternative state permitting program (40 CFR Part 501). The advantages to the states and EPA for the states that request and receive this delegation are obvious. The state gains control over the biosolids permitting program. The state regulatory officials are in the best position to know the biosolids situation and issues in the state and, therefore, are in a better position to manage the program than EPA. In addition, regulatory efficiency is increased in that only one set of permits is issued. EPA does not have to expend unnecessary permitting resources to issue in many cases duplicative permits. Likewise, the reporting requirements are reduced by one-half since reports would not have to be submitted to both EPA and the state.

States delegated for NPDES permitting or those states with the legal authority to issue water quality, solid waste, or other appropriate permits should experience little if any financial impact by accepting delegation for the biosolids management program. WEF supports strong, sound state programs because state input is needed on local issues, including, but not limited to, management practices, agronomic rates, and buffers.

5. WEF wants everyone to become proactive in promoting the beneficial recycling of biosolids. We are all encouraged to do a better job in promoting the benefits of biosolids recycling to those who could most benefit - namely: farmers, nurseries, landscapers, administrators of public works projects, and others. We have been effective in promoting beneficial use programs to POTW operators, but more effort must be made to expand this concept to the users of biosolids. WEF encourages states to implement a responsible public policy for managing biosolids. WEF also encourages public participation and dissemination of information to overcome the NIMBY response which can occur due to fear and ignorance.

6. WEF encourages regulatory officials to take advantage of the resources offered by the federation. Publications, videos, and technical assistance from people like Dr. Alan Rubin and members of the Residuals and Biosolids Committee are available.

WEF urges states and other regulatory officials to exercise leadership in designing environmentally protective, implementable biosolids management programs. There is also the need for a grass roots effort of citizens and respected community leaders to facilitate public acceptance, particularly where there is a high probability of controversy. One of the biggest challenges facing us today is to develop positive perceptions by the public. Perception is reality, and it will make the difference as to whether or not a project is successful. Many false starts in developing biosolids recycling projects throughout the country are now being turned into creative opportunities with public understanding and support.

WEF invites all regulatory officials to be a partner in *Biosolids 2000,* the culmination of more than 20 years of research, development, implementation and outreach. The choice is <u>yours</u>! Working together we can raise the public's awareness and acceptance of biosolids recycling as we move into the 21st century. In essence, we can provide the agricultural community with a valuable material that is the result of enhanced water quality. Once this is done, the goal of having biosolids recycling publicly acceptable by the year 2000 will come naturally.

BIOSOLIDS IN AGRICULTURE - A FARMER'S PERSPECTIVE

Heather Rheingans, Farmer

We (Phil and Heather Rheingans) have been working with biosolids on our farm since 1991. We have used biosolids that are both composted and straight from the wastewater treatment plant. Typically, composted biosolids are not regulated, but cost much more.

Biosolids are an excellent source of micronutrients and organic material. The nitrogen from biosolids is primarily in the organic form. It becomes available slowly over time, making biosolids less likely to leach nitrates than most chemical fertilizers. Plants in biosolids applied areas are more vigorous and healthy. The yield of biosolids applied areas has increased up to 30%.

Biosolids, like all other agricultural products, need to be used in an appropriate manner. Application rates need to correspond with the crop to be grown. Biosolids straight from the wastewater treatment plant should not be used on edible root crops, and need to be kept out of water supplies. Similar management guidelines exist for many of the pesticides used in agriculture. For biosolids, these guidelines are found in EPA 40 CFR Part 503 - a Federal EPA document based upon over 20 years of research. Prior to this regulation, biosolids were used in an often inappropriate manner for years without the deterioration of public, environmental, or agricultural health. Regulating biosolids establishes appropriate uses and ensures that these remain intact.

If a farmer is considering biosolids use, they should contact their local Regional Water Quality Control Board, and if appropriate, their County Department of Environmental Health Services. These agencies regulate biosolids use in California and should be able to provide you with local regulations for your area. Also ask about the company that will be providing you with biosolids. Unregulated biosolids products have to meet specific requirements before they become unregulated. Ask your supplier to demonstrate that their products meet metals, pathogen reduction, and pest attraction reduction requirements.

Using biosolids as an agricultural amendment is the ultimate in sustainable agriculture. We are simply returning nutrients back to the soil to again grow food and feed. It would be silly to waste these nutrients by putting them in a landfill. There are many agricultural amendments on the market. Biosolids are simply one of those products that we have found to work very well, and increase profitability, on our farm.

SWEET CORN RESPONSE TO BIOSOLIDS COMPOST

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INTRODUCTION:

Several California communities are facing an environmental challenge trying to cope with the disposal of municipal biosolids (sewage sludge). Land application has proven the most cost- effective to landfilling these residues. The field study described here investigated the benefits of three biosolids compost application rates in combination with two levels of nitrogen fertilization on sweet corn yield and quality.

MATERIAL AND METHODS:

The study was conducted at the UCR Moreno Valley field station, 15 miles south of Riverside. An area of 2.2 acres was reserved for the trial and divided into 16 strips. Each strip was 34 feet wide and 200 feet long. Adjacent strips were separated by three foot alleys.

Each strip received one of four compost application rates (0, 6, 12, and 48 tons/acre). In addition, three nitrogen treatments (50 pounds pre-plant, 50 preplant and 75 pounds side-dressing) were added to the biosolids treatments, for a total of twelve (12) experimental permutations. Permutations were replicated four times for a total of 48 plots.

Table 1. Summary of different treatments (inputs)

Treatment code	Biosolids & nitrogen combination			Treatment code	Biosolids & nitrogen combination		
	Biosolids t/acre	Nitrogen pounds/acre			Biosolids t/acre	Nitrogen pounds/acre	
		Pre-plant	Side dressing			Pre-plant	Side dressing
1	0	0	0	7	12	0	0
2	0	50	0	8	12	50	0
3	0	50	75	9	12	50	75
4	6	0	0	10	48	0	0
5	6	50	0	11	48	50	0
6	6	50	75	12	48	50	75

The composted biosolids were donated and delivered by a local biosolids/yard trimmings composter. Compost was applied to the appropriate strips with a manure spreader, and incorporated to six inches with a cultivator after a soil application of Atrazine herbicide. Corn was planted in 30-inch beds. Fifty pounds of pre-plant nitrogen was added to the appropriate plots at this time (Table 1). All plots were seeded with sweet corn variety "Sugar Ace" donated by Harris Moran seed company. Just before silking, an insecticide (Asana) was applied to all plots.

Three tensiometers and two lysimeter tubes were installed in each plot. Also, a PVC pipe was installed for neutron probe readings up to one meter deep. Tensiometer readings (at 12, 24, and 36 inches depths) and neutron probe measurements (at 20, 40, 60, 80, and 100 cm depths) were made on a weekly schedule, just prior to irrigation. Lysimeter water samples (at 100 cm depths) were collected at this time. Other management activities included the following:

- All plots were irrigated with overhead sprinkler through a single irrigation system. Risers were added at mid-growth stage.

- At the tasseling stage, tissue samples were collected for NPK analysis at the UC Davis laboratory.

- On September 12, 1995, an area of four rows 10 feet long was harvested from each plot. Ears were then counted and weighed. From a sub-sample of three representative corn ears, we measured the length and the diameter of each ear. The data were analyzed with the statistical package "Mstat" as a two factor randomized complete block design using a standard strips configuration.

RESULTS AND DISCUSSION:

Yield and Other Parameters

Over-application slowed corn development. Yields decreased by 35-40% when 48 tons of biosolids were added, in comparison to all other treatments (Fig. 1). Also, ear diameter was significantly reduced by excessive biosolids application. The two middle compost rates (6 and 12 tons) showed noticeable yield improvements over the control. These were not statistically significant, however (Table 2-a).

Similar trends were detected in other measured parameters. Ear size (grams/ear), showed no differences in response to different treatments. Plant productivity (yield per plant) showed little variation between the control and the two middle biosolids treatments. Plots receiving the highest compost applications were decidedly less productive, although differences were not statistically significant at confidence a=0.95.

Adding compost at 6 and 12 tons per acre increased yields of compared to control treatments, regardless of the inorganic nitrogen fertilizer provided. The best yield responses (over 19,000 pounds per acre) were recorded in response to the combinations "6 and 50" and "12 and 50+75" (Table 2-c). At the 48 tons per acre application rate, increased fertilizer rates depressed plant growth and production (Table 2-c). Difference again were not statistically significant at confidence a=0.95

Corn ear measurements showed little variation in response to treatments. However, ear diameter tended to be smaller at the 48 tons level. This is likely due to the immature stage of the plants at harvest time.

Plant Characteristics

Plant characteristics such as height, weight, and NPK content had a varied and inconsistent response to composted biosolids. When considering biosolids effect, plants grew taller regardless of nitrogen levels, as long as the plots received less than 48 tons compost per acre. Plant that received 48 tons were significantly shorter than those in other treatments (Table 3-a). Again, when comparing treatments combinations, no statistical differences were detected, despite the obvious stunting effect at the 48 tons level (Table 3-c).

Plant nutrients (NO_3^-, P, and K) showed a significant linear increase in response to biosolids application levels, when inorganic fertilizer was not added (Table 3-a). When inorganic fertilizer was used, significant differences did not emerge, regardless of the amount of compost applied (Table 3-c). The side-dressing application may not have had time to take effect before mid-season sampling took place, however. Nutrient content in plant tissue showed no relationship to yield or to plant height.

Generally speaking, plant fresh weights were higher when biosolids were added (Table 2-c) while dry matter content (% dry weight) showed no consistent trend (Table 2-a).

CONCLUSIONS:

Results of this first year study indicate that biosolids applications at six and 12 tons per acre increased yield and plant productivity over the control (no biosolids and no N fertilizer). They also show that applying very high rates of biosolids (48 tons per acre) reduced yields by 35-40%, in comparison to controls. Very high levels of biosolids input have also negatively affected yield components such ear weight and plant productivity.

The interaction of biosolids and nitrogen fertilizer showed that optimal yields were achieved at the combinations 6 and 12 tons in combination with 50 and 125 pounds of N, respectively.

Similarly, combinations of high inputs had a negative effect on plant characteristics. Plant height was reduced, ear length was reduced, and plant leaves showed a marked rate of leaf burn. Plant nutrient content (NPK) significantly increased as biosolids ap

Table 2-a. Sweet corn yield and yield components in response to biosolids application rates.

Treatment compost t/a	Yield pounds/acre	Ears/ plot	Ear per plant	Ear size grams	Ear length cm	Ear diameter mm	Yield/plant pounds
00+**	16557	45	0.97	375	17.79	48.87	0.81
06+**	16853	48	1.06	365	18.14	47.24	0.87
12+**	17552	47	1.03	389	17.80	47.51	0.89
48+**	10685	32	0.76	343	17.77	42.51	0.59
DMR (5%)	*525*	*ns*	*ns*	*ns*	*ns*	*3.37*	*ns*

Table 2-b. Sweet corn yield and yield components in response to nitrogen fertilizer.

Treatment nitrogen #/a	Yield pounds/acre	Ears/ plot	Ear per plant	Ear size grams	Ear length cm	Ear diameter mm	Yield/plant pounds
00+**	15190	41	0.92	375	18.02	48.34	0.78
50+**	15901	44	1.02	371	17.98	45.71	0.85
50+75	15145	43	0.93	359	17.63	45.53	0.75
DMR (5%)	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

Table 2-c. Sweet corn yield and yield components in response to the interaction of biosolids and nitrogen fertilizer.

Treatment combination	Yield pounds/acre	E+D1ars/ plot	Ear per plant	Ear size grams	Ear length cm	Ear diameter mm	Yield/plant pounds
00+00+00	15017	38	0.78	401.75	18.45	53.30	0.71
00+50+00	17154	46	1.07	382.25	18.00	47.79	0.91
00+50+75	17500	52	1.05	341.00	16.92	45.52	0.81
06+00+00	17180	48	1.07	372.00	17.87	48.55	0.90
06+50+00	19500	57	1.36	351.25	18.48	46.74	1.06
06+50+75	13880	38	0.76	372.25	18.08	46.42	0.64
12+00+00	17461	46	1.03	388.25	17.73	47.80	0.90
12+50+00	16163	42	0.91	400.50	18.13	47.45	0.81
12+50+75	19032	52	1.16	379.00	17.55	47.27	0.96
48+00+00	11101	34	0.81	336.25	18.05	43.72	0.62
48+50+00	10787	31	0.74	351.75	17.30	40.87	0.60
48+50+75	10167	30	0.73	342.25	17.98	42.93	0.56
DMR (5%)	*ns*	*ns*	*0.32*	*ns*	*ns*	*ns*	*0.09*

Table 3-a. Response of sweet corn plant characteristics to biosolids & N fertilizer.

Treatment	Plant fresh	% dry	Plant height	Plant nutrient content			
compost t/a	weight g	matter	inches z	% N	NO3 ppm	% P	% K
00+**	254.08	36.36	37.70	3.23	762.50	0.41	2.54
06+**	290.58	35.29	35.65	3.81	1127.50	0.46	2.60
12+**	299.11	35.94	37.86	3.71	1235.00	0.50	2.70
48+**	257.19	31.69	26.35	3.75	2071.70	0.55	3.19
DMR (5%)	*ns*	*ns*	*ns*	*ns*	*409.20*	*0.07*	*0.35*

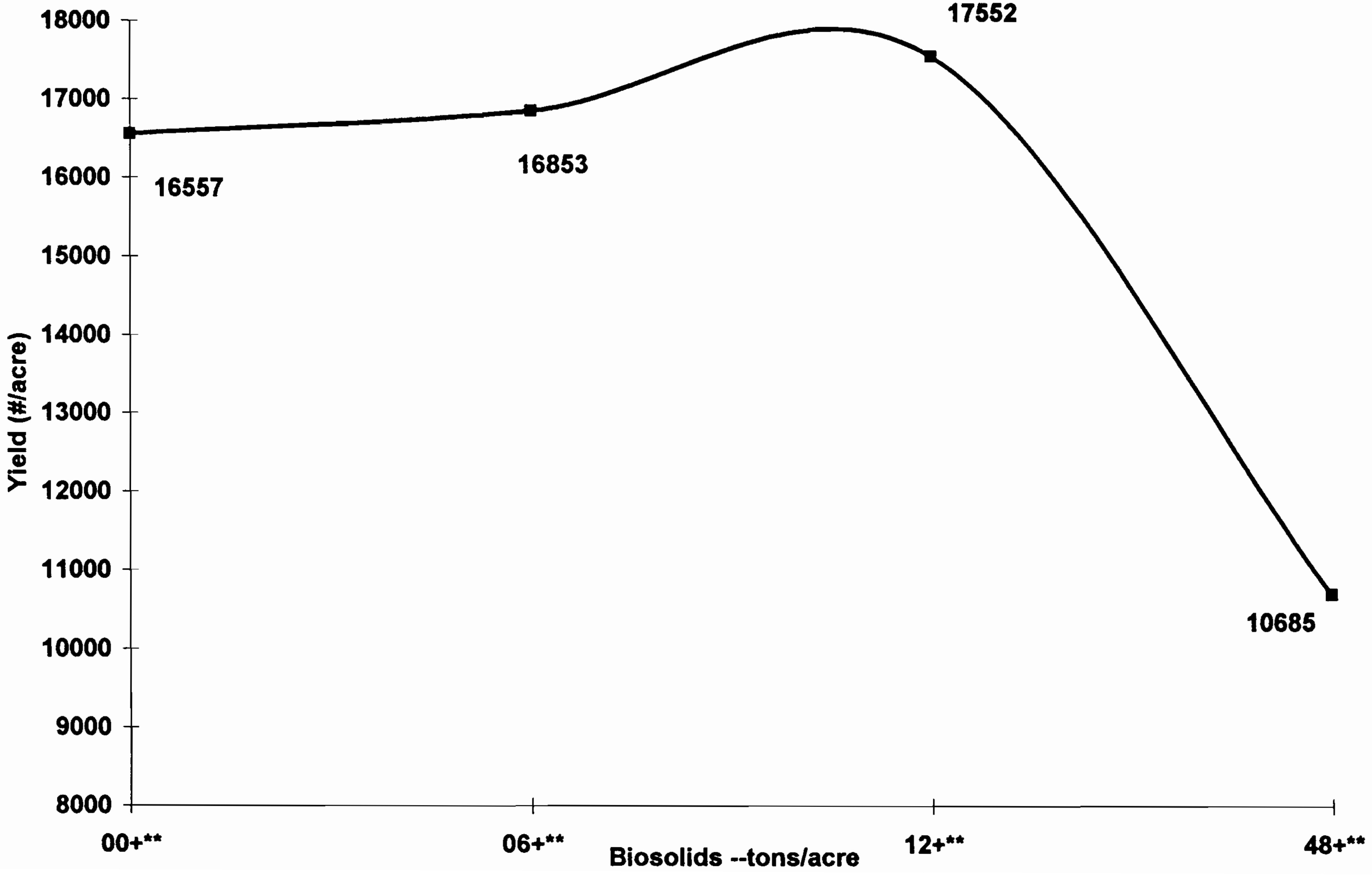
Table 3-b. Response of sweet corn plant characteristics to biosolids & N fertilizer.

Treatment	Plant fresh	% dry	Plant height	Plant nutrient content			
compost t/a	weight g	matter	inches z	% N	NO3 ppm	% P	% K
00+**	279.42	34.79	35.53	3.48	1066.90	0.46	2.68
50+**	289.48	35.67	33.88	3.72	1514.40	0.50	2.79
50+75+**	286.00	33.83	33.75	3.67	1316.30	0.47	2.82
DMR (5%)	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

Table 3-c. Response of sweet corn plant characteristics to biosolids & N fertilizer.

Treatment	Plant fresh	% dry	Plant height	Plant nutrient content			
compost t/a	weight g	matter	inches z	% N	NO3 ppm	% P	% K
00+00+00	264.25	65.53	38.35	2.77	460.00	0.39	2.57
00+50+00	266.33	63.52	37.11	3.53	1295.00	0.46	2.51
00+50+75	231.67	61.62	37.63	3.63	1180.00	0.49	2.56
06+00+00	280.08	64.62	37.60	3.44	935.00	0.44	2.46
06+50+00	305.83	64.60	34.42	4.35	1190.00	0.47	2.66
06+50+75	285.83	64.90	34.94	3.93	1857.50	0.52	2.69
12+00+00	280.92	63.10	38.75	3.49	892.50	0.41	2.59
12+50+00	298.33	61.79	38.12	3.66	1052.50	0.47	2.84
12+50+75	318.08	67.04	36.71	4.06	2355.00	0.59	2.69
48+00+00	292.42	67.51	27.43	3.57	897.50	0.47	3.10
48+50+00	287.42	67.44	25.89	3.86	1472.50	0.54	3.15
48+50+75	308.42	69.87	25.72	3.24	2002.50	0.53	3.33
DMR (5%)	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

Fig. 1. Sweet Corn Yield Response to Bisolids Application Rates



Biosolids: A Regulatory Approach

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The use of biosolids, or wastewater treatment plant sludge, as a fertilizer and soil amendment is becoming increasingly widespread. Biosolids have properties similar to any manure. The material contains nitrogen, organic matter and a wide variety of micro-nutrients which are valuable to agriculture. The nitrogen is released over many years as the organic nitrogen mineralizes to plant-available forms. Biosolids use at some locations is fully accepted, and it is a matter of great public controversy at other locations. The United States Environmental Protection Agency (EPA) and the Central Valley Regional Water Quality Control Board (Board) have regulations concerning the handling and use of biosolids.

Biosolids are the main residuals generated by the removal of organic pollutants from domestic wastewater. Wastewater treatment plants grow microorganisms which consume the pollutants in the wastewater, and then the microorganisms are removed from the wastewater, leaving a treated wastewater for discharge or reuse. These removed microorganisms, along with other solids removed from the wastewater, undergo further treatment to improve handling characteristics and reduce the potential for odor or insect problems. The resultant material is mostly organic matter and contains from one to six percent nitrogen, so it can be beneficially used as a soil amendment or fertilizer, similar to any other manure. The biosolids potentially contain any other pollutant which is disposed of into the sewer system, so some restrictions on the use of the biosolids are necessary for safe use.

Human waste has been used for its fertilizer value for many thousands of years, but has been in large scale use in the United States and carefully studied for the past few decades. EPA recently concluded a major study and risk assessment of biosolids use, culminating in nationwide biosolids regulations promulgated in November 1992 in 40 CFR 503 (the 503 regulations).

The 503 regulations establish several sets of standards for the use of biosolids:

* Pathogens (disease causing organisms) - two levels of pathogen concentrations are established. Class A biosolids have been disinfected sufficiently so that no use restrictions are necessary to protect public health. Class B biosolids have had a significant reduction in pathogens, but sufficient pathogens remain so that restrictions on use must be taken to protect public health. EPA established waiting periods ranging from 30 days to 38 months from the time of Class B biosolids application to grazing or harvest of crops, depending on how the biosolids are applied and the types of crops. These waiting periods allow for natural die off of remaining pathogens to safe levels prior to harvest or land use involving public contact.

Cities achieve compliance with Class B standards in a normally-operating treatment system - no special biosolids treatment is usually necessary. Class A biosolids requires some level of treatment beyond the norm. The additional treatment may be longer detention times within existing sludge digestion units, heat treatment, composting, drying of biosolids in drying beds for several years, or several other techniques.

Treatment to Class A standards removes any pathogen-related restrictions on use of the biosolids, but the treatment usually also reduces the nitrogen concentration in the biosolids.

* Pollutant limitations - EPA conducted the National Sewage Sludge Survey, involving the testing of biosolids from wastewater treatment plants throughout the country for every compound for which EPA had a test method, including heavy metals, pesticides, volatile and semi-volatile organics, dioxins and PCBs. EPA then conducted a multi-media health risk assessment of the detected pollutants looking at sixteen different pathways for adverse impacts on humans, animals, wildlife, crop productivity, soil quality, and ground water. EPA concluded that only ten pollutants (arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc) were found in sufficient concentrations to pose a threat via one or more of the exposure pathways. EPA then established four sets of limits for these ten metals:

- Ceiling Concentrations (mg/kg) of the metals, above which application to land is prohibited
- Cumulative Pollutant Loading Rates (kg/hectare) which set the maximum mass of a metal which may be applied to each hectare of land. Once this mass loading for any metal has been met, no further biosolids applications to that parcel are allowed.
- Pollutant Concentrations (mg/kg). The "clean sludge" criteria. Biosolids contain a substantial portion of refractory organic and inert material, and so effectively add "diluting" soil along with additional heavy metals. EPA's model shows that compliance with these concentration limits will prevent accumulation of metals to toxic levels when using biosolids as the only source of nitrogen in routine farming operations for 100 years. Biosolids complying with these limits need not comply with the Cumulative Pollutant Loading Rates (kg/hectare), which saves considerable effort in tracking metal accumulation data.
- Annual Pollutant Loading Rates (kg/hectare). For biosolids which are used as part of a mixture intended for distribution in bags or containers for unrestricted public use (such as compost), the anticipated metals loadings from normal use of the product can not exceed these loading rates. This insures protection of the home gardener.

Wastewater treatment plants generally have no treatment process for metals removal. In fact, the metals tend to accumulate in the biosolids. To control the amount of metals in the biosolids, the community must regulate discharges of wastes into the sewer system by implementing an industrial source control program. The metals concentrated from water supplies and normal domestic wastewater are not normally a problem.

* Vector Attraction Reduction Standards are a collection of alternative biosolids treatment standards and application practices to assure that the biosolids have been adequately treated prior to use to prevent odor and vector problems.

* Management Practices, which deal with keeping the biosolids on the application site. These include a 10 meter (33 foot) setback from surface waters, prohibition against placement in wetlands, and a prohibition against placement on frozen or flooded ground.

Historically, most biosolids have been disposed of to landfills or indefinitely "stored" at the treatment plant site with no plan or intent of ever moving it. Interest in the land application of biosolids has increased greatly over the past few years. The California Integrated Waste Management Board has adopted regulations requiring municipalities to divert certain percentages of their solid waste away from landfills; land application of biosolids counts toward achieving these goals. EPA's 503 regulations also prohibit onsite storage of biosolids for more than two years without a plan for removal of the biosolids from the site, which has forced many communities to finally address biosolids accumulation.

The Central Valley Regional Water Quality Control Board has adopted Waste Discharge Requirements (WDRs) on biosolids use as a fertilizer and soil amendment for over a decade. Biosolids are considered to be a waste which has properties allowing for beneficial use. The WDRs have been aimed at assuring protection of water quality and public health, and assuring that the biosolids are being beneficially used and not just "dumped". The adoption of individual WDRs for each application site is time consuming, however, requiring from three to four months, and longer if the Board has to process environmental documents. This response time was too great to allow flexible use of biosolids in routine farming operations.

The Regional Board recently completed the adoption of General WDRs, which effectively give "instant" WDRs to biosolids application projects. Applying biosolids under the General WDRs is a two step process. First a "Notice of Intent" and filing fee (currently $1200) is submitted by the property owner(s) and the persons or company proposing to apply the biosolids. If the form is filled out completely, coverage under the General WDRs is automatic. Second, a Pre-Application Report is submitted, which details the source and characteristics of the biosolids, types of crops to be grown, calculates nitrogen and metals loading values, and summarizes how the project complies with the General WDRs. The Pre-Application Report must be reviewed and approved by Board staff, which generally takes less than two weeks, a significant reduction from the previous three or four month process.

The Board also adopted a resolution waiving the need for WDRs for "exceptional quality" biosolids, that is, biosolids which meet Class A pathogen criteria and also meet the "clean sludge" metals criteria. The project proponents submit a form describing the source of biosolids and how it complies with the criteria, and a fee to cover staff costs (currently $400). If staff concurs with the submitted data, WDRs are waived, and the proponents may proceed indefinitely with biosolids application with no further review or approval by the Board.

The Board used EPA regulation as a technical basis for the General WDRs, with the following additions:

* Additional setbacks have been established between the application sites for Class B biosolids and homes, roads, property lines, and wells.
* The setback from surface waters was increased from 10 meters (33 feet) to 100 feet.
* A one year waiting period was established between the application of Class B biosolids and the grazing of animals used in the production of unpasteurized milk.
* The exception from tracking lifetime metals loadings for biosolids meeting the "clean sludge" metals criteria was not granted. Metals loadings must be tracked for all biosolids applied under the General WDRs.
* Biosolids may not be applied when there is less than a two foot depth to ground water at the time of application.
* Storage of biosolids at the application site is prohibited for more than seven consecutive days, and requirements are imposed for runoff and flood controls during the winter.

Compliance with the General WDRs does not assure compliance with the EPA regulations. The State decided not to seek authorization from EPA to administer the biosolids program. There are compliance and reporting requirements in the 503 regulations which are not included in the General WDRs. The General WDRs also do not over ride any local regulation of biosolids, so some localities have adopted their own regulations on biosolids use.

The adoption of the General WDRs and waiver policy was controversial. Some parties believed this action was over-regulation and that EPA provided adequate regulation of biosolids. Some parties believed that the orders were far too lenient, and that biosolids application should be much more severely restricted. The General WDRs and waiver resolution have been appealed to the State Water Resources Control Board, but remain effective pending a decision by the State Board.

The use of General WDRs for regulation of biosolids is increasing. The Lahontan Regional Water Quality Control Board adopted General WDRs for biosolids similar to the Central Valley Region's, and other Regional Boards are working on them. Legislation was recently enacted (SB 205) requiring the adoption of General WDRs for biosolids, either by each Region or by the State Board for the entire state. At this time, the method and time frame for implementing SB 205 is unknown.

For farmers, biosolids may be an economical source of nitrogen, micro-nutrients and organic matter. To avoid the costs of landfill disposal, municipalities usually pay to have the biosolids removed from the treatment facilities and land applied. The result is that biosolids may be applied to farm land at little or no cost to the.

Public acceptance of biosolids remains a major concern. Few people are excited about having “excrement” dumped on land next to them, so public education on the true nature of the material and the regulations with which it must comply is needed. Residents down stream of proposed application sites can particularly become concerned. Odors can be generated during the application of the biosolids by the release of ammonia and related compounds. It is imperative that appliers of biosolids take all feasible steps to minimize the creation of odor nuisances and maintain a "good neighbor" relation with adjacent residents. Since most biosolids are generated in urban areas, and most opportunities for reuse are in rural areas, importation of wastes becomes an often emotionally-charged issue. Many food processors have contracts with growers which prohibit biosolids application to any crops that they purchase. The food processors have both technical questions on the safety of crops grown with biosolids and concerns with public acceptance of their products. Growers need to verify the acceptability of biosolids use with the intended purchasers of their crops. Many of the concerns with biosolids (pathogens, salts, metals, runoff, and odors) are the same concerns which exist with other manures, but because cow and poultry manures are part of routine agricultural operations, these issues are generally ignored unless biosolids are being used.

The application of biosolids to land as a fertilizer and soil amendment is a beneficial, although sometimes controversial, use of a waste material. As with any fertilizing material, it is possible to create environmental problems through overuse or misuse of biosolids, however, regulations developed by EPA set conditions under which biosolids can be safely applied to agricultural lands. Two regional boards have adopted streamlined permitting mechanisms for biosolids use, and other regions are considering the adoption of similar orders. Public education is needed to increase the acceptability of biosolids use to prevent biosolids from being handled in a more expensive, less environmentally-friendly manner.

CALTRANS' USE OF MULCHES AND SOIL AMENDMENTS

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Caltrans has traditionally used some mulch and soil amendment in highway landscapes, but this usage has been quite limited. Generally, about one cubic foot of mulch was used in plant basins, and a similar amount of soil amount was used in the plant holes. The use of soil amendment has recently declined as a result of information indicating detrimental effects or lack of benefit of using amendments.

Prior to 1985, Caltrans landscapes usually consisted of trees and shrubs, and ground cover that spread from the edge of pavement to the right of way fences. Due to the cost of this intensity of planting and the watering requirements, and in some Highway Commissioners' mind the "frivolous use of transportation dollars", highway planting was greatly reduced in cost and limited to trees and clusters of shrubs, or 'weeds and trees' as labeled by internal critics. This form of landscaping left large areas of herbaceous vegetation, which in many cases was weeds. This herbaceous vegetation in landscaped areas, as well as non-landscaped right of way was controlled by mowing and herbicide applications.

During this same time, criticism arose about the extensive reliance of herbicides in Caltrans maintenance practices. Lawsuits were filed and injunctions administered that limited the use of herbicides in some areas. Two counties had outright bans of pesticide usage on the right of way. Due to these pressures, Caltrans had an EIS written to examine our pesticide use and look at alternatives, including integrated pest management. Shortly afterward, the director of Transportation committed Caltrans to 50% reduction in pesticides by the year 2000 and an 80% reduction by the year 2012. A Roadside Vegetation Management Committee has been formed to review the management of the roadside and find alternatives for vegetation control.

The passage of AB 939 created the incentive for municipalities to process yard waste and remove it from the waste stream. The completion of the contract for utilities purchasing power from cogeneration facilities left a lot of wood waste on the market. The combination of these two events provide for a glut of mulch material on the market, and drove the price down. Often the producers were willing to give mulch away to reduce the volume of material is storage.

With the necessity of having to find alternative vegetation control methods and the availability of low cost mulching material, coupled with the emergence of mechanical spreading equipment, Caltrans started using much more mulch in landscaped areas. To encourage this use in the districts, a policy was changed to exclude the cost of mulch from the maximum allowable cost per acre allowed for landscapes. To assist the communities in their AB 939 diversion requirements, Caltrans developed a special provision to give preference to the use of urban green resources (waste) as a mulching material.

It was soon recognized that along with providing weed control, water conservation and reduced wildfire intensity, green resource mulching also provided good erosion control. With that recognition, a special provision was developed to use wood chip mulch as a primary erosion control material. On most projects, a vegetative erosion control cover is provided at the completion of the highway construction. When a landscape is installed, that vegetative cover is removed, generally at greater expense than to put it there in the first place. The cost of using mulch for erosion control is considerably more expensive ($1500 vs $4000 per acre) than the typical erosion control application, but when the vegetation removal cost and the mulching that would be placed with the landscape in considered, the project life costs are much less.

Caltrans has thousands of acres of landscaped and non-landscaped right of way that has not been mulched. There is no current budget for treating these areas, but there is still weed control and erosion control needs. To help meet these needs, and relieve the mounting volumes of green waste arising from the diversion programs, Caltrans is considering an Adopt a Highway program to allow producers to deliver and spread mulch within the right of way. Consideration is still being given to the types of mulch and where and how it can be spread.

Even though soil amendment is not often being used in plant holes, there is recognition of possible benefits in Caltrans operations. Topsoil is rarely saved and reapplied on construction projects. The first layer excavated is generally placed at the bottom of embankments. The last layer excavated is the surface material left to support erosion control or landscape plantings. This materials has never supported life forms, has little or no organic content and little nutrient or nutrient holding capacity. Caltrans has recently entered into a research contract with the University of California at Davis to investigate the use of organic inputs to provide for soil aggregation and long term nutrient cycling. The goal is to try and mimic well developed soil profiles. This research also hopes to be able to prescribe various form of amendments based on the carbon and nitrogen makeup of the materials.

One other effort by Caltrans is to use composted urban green resources and biosolids products as a hydroseeding mulch medium.. There has been some progress to date; we know that these materials can be hydraulically applied, but there must be a cellulose mulch component. The compost materials by themselves don't go into a good slurry. they need a bulking agent. The biggest obstacle today is a good definition of what compost is. It is anticipated that the wood and cellulose material currently in use will be largely replaced by compost materials within the next two years.

Development of Alternative Insecticide Programs

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Paper not submitted in time for inclusion in Proceedings.

USE OF COMPOSTS FOR ALTERNATIVE NON-CHEMICAL PLANT DISEASE MANAGEMENT

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For over twenty years, researchers have been studying the disease suppressive properties of composted organic potting mix amendments. Containerized systems are more amenable to this disease management approach than are field grown crops. Examples of plant diseases that can be suppressed by compost amendments include those caused by: *Fusarium oxysporum* f. sp. *conglutinans, Rhizoctonia solani, Pythium* spp., *Phytophthora spp., Verticillium dahliae,* and *Thielaviopsis basicola.* Plant diseases can be biologically controlled by any combination of four different mechanisms: competition, antibiosis, hyperparasitism, and systemically acquired host resistance (through preconditioning). The addition of composts to container media can result in a more diverse and/or greater populations of microflora available to interact with potential pathogens in the rhizosphere.

It is important to have a basic knowledge of the composting process in order to understand how composts can control plant diseases. The composting process can be divided into three phases. During the first phase, easily biodegraded (sugars and water soluble carbohydrates) materials are metabolized. This phase occurs during the initial 48-72 hours of the process. Temperatures are greatest during this phase and must be maintained below 70C. If temperatures rise above this critical threshold, the active microflora are thermally inactivated and the biodegradation (i.e. composting) process is inhibited. During the second phase of the composting process, cellulosic materials, lignins and suberins are metabolized. This process generates an intermediate amount of heat and generally proceeds over a several week period. The third phase of the composting process is curing. During the curing phase, internal pile temperatures decrease gradually as less substrates are available for microbial consumption, and mesophilic microorganisms recolonize. The first microorganisms to recolonize the compost preempt other organisms and may predominate. This chance event can result in disease suppressive or conducive media, depending upon which microorganisms happened to establish significant populations.

The recolonization of compost substrates during curing by beneficial (disease suppressive) microorganisms can be influenced by a number of mechanisms, including artificial inoculation with specific beneficial microorganisms such as *Trichoderm*a spp., *Gliocladium* spp., *Flavobacterium* spp., and fluorescent Pseudomonads. Nutritional substrate composition is an important factor in the efficacy of these beneficial microorganisms - if the necessary nutrients are not present in sufficient amounts, even highly effective biocontrol agents may not perform in disease control.

Numerous inoculants are being marketed commercially as alternatives to pesticides for plant disease control. Compost amendments are an ideal delivery system for these beneficial microorganisms. It is essential that these processes be understood to facilitate transfer of this technology for horticultural use.

Potential Herbicide Savings Using a Light Activated Sprayer

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Paper not submitted in time for inclusion in Proceedings.

SITE-SPECIFIC CROP MANAGEMENT IN CALIFORNIA

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INTRODUCTION:

Farmers have long recognized that soil properties vary spatially within their fields. Over 65 years ago researchers at the Illinois Agricultural Experiment station recommended a mapping procedure to guide spatially-variable applications of lime (Linsley and Bauer, 1929). During this period, inputs were expensive and application technology (horse-drawn wagon) was easy to adapt to site-specific practices (Goering, 1993). After World War II, fertilizer was relatively inexpensive, and farms grew in size as they became mechanized. Consequently, interest in matching inputs with crop needs declined. In recent years, attention has returned to site-specific crop management (SSCM) as a Best Management Practice to minimize the environmental impact of agriculture. With the aid of computers and sensors, growers are managing within-field spatial variation by mapping soil chemical and physical properties, and by using precision applicators to vary rates of seed, fertilizer, and pesticides to suit the inherent spatial variability of fields.

Many of the advances in SSCM were made in the Midwest, where SSCM practices are used extensively to manage grain crops. Therefore, much of the SSCM equipment and analytical tools are biased towards Midwestern agricultural systems. Due to the complexity of Californian agriculture many challenges exist in developing appropriate site-specific technology. Site-specific practices must be relevant to hundreds of different agricultural commodities and management systems. In high value crops, such as trees and vegetables that receive multiple applications of fertilizer and pesticides, time-specific technology may be more beneficial than site-specific technology. By forecasting diseases and insect infestations, pesticide applications would be more efficient in controlling pest outbreaks, and result in less use of chemical pesticides. In addition, the arid environment of California offers some unique opportunities for SSCM. Site-specific technology may be useful for mapping saline areas of fields, or for increasing irrigation efficiency on soils with spatially variable hydraulic properties. The purpose of this paper is to present an overview of site-specific agriculture, and to speculate on its relevancy to Californian cropping systems.

EQUIPMENT:

Equipment is needed for determining locations within fields, sensing soil, crop, and atmospheric variables, and for modulating rates of inputs. Recent developments in site-specific equipment can be found in conference proceedings (Robert et al., 1994).

Navigation Geographical Positioning Systems (GPS), developed by the U. S. Department of Defense provide accurate real-time fixes of location when used in conjunction with a differential correction signal. Positioning accuracy depends on the quality of the receiver. Low-end units with differential correction provide 3 to 5-m precision in real-time mode, and high-end units provide submeter accuracy. The GPS receiver uses the differential signal, broadcasted from a base station, to correct errors in the satellite signals. Along the coast and Mississippi River differential correction signals, broadcasted by the U.S. Coast Guard, are available to the public. Inland GPS users usually can subscribe to differential signals broadcasted by private companies.

Sensors Information on sensor technology rapidly becomes outdated; therefore, thorough searches are recommended when selecting equipment. Near infra-red sensors have been developed for real-time measurements of soil organic matter content and soil moisture. These sensors are used for varying pre-emergent herbicides and varying planting depth. Electrical magnetic induction has been used to map clay-pan depth, which has been shown to correlate with maize yields in Missouri soils. Sensors for real-time measurement of soil nutrients are still under development. Although rapidly responding flow-injections systems exist for simultaneous measurement of NO_3, Na, K, and pH, a scheme for real-time extractions is an important limitation to their practicability. Presently the most widely accepted method of mapping soil nutrients is to sample fields on a grid pattern, analyze samples for nutrients using traditional methodologies, and develop nutrient maps using geostatistical methods.

Grain yield sensors have special importance to SSCM, for they allow growers to evaluate their farming practices, identify low yielding areas, conduct on-farm experiments, and document yield losses. Most impact- and light- based sensors have a 95% accuracy. Yield sensors are also being developed for mechanically harvested vegetable and fruit crops (tomatoes and potatoes). Light sensors and video cameras have been used to determine the presence of weeds in fallow fields for varying applications of herbicides. On a larger scale, areal and satellite infrared imaging may identify areas of crop stress, induced by drought or pests.

Data loggers that send data real-time to a base station computer using radio telemetry technology, have much potential for simultaneously monitoring micro climatic and transient soil properties, such as soil moisture and temperature, which are important for predicting soil biological activity and crop growth. Automated weather stations equipped with air temperature and leaf wetness sensors have been used to forecast blackmold in processing tomatoes, and may also have potential to predict powdery mildew and late blight. These stations may also be useful in tree crops where day-degree models are used to time pesticide applications.

Applicators Variable rate applicators range in complexity, from systems that control flow rate, change chemicals, and vary application pattern to those that only modulate flow rates. Applicators equipped with flow meters and GPS can map the amount of inputs applied to each location within a field. Applications which need to vary across short distances would require fast response times. For example, a system with a 2-s response time traveling at 8 km h^{-1} and modulating rates at 20-m intervals, would apply the correct rate to only 78% of the interval. Application error reduces the benefits of SSCM.

Data Analysis Geostatistics, geographic information systems (GIS), and multivariate modeling are used to interpret spatial data and develop Best Management Practices for agriculture. Geostatistics consists of variography and kriging. Variography uses semivariograms to model spatial variance and estimate the components of spatial and nonspatial variation in data. Spatial variation needs to be quantified to estimate the benefits of SSCM and to develop appropriate SSCM practices. The semivariogram illustrates the relationship of the sample variance and the lateral distance, known as a lag, separating samples (Fig. 2). The lag distance where the variance approaches an asymptotic maximum, know as a sill, is the range across which data are spatially correlated. The variance usually approaches a finite value, know as a nugget, at small lag distances. The nugget variance represents the component of non-spatial, or residual variation. The semivariance of soybean yield data in Fig. 3 increases with lag distance without reaching a sill, presumably because a trend exists across the field. The trend represents large scale spatial variation, perhaps caused by a transition in soil properties across the field. Detrending methods, such as median polishing, can remove large scale variation from data so that small scale variation can be examined. The inset of Fig. 3 shows that small scale variation with a 20-m range is also present.

Kriging uses the modeled variance of semivariograms to estimate values between samples, thus forming maps of soil properties and crop yield. Each mapped variable can be entered as a layer of information in a GIS. Geographical information systems are used in SSCM to explore relationships among soil and crop variables. For example, a user may be interested to know if the spatial pattern of yields in Fig. 3 correlates with soil type, texture, or fertility. Geographical information systems suitable for SSCM need query tools to identify high and low values, and tools to export selected data for multivariate analysis.

Multivariate analyses can identify soil properties that influence crop yield, and determine crop yield response to input rates. This information can be developed into Best Management Practices (BMP) for reducing agricultural impacts on the environment. In the Midwest, where farmers have extensively mapped soil properties and crop yields, the possibility already exists for researchers to use on-farm data to develop Best Management Practices, which would be used to control variable rate applications. Hence, an information cycle (Fig 3.) may evolve that will allow researchers and industry to collaborate in reducing input costs and addressing public concerns about agricultural effects on the environment.

CONCLUSIONS:

Progress in SSCM technology presents new opportunities to study spatial variation of soil and crop variables across a wide range of landscapes, and offers unique opportunities for researchers to interact with industry and environmental agencies. Expertise is needed to accurately analyze and interpret spatial data, and formulate management practices that will improve the sustainability of agricultural systems and minimize the environmental impact of agriculture.

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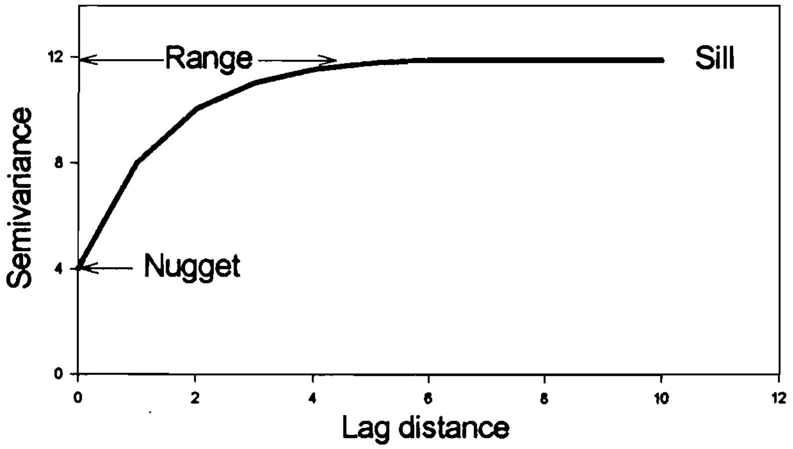

Fig. 1. Semivariogram, showing the range, nugget, and sill.

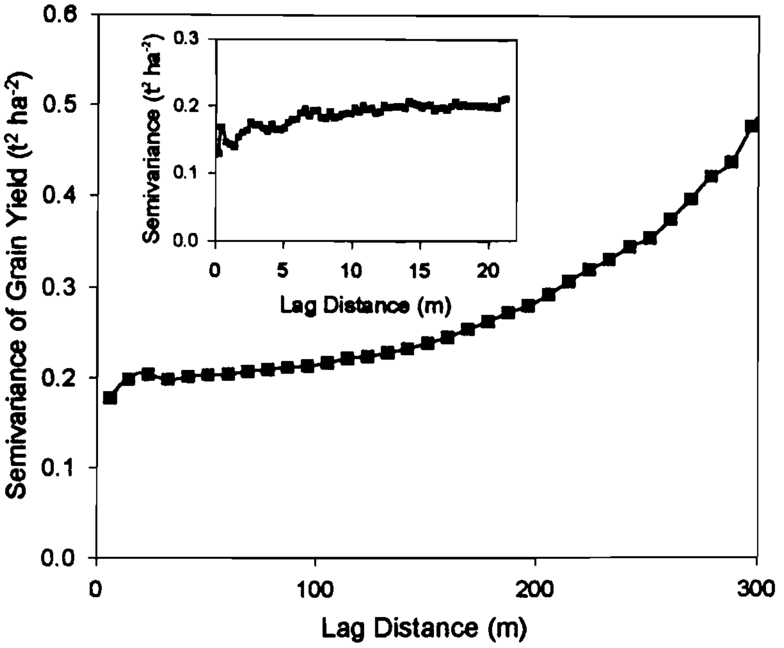

Fig. 2. Semivariogram of soybean grain yield measured with a yield sensor.

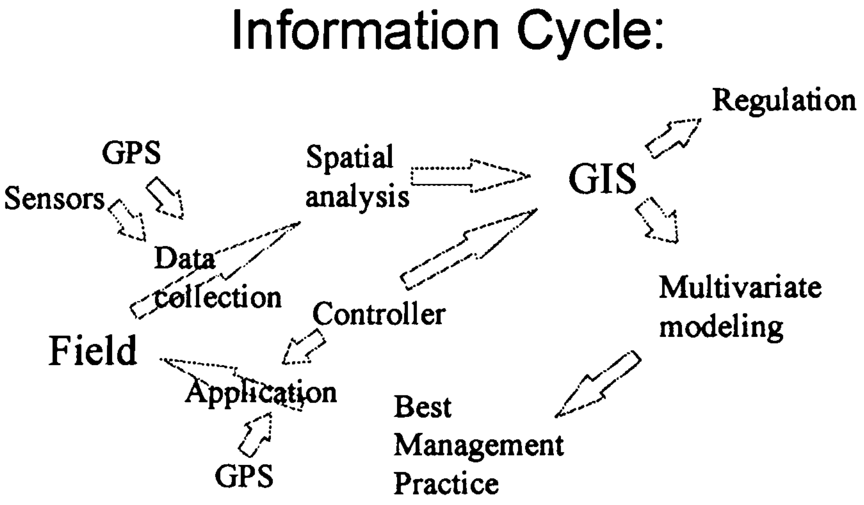

Fig. 3. Flow of information in site-specific crop management.

LOCATION, LOCATION, LOCATION: PRACTICAL CONSIDERATIONS FOR APPLYING GPS FOR IPM PROGRAMS

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The explosion in interest in precision agriculture technology has been accompanied by a blossoming uses for a number of enabling technologies, the two most important of which are the Global Positioning System (GPS) and Geographic Information Systems (GIS). While GIS technology offers tremendous capabilities for more informed Integrated Pest Management decision making, rendering competent decisions still depends on having reliable data available. This paper deals with two issues related to obtaining reliable data. One, the importance of accurately identified locations to which all field mapping and subsequent treatments can be linked. Second, how Global Positioning System (GPS) technology can be used to build your data base and to collect data efficiently. What is reliable? What is accurate enough data? It depends on the functions and the objectives for which the GIS data base was developed. Some precision agriculture applications can be performed with less accurate data which cost much less to acquire. However, other applications, like spray control with GPS may require higher accuracy in order to prevent overlapping applications of chemicals.

Determination of accurate coordinates for weed or insect infestations is essential for proper assessment requiring grower intervention. Once the grower determines where a problem requiring treatment exists, it is important to only treat the problem area, and leave the rest of the field alone, both to save money and not harm "good insects," both important aims of an IPM program

This paper's goal is to give an overview of GPS and how it may be used in precision agriculture applications including integrated pest management.

What Is GPS?

The Navigation Satellite Timing And Range Global Positioning System, or NAVSTAR GPS, is a satellite based radio-navigation system that is capable of providing extremely accurate worldwide, 24 hour, 3-dimensional location data (latitude, longitude, and elevation). The system was designed and is maintained by the US Department of Defense (DoD) as an accurate, all weather, navigation system. Though designed as a military system, it is freely available with certain restrictions to civilians for positioning. The system has reached the full operational capability with a complete set of at least 24 satellites orbiting the earth in a carefully designed pattern.

The Fundamental Components of GPS

The NAVSTAR GPS has three basic segments: space, control, and user. The space segment consists of the orbiting satellites making up the constellation. This constellation is comprised of 24 satellites, each orbiting at an altitude of approximately 11,000 nautical miles, in one of six orbital planes inclined 55 degrees relative to the earth's equator. Each satellite broadcasts a unique coded signal, known as Pseudo Random Noise (PRN) code, that enables GPS receivers to identify the satellites from which the signals came, and makes positioning possible.

The control segment, under DoD's direction, oversees the building, launching, orbital positioning, monitoring, and provides two classes of GPS service. Monitoring and ground control stations, located around the globe near the equator, constantly monitor the performance of each satellite and the constellation as a whole. A master control station updates the information component of the GPS signal with satellite ephemeris data and other messages to the users. This information is then decoded by the receiver and used in the positioning process.

There are two classes of GPS service; the Precise Positioning Service (PPS) which is available only to users authorized by the military, and the Standard Positioning Service (SPS) which is available for civilian use.

The user segment is the most important segment of the system and is comprised of all of the users making observations with GPS receivers. The civilian GPS user community has increased dramatically in recent years, due to the emergence of low cost portable GPS receivers and the ever expending areas of applications in which GPS was found to be very useful. Some of these applications are: surveying, mapping, precision agriculture, navigation and vehicle tracking. The number of civilian users now greatly out number military users.

GPS Limitations

Though GPS can provide worldwide, 3D positions, 24 hours a day, in any type of weather, the system does have some limitations. First, there must be a (relatively) clear "line of sight" between the receiver's antenna and several orbiting satellites. Anything shielding the antenna from a satellite can potentially weaken the satellite's signal to such a degree that it becomes too difficult to make reliable positioning. As a rule of thumb, an obstruction that can block sunlight can effectively block GPS signals.

The receiver must receive signals from at least four satellites in order to be able to make reliable position measurements. In addition, these satellites must be in a favorable geometrical arrangement. The four satellites used by the receiver for positioning must be fairly spread apart. In areas with a relatively open view of the sky, this will almost always be the case because of the ways these satellites were placed in orbit.

How Does A GPS Receiver Determine Positions?

The position of a point is determined by measuring distances (pseudo-ranges) from the receiver to at least 4 satellites. The GPS receiver "knows" where each of the satellites is at the instant in which the distance was measured. These distances will intersect only at one point, the position of the GPS receiver (antenna). How does the receiver "know" the position of the satellites? Well, this information comes from the broadcast ephemeris that are down-loaded when the GPS receiver is turned on. The GPS receiver performs the necessary mathematical calculations, then displays and/or stores the position, along with any other descriptive information entered by the operator from the keyboard.

The way in which a GPS receiver determines distances (called pseudo-ranges) to the satellites depends on the type of GPS receiver. Basically, there are two broad classes: carrier phase based and code based.

Carrier phase receivers

The carrier phase receivers, used extensively in geodetic control and precise survey applications, are capable of sub-centimeter (cm) accuracy. These receivers calculate distances (called pseudo-ranges) to visible satellites by determining the number (N) of whole wavelengths (λ) and measuring the partial (phase) signal wavelength (Φ) there are between the satellites and the receiver's antenna. Once the number of wavelengths is known, a pseudo-range may be calculated by multiplying 'N' by the wavelength of the carrier signal (L1 and/or L2, 19 cm and 24.4 cm respectively) plus the partial wavelength. It is then a straight forward (albeit complex) task to compute a baseline distance and azimuth between any pair of receivers operating simultaneously. With one receiver placed on a point with precisely known latitude, longitude, and elevation, and with the calculated baseline (distance between 2 points), the coordinate for the unknown point may be determined.

The relative cost of the carrier phase receivers is high, but technological advances have made the dual frequency (using both, L1 and L2) carrier phase receivers of today much more efficient than the single frequency (using L1 only) receivers that were state-of-the-art only a few years ago. With some of the newest dual frequency receivers very precise measurements (± 1 cm) can be made in real-time. These receivers will be used in machine control applications requiring a high degree of accuracy.

Code-based receivers

Though less accurate than their carrier phase cousins, code-based receivers have gained widespread appeal for applications such precision farming. This popularity stems mainly from their relatively low cost, portability and ease of use.

Instead of using the number of signal wavelengths to establish pseudo-ranges, code-based receivers use the speed of light and the time interval that it takes for the signal to travel from the satellite to the receiver, to compute the distance to the satellites. The time interval is determined by comparing the time in which a specific part of the coded signal left the satellite with the time it arrived at the antenna. The time interval is translated to a range by multiplying the interval by the speed of light constant (c=l 86,000 miles/second). Ranges from at least four satellites are needed in order for a receiver to produce a position fix. Position fixes are made by the receiver roughly every second, and the more advanced receivers enable the user to store the position fixes in a file that can be downloaded to a computer for post processing.

Under normal circumstances, autonomous standard position fixes (SPS) made by code-based receivers would be accurate to within 25 meters. The DoD however began imposing its selective availability (SA) policy in July of 1992, which limits position fix accuracy to within 100 meters. The purpose of SA is to deny potential hostile forces accurate positioning capabilities. Military P-code (Y-code) receivers are not affected by SA, but as mentioned earlier are not available for the general public. In order to overcome the limited positioning accuracy, differential GPS (DGPS) techniques have been developed. DGPS enables the user to improve SPS and also to remove the effects of SA and some other sources of error. These differential correction techniques can produce positions generally accurate to within a few meters.

There are also now code based receivers capable of sub-meter accuracy. Most sub-meter receivers require longer data collection times (about ten minutes), and perform best under very favorable satellite geometry, and with an unobstructed view of the sky. Some newer receivers can provide sub-meter in seconds. These receivers cost more at the outset, but provide a good return on the added investment by providing substantially higher productivity.

It is very important that users of code based receivers understand the position accuracy limitations of the receiver. Due to SA, each coordinate viewed on a non-differential GPS receiver's display is only accurate to within 100 meters. This accuracy can be improved on by taking an average of 200 or so repeated position observations of the same point. The resulting accuracy would still be below what many users would consider acceptable quality. In order to produce acceptable results, GPS data collected in the field must be differentially corrected either in real-time, or by post-processing the data.

Differential GPS and the Base Station Concept

Differential GPS (DGPS) can be employed to eliminate the error introduced by SA and other systematic errors. Differential GPS requires the existence of a base station, which is simply a GPS receiver collecting measurements at a known latitude, longitude, and elevation. The base station's antenna location must be located precisely, using carrier phase GPS or other traditional surveying techniques. The base station may store measurements (for post processed DGPS), broadcast corrections over a radio frequency (for real-time DGPS), or both.

The assumption made with the base station concept is that errors affecting the measurements of a particular GPS receiver will equally affect other GPS receivers within a radius of 200-300 miles. If the differences between the base station's known location and the base station's locations as calculated by GPS can be determined, those differences can be applied to data collected simultaneously by receivers in the field. These differences can be applied in real-time (especially applicable for accurate navigation) if the GPS receiver is linked to a radio receiver designed to receive the broadcast corrections. In some GIS mapping applications, these differences are applied in a post-processing step after the collected field data has been downloaded to a computer running a GPS processing software package. GPS processing software is typically integrated with GPS hardware and thus is provided by the receiver manufacturer. As a rule, post-processed DGPS is considered slightly more accurate than real-time DGPS.

Base Stations - The Source For Reference Data For DGPS

There are many permanent GPS base stations currently up and running in the United States, with several in California that can provide the users of code based receivers with data necessary for differentially correcting positions over an electronic bulletin board:

In addition installation and testing has started in California of the US Coast Guard's DGPS beacon system. These stations are part of a coastal network of stations the US Coast Guard is planning that will provide real-time corrections over a radio frequency.

Precision Agriculture Considerations

Several key issues need to be explored when considering GPS as a tool for capturing coordinate data for a precision agriculture application. First and foremost, what are the position accuracy requirements? If the data will be used for site specific analysis that require position accuracy to be within three feet, code based differential GPS receivers will be used. If better accuracy is required, as for a spray controller, then carrier phase GPS techniques have to be employed.

Every GIS database must be referenced to a base map or base data layer. Ideally, the database should be referenced to a large scale, very accurate base map. If instead the base map is smaller scale (quad scale or smaller) there could be problems when attempting to view the true spatial relationships between features digitized from a small scale map and features whose coordinates were captured with GPS. This can be a real problem if an grower decides to use a particular GIS data layer that was originally generated using small scale base maps as a base to which all new data generated is referenced. The best way to avoid such incompatibility one should consider developing an accurate base data layer, based on geodetic control and photogrammetric mapping.

Is GPS The Answer To All Our Mapping Needs?

As mentioned earlier GPS has its limitations. The most important one is that it requires clear view of the satellites. Buildings, trees, overpasses and other obstructions that block the line of sight between the satellite and the observer (GPS antenna), make it impossible to work with GPS. Urban areas are especially affected by these types of difficulties. Bouncing of the signal off nearby objects may present another problem, that of distinguishing between the signal coming directly from the satellite and the "echo" signal that reaches the receiver indirectly. In areas that posses these type of characteristics, traditional surveying techniques must be used instead or to complement GPS positioning.

GPS is a positioning system that can also be used as a real-world digitizer for mapping point and line features such as roads or wetland boundaries. However, for large volume data collection which includes measuring many points, mapping, contouring, etc., one should consider photogrammetry, as a more efficient data collection tool.

GPS is an important (future) tool for IPM

Field portable GPS receivers are available for rapidly mapping insect infestations and this data can be accurately communicated to the field manager who may employ a custom spray operator to apply the correct chemicals only where they are needed. In addition, the spray operator will be able to provide a permanent record back to the field manager with GPS data of where and when the treatment took place.

Field Data Collection and Agricultural Information

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'NUTRIENT MANAGEMENT IN THE CENTRAL PLATTE RIVER VALLEY, NEBRASKA'

Presented during the session on "Advances in Nutrient Management"
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The Central Platte Natural Resources District is located in south-central Nebraska. It is one of 23 NRDs (Natural Resources Districts) across the state. NRDs are local units of government charged with the responsibility of conservation, wise development and proper utilization of the natural resources. The NRDs' responsibilities include a whole host of activities dealing with soil, water and other natural resources. Of the 13 different NRD purposes outlined in Nebraska Statutes, two deal directly with groundwater quality: Purpose No. 6, "the development, management, utilization and conservation of groundwater and surface water" and Purpose No. 7, "pollution control."

Central Platte NRD's groundwater quality plan is undertaking a long-term solution for widespread high groundwater nitrate-nitrogen problems. Developed by the NRD after years of research, the groundwater quality plan has received high acclaim, statewide and nationally, for achieving the plan's objectives. Groundwater is a valued natural resource in the district. While much of it is used for irrigation, nearly all residents, including farmers and their families who rely on agriculture for their livelihood, use groundwater for drinking water.

High groundwater nitrates in some areas of the valley were first identified in 1961 when the University Extension Service documented cases of groundwater nitrates above 10 ppm (parts per million) in Merrick County, which is the eastern part of the Central Platte district. The U.S. Public Health Service and Environmental Protection Agency has set a standard of 10 ppm as the maximum safe level for human or animal consumption.

Nitrates can be particularly harmful to infants under six months of age. Excessively high nitrates can lead to *methemoglobinemia,* a condition that is commonly known as *"blue baby syndrome."* High nitrates also are a potential hazard to livestock.

When the NRDs came into existence on July 1, 1972, some 11 years after those early indications of high groundwater nitrates, one of the first actions of the new Central Platte NRD was to form a water quality committee. The committee's efforts led to a contract between the NRD and the Conservation and Survey Division of the University of Nebraska - Lincoln to conduct a baseline study of groundwater quality across the Central Platte district.

The results of the study, published in 1974, showed that the groundwater nitrate problem was not unique to Merrick County. About half the district had nitrate levels at less than 2.5 ppm, but the other half had significant amounts of nitrates in the groundwater. Approximately 20% of the district, extending from Kearney in the central part of the NRD, to Columbus at the northeast corner of the district, had groundwater nitrates that exceeded 10 ppm.

The district and the Cooperative Extension Service started a project in 1974 in Merrick County to study methods of extracting nitrates from groundwater through irrigated corn production. The study continued through 1975, 1976 and 1977.

Also in 1974, the district, in cooperation with the Department of Agricultural Engineering at the university, conducted a study to determine what contribution was made by septic tanks to groundwater nitrates. The results of the septic tank studies, completed in 1975, indicated that septic systems can be contributing factor, especially in development areas that have a concentration of septic systems for sanitary disposal. However, the study concluded that septic tank leaching could not be a primary source of groundwater nitrates in the Central Platte district.

In 1977, the district entered into a second contract with the Conservation and Survey Division of the University of Nebraska to carry out a study to determine the original sources of nitrates in the groundwater. That study, conducted chiefly with an isotope ratio mass spectrometer to identify nitrate sources, was completed in 1978. It identified commercial fertilizers applied to irrigated croplands as, not the only, but the *major* source of groundwater nitrates in the Central Platte district. Commercial fertilizers applied to the fields were leached down below the root zone and into the aquifer by rainfall and over-application of irrigation water.

Two additional studies were conducted in 1978 by the Conservation and Survey Division. One looked at the carbon content of groundwater, and the other one looked at atrazine in groundwater within the district. Then, in 1979, the district entered into still another contract with the Conservation and Survey Division. This time, chemical seepage, primarily the nitrate seepage from irrigation tailwater recovery pits, was studied to determine what contribution the pits made to groundwater nitrate problems.

Also in 1979, the district, working in cooperation with the County Extension Service, ASCS (Agricultural Stabilization and Conservation Service) and the Hall County SCS (Soil Conservation Service), applied for and received a grant through the Nebraska DEC (Department of Environmental Control) with cost-share monies through ASCS. These funds enabled the NRD to establish the Hall County Water Quality Special Project. This was a major research and demonstration project covering 65 square miles in an area of Hall County that had high nitrates and varying soil types. The program got undwary in 1980 and was carried out for the next four crop years. The project objectives were to study ways to impede the leaching of nitrates into the aquifer from fertilizer applications, to improve water quality by mining groundwater with high nitrate content, and to demonstrate that nitrates can be managed efficiently and effectively while maintaining crop yields.

In 1984, ten years after the first baseline study, the district did another inventory of groundwater nitrates, which indicated that the areas of high nitrate had grown in size and it showed that the average concentrations continued to increase over time.

All of the investigations, demonstrations and research conducted between 1973 and 1983 showed the quality of groundwater in the Central Platte district is impacted by three things:

- Residual nitrates: the nitrogen left over after the crop is harvested is just sitting there, subject to leaching down into the groundwater supply.
- Irrigation water itself: due to the content of the nitrogen in the water and also the rate at which the irrigation water is applied. Over-application of irrigation water leads to leaching the nitrogen below the root zone and eventually into the groundwater aquifer.
- Fertilizer applications: for a variety of reasons. The rate can have an impact if more fertilizer is applied than is needed or can be used by the crop, resulting in more nitrogen available to be leached down below the root zone. The form of the nitrogen fertilizer can also have an impact since fertilizer can be either in a leachable form or not. The time of the application can also have an impact. For example, a fall application extends the "opportunity time" for the nitrogen to be leached below the root zone and into the aquifer.

Central Platte NRD, the NRCS and the Cooperative Extension Service entered into an agreement in 1984 to continue the demonstrations that had been started by the Hall County Water Quality Special Project. The project was expanded, utilizing "best management practices" that were found to be most effective in the Hall County project. A full-time employee was hired to work with farmers, fertilizer dealers, soil testing labs and the public to promote sound nitrogen management. The employee set up demonstration fields in Buffalo, Hall and Merrick counties on which he took deep soils samples for analysis. He also took water samples from each well, determined fertilizer application rates, scheduled irrigation applications and finally checked yields on each of the demonstration fields at harvest time.

The results of the yield checks demonstrated that applications of additional nitrogen do not result in higher yields. Typical of the findings was a demonstration field in Buffalo County in 1984, produced these results: The recommended rate of application of commercial fertilizer, after taking into account the nitrogen available in the soil and water, was an application of 150 pounds of nitrogen per acre. The field was stripped out into test plots with some of the plots having applications of the recommended 150 pounds per acre, some plots at 40 pounds less, or 110 pounds per acre, and other plots at 40 pounds over, or 190 pounds per acre. At the end of the year, the yield check indicated that the plots using the recommended 150-pound rate yielded 187 bushels an acre. The yield for the 110-pound rate was within 1 bushel (186 bushels an acre) and in fact out-yielded the 190-pound rate by two bushels (184 bushels an acre).

Another field in Merrick County basically showed the same results in 1984 with an application rate of 56 pounds per acre yielding within 1 bushel of those plots on which 225 pounds per acre were applied.

Farmers from throughout the District, with varying soils and conditions, were recruited to work with the NRD in using the best management practices to demonstrate that nitrates can be managed efficiently and effectively while maintaining crop yields. Their neighbors are aware of the "demonstrations" and watch the progress of the fields during the growing season. A "Demonstration Day" is held at the field in the fall to enable those neighbors to ask questions of the farmer, those who designed and implemented the demonstration and various "experts," generally from the University of Nebraska College of Agriculture, who could address the results and implications of the demonstration.

The NRD developed a program of education and cost-share funding to solve the high nitrate problem. Practices that would impede nitrogen fertilizer from leaching into the aquifer were successfully demonstrated throughout the District. Many tools needed by farmers to establish best management practices, including fertilizer calibration meters, irrigation well hour meters, surge valves, vertical dam manifolds, irrigation flow meters and reuse pits, were encouraged through the availability of cost sharing by the District. As farmers began using the new tools, word of mouth spread the story of their effectiveness. And, as new technology developed to help the farmers practice better manage-ment, the District board has modified its cost share program to accommodate the new tools.

By 1986, the high nitrate problem was recognized in other parts of the state as well, so the Nebraska Legislature expanded the authorities and responsibilities of the NRDs by adding to their management area authorities the ability to require "best management practices" and "education programs designed to protect water quality." The directors of the Central Platte NRD welcomed this responsibility, and as a result of continuing research; numerous meetings with farmers, crop consultants, fertilizer industry representatives and others, and public hearings, the NRD adopted the necessary rules, regulations, boundaries and controls for a formal groundwater quality management program, which was included in the comprehensive Groundwater Management Plan adopted by the directors on July 23, 1987. The formal plan became effective on Aug. 26, 1987, and it has been updated from time to time and was reissued and reauthorized in 1995.

The programs rules include district-wide mandatory training in nitrogen fertilizer management for all producers of corn and sorghum. Other requirements, such as soil and water testing and water management, are mandated in areas of the district that have a greater problem. In high nitrate areas, corn and sorghum farmers have restrictions on how and when they apply fertilizer and also must file an annual report on a form that is designed to be used not only as a report to help the NRD evaluate its program, but also as a worksheet for the farmer to develop a plan for management.

After the program's first crop year (1988), the reports showed the first recorded decline in the average ppm in the NRD's high nitrate area. With favorable conditions, the ppm level continued to decline, dropping a full part in the first three years. However, adverse weather conditions sometimes prevent farmers from following the entire program, resulting in a slower reduction. This illustrates an immediate positive effect from following the entire program. It further demonstrates that high nitrates, which developed over a long period of time, will also take some time to be reduced to safe drinking water levels.

NITROGEN FERTILIZER MANAGEMENT TO REDUCE GROUNDWATER DEGRADATION

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OBJECTIVES:

1. Assess the sensitivity of leaf nitrogen (N) concentration to overfertilization.
2. Determine the relationship between leaf N concentration and tree productivity (i.e., reassess the validity of the currently-accepted leaf N diagnostic guidelines)
3. Assess the relationship between the rate of applied fertilizer N, tree N status and the percentage recovery of isotopically labeled (^{15}N-depleted) fertilizer N.
4. Assess nitrate leaching below the root zone and its relationship to fertilizer N application rate and tree N status.
5. Refine current management guidelines for N usage which will help maintain productivity while reducing the amount of fertilizer N leached below the root zone under conditions typical of the Northern San Joaquin Valley.

DESCRIPTION:

Two research plots were established in nitrate-sensitive areas of Stanislaus County, one in Salida and one in Ceres. Both orchards, planted in 1980, are growing in Hanford sandy loam soils.

The project was conducted in three phases. In 1990, pretreatment baseline data were obtained (on tree yields, leaf N, concentrations, and soil and irrigation water nitrate concentrations); and experimental plots were established. From 1990-1993, differences in tree N status and related effects were established (including yield differentials and soil nitrate levels) using 4 levels of applied fertilizer N (0, 125, 250, and 500 lbs N/acre/year) applied as a 1/3, 2/3 split in April and early October, respectively. From 1993-1995, a uniform amount of isotopically labeled ammonium sulfate was applied to selected trees differing in tree N status, and tree recovery of labeled fertilizer N and the likelihood of nitrate leaching below the rootzone was determined.

RESULTS:

Current fertilization practices in many almond orchards favor overfertilization--the application of fertilizer nitrogen in excess of the tree's capacity to utilize it. The following evidence is consistent with that interpretation:

The presence of high residual levels of nitrate in the soil. These may result from the use of high nitrate-containing irrigation water (33 ppm nitrate in Salida and 44 ppm nitrate in Ceres) as well as excessive application rates of fertilizer N.

Lack of a yield response to the fertilizer. A significant yield reduction in unfertilized trees occurred only in 1993, which was 3 1/2 years after the last fertilization (Table 1). The lack of significant yield reduction in unfertilized trees in 3 out of 4 years (Table 1) indicates that fertilization was not required annually to maintain productivity under the orchard conditions. We must conclude that sufficient N is available from other sources (e.g. high nitrate irrigation water, etc.) to maintain productivity without supplemental fertilization.

High leaf N concentrations. Pretreatment (1990) leaf N concentrations averaged above 2.6% in both orchards (Table 2). There is no evidence that almond yields increase above a leaf N concentration of 2.5%. Leaf N concentration appears to be insensitive to overfertilization, thus there is virtually no difference in leaf N concentrations between trees receiving 250 lbs N/acre/year and those receiving 500 lbs N/Acre/Year (Table 2). This probably means that at higher levels of available soil N, tree capacity for N uptake is limited and additional fertilizer N accumulates in the soil and becomes vulnerable to loss--probably leaching--in coarse-textured, sandy soils. On the basis of our data, the ideal range of leaf N concentration to both maintain yield and minimize subsequent leaching appears to be between 2.3% and 2.5%N.

Preliminary analyses indicate not only that almond tree productivity is N-limited when mid-summer leaf N concentration is below 2.2%, but yield may even be reduced when leaf N concentrations are between 2.2 and 2.3%. A major determinant of yield is fruit number. As flower differentiation occurs in the summer soon after diagnostic leaf sampling in July, our data suggest that leaf analysis is more predictive of the subsequent year's crop than the current year crop. Thus, a leaf N concentration below 2.3% in July 1993 may be indicative of a reduced crop in 1994.

Tree N status and recovery of isotopically labeled fertilizer N. Following three years (1990-1993) of differential rates of N fertilization, we selected 18 trees (Salida orchard) varying in leaf N concentration (Table 3), and 1993 yield relative to pretreatment yields in 1990. Labeled ammonium sulfate was applied post-harvest (October 2, 1993) at the rate of 166 lbs N/Acre/Year. Trees also received 84 lbs N/Acre/Year (non-labeled) in April 1994. We then determined total recovery of labeled N in the fruit (1994). Four of the trees were also excavated completely in February, 1995, and analyzed for residual labeled N content.

Between 65% and 79% of the labeled N absorbed by the trees was in the fruit with the remainder present in the perennial tree parts (branches, trunk, roots, etc.), as shown in Table 3.

Trees that were fertilized at the rate of 500 lbs N/Acre/Year only recovered about 20.5% of the fertilizer N applied (Table 3). In contrast, trees that received 0, 125 or 250 lbs N/Acre recovered 30% of the labeled N applied--about 50% more. Thus, the high rates of N fertilizer application between 1990 and 1993 reduced recovery of fertilizer N in 1993-1994. Two factors may have limited uptake of fertilizer N by trees receiving 500 lbs N/A/Year between 1990 and 1993: a) dilution of labeled fertilizer N in the soil by high residual levels of nitrate (Table 3) and b) reduced tree N demand. As discussed below, leaching did not occur during the winter of 1993-1994.

We are finding (in other studies) that the N requirements of fruit growth, shoot growth and nut fill are important determinants of N uptake. During the post-harvest and dormant periods, growth nearly ceases, and dormant trees have a greatly limited capacity for N uptake. In years of heavy rainfall, significant leaching can occur between November and March. High residual levels of nitrate in the soil after harvest may be vulnerable to leaching within one to two months. Thus, a) low N uptake by trees during the post-harvest and dormant periods coupled with b) vulnerability of nitrate to leaching with the winter rains should discourage heavy post-harvest applications of fertilizer N. The winter of 1993-1994 was relatively dry, receiving only about 2/3 of the normal annual rainfall. Fertilizer recovery (Table 3) might have been even lower if we had conducted the study in 1994-1995 when rainfall was nearly double the long-term average. Our data do not allow us to determine how much of the labeled N recovery occurred between October, 1993 and March 1994 (bloom) and how much between bloom and harvest (August, 1994).

Table 1. Differential N Fertilization and Almond Yields in 2 Stanislaus County Orchards

Orchard	Treatment[z] (lbs N/A/Yr)	Meat Pounds Per Acre[x]				
		1990[y]	1991	1992	1993	1994
Salida	0	3508	3587 a	1470 a	1938 c	*
	125	3508	3554 a	1538 a	2735 ab	*
	250	3508	3421 a	1606 a	3120 ab	*
	500	3508	3610 a	1789 a	3710 a	*
Ceres	0	4444	1633 a	2512 a	2421 b	3967 a
	125	4444	2309 a	2542 a	2956 ab	3837a
	250	4444	1807 a	2712 a	2913 ab	3786 a
	500	4444	1919 a	2879 a	3315 a	4008 a

[z] Treatments initiated post-harvest in 1990

[y] Pretreatment yields

[x] Values sharing a common letter within columns (years) in a given orchard do not vary statistically

* Plot treated with labeled N to assess effect of tree N status on fertilizer N recovery

Table 2. Changes in Leaf N Concentration With Rates of Applied Fertilizer N in 2 Stanislaus County Orchards

Orchard	Treatment[z] (lbs N/A/Yr)	Leaf N Concentration (% dry wt.)[x]				
		1990[y]	1991	1992	1993	1994
Salida	0	2.61	2.27c	2.13c	2.28 c	*
	125	2.61	2.34 bc	2.18 c	2.40 bc	*
	250	2.61	2.36 bc	2.24 b	2.52b	*
	500	2.61	2.42 ab	2.37 a	2.68a	*
Ceres	0	2.69	2.49 a	2.29 b	2.37 c	2.51 a
	125	2.69	2.48 a	2.30 b	2.51 b	2.64 ab
	250	2.69	2.49 a	2.44 a	2.68 a	2.75 bc
	500	2.69	2.53 a	2.49 a	2.74 a	2.82 a

[z] Treatments initiated post-harvest in 1990.

[y] Pretreatment values.

[x] Values sharing the same letter within a column (same orchard) did not differ statistically at $P<0.05$.

*Plot fertilized with labeled N to asses effect of tree N status on fertilizer N recovery.

Table 3. Effect of previous fertilizer application rate on recovery of a uniform post-harvest application of isotopically-labelled ammonium sulfate[z]

Tree	Fertilization (1990 - 1993) (lbs N/A/Yr)	1993 Leaf N (% dry wt.)	Soil Nitrate - N[y] (ppm)	Labeled N recovery (%) Fruit Aug 1994	Tree Feb 1995	Total
10-19	0	2.06	1.95	24	--	--
14-19	125	2.28	0.81	26	7	33
18-12	0	2.37	0.81	19	8	27
10-8	125	2.46	0.37	22	--	--
10-9	125	2.65	--	22	--	--
6-10	250	2.59	15.5	27	--	--
10-11	500	2.70	193.6	14	7	21
10-13	500	2.92	48.1	15	5	20

[z] 872 g labeled N per tree was applied on 2 October, 1993.

[y] mg N-NO3 per g of oven-dried soil. Analyses based on 4 soil cores per tree between 2 and 2.5 feet deep 10 days prior to application of labeled N.

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

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OBJECTIVES:

1. To develop a more sensitive measure of tree N status.

2. To develop recommendations based on soil and/or plant testing to maximize fertilizer use efficiency and reduce the contribution of orchard crops to nitrate contamination of groundwater.

DESCRIPTION:

Orchard crops utilize large amounts of fertilizer N and are potentially major contributors to groundwater pollution in many areas of California. Large acreages of orchard crops are grown in areas designated as "nitrate sensitive" in recent water quality assessments. Fertilizer management of orchard crops is, however, not regulated and the dynamics of N in orchard crops is the least well understood of any cropping system.

In this project, we aim to improve plant N-monitoring techniques so that fertilizer applications can be better managed. This aim will be achieved by monitoring the concentration, composition and distribution of a range of N-compounds in mature trees and relating this to plant yield, fertilizer N application and nitrate movement in the soil. Research of this type has been performed in annual crops but has not been adapted to perennial systems. Results will be used to develop fertilizer recommendations and monitoring procedures for orchard crops that will maintain profitability, optimize crop nutrient uptake and minimize nitrate leaching from the root zone.

Experimental design: A field experiment was initiated in young trees growing in Yolo county. Follow-up measurements were made in Stanislaus and Fresno counties. The trial consists of four N treatments replicated four times each in two crops: nectarine and almond. The rootstock for both crops is Nemaguard and the scions are Mission/Texas in almond and Fantasia in nectarine. All the trees were managed according to normal agricultural practices. The fertilizer was applied through a drip irrigation system to only the wetted zone where roots were presumed to be present. Leaf samples were collected in July and analyzed for NH_4, NO_3, amino acids, ureides, total soluble N and total N. Trunk diameter in young trees and yield in mature trees was measured throughout the experimental period which has run three years.

RESULTS

Figure 1 shows that nitrate concentration in leaves is the best indicator of nitrogen status in almond.

The growth of young almond (trunk diameter) increased as nitrogen application increased from 0 to 79 g N/tree/year. There was no growth benefit from additional N and no increase in leaf total nitrogen (Kjeldahl N) or the amount of soluble N when N was increased past 79 g N/tree/year. (79 g is roughly equivalent to 125 lbs/acre, assuming roots occupy 40% of the soil per acre). The concentration of nitrate in almond leaves, however, increased linearly with increasing N over the entire range of applications. Thus, when N is less than optimal there is a good relationship between total N, leaf nitrate and tree growth. However, when N is excessive, leaf total N did not increase, while leaf nitrate concentrations increased in direct proportion to N application.

N application in excess of 79 g N/tree/year was not beneficial to young tree growth. Leaf nitrate in young almond trees is a good indicator of tree N status and excess N application.

Figure 2 shows that ammonium is the best indicator of nitrogen status in nectarine. This response is similar to Figure 1. The growth of young nectarine trees increased as N increased from 0 to 79 g N/tree/year; higher N application did not increase growth. As in almonds, total N was a good indicator of tree growth only from 0 to 79 g N/tree/year and did not respond to additional N applications, hence it was a good indicator of excess N applications. In young nectarine trees, leaf ammonium is a good indicator of tree N status and excess N application.

Figure 3 indicates that application of N in excess of tree requirements results in accumulation of potentially leachable nitrogen in the soil. The concentration of N in the soil with depth below almond and nectarine trees is shown. In both types of trees, the lowest N application (N1 = 79 g N/tree/year) resulted in maximal growth. Above this application rate (N2 and N3), soluble nitrogen accumulated in the soil where it may subsequently be leached to the groundwater.

These experiments were repeated in two mature almond orchards and one mature nectarine orchard. To determine which N compounds best represents tree N status we utilized a procedure similar to above. Trees were grown at four different N levels. Leaf N characteristics and yield were then determined over a three-year period. The sensitivity of an N compound to N application was determined as the percent increment in concentration with the application of the fertilizer N. We also calculated the total increment in concentration with the application of the N fertilizer. In addition, the total increment in leaf N compounds that occurred at N rates above those required for maximal growth was calculated. These are shown in Table 1. We also calculated the tissue concentration of the various N coincided with maximal tree yield (CV in Table 1).

The results show that in almond, leaf nitrate responds dramatically to increasing N applications, increasing by 172% as N increased from 0-250 kg/ha/yr, whereas total N increased only 14%. The optimal N application rate was determined by measuring yield in all N treatments. Maximal yield occurred at different N applications in each year, and varied between orchards and species. Thus, there was no clear relation between N application rate and yield. Nevertheless, there was a consistent relationship between yield and tissue N concentrations and the critical value (CV) could be calculated.

In almond, maximal yield occurred when leaf nitrate was 180 ppm, or total leaf N was 2.5%.

In nectarine, maximal yield occurred when total leaf N was 2.7%. No other N compound was significantly correlated with yield. Thus the concentration of N that corresponds to maximum yield (CV) is 2.5% N or 180 ppm nitrate in almond and 2.7% N in nectarine. When N is supplied in excess of that required for maximal yield, nitrate in almond increases by 83% while total N increases by 12%. (Table 1.)

Table 1. Nutrient concentrations in almond and nectarine and their relative change with N application. A high value indicates the N component measured is sensitive to changes in N application.

Species	Total N (% change)	Nitrate-N (% change)
Almond		
% Increment as N is increased from 0 - 560 lbs/acre/year	14	172
% Increment as N is increased above the critical value	12	83
Critical Value*	2.50%	180 ppm
	Total N (% change)	Ammonium-N (% change)
Nectarine		
% Increment as N is increased from 0 - 560 lbs/acre/year	32	49
% Increment as N is increased above the critical value	16	10
Critical Value*	2.70%	ND

* Critical value is the tissue nutrient concentration at which growth and yield are optimal.

In summary, nitrate is the best indicator of N excess in almond. In nectarine, the most reliable indicator of N status is total N which, unlike in almond, continues to increase as N availability increases.

Sampling Procedures: Experiments were conducted to determine the best sampling procedure for leaf nitrate and total leaf N. The key result is that leaf samples should be collected from June through August between 10am and 5pm, from the non-fruiting basal or spur leaves.

CONCLUSIONS

In almond, leaf nitrate is the best indicator of soil N levels and can be used to detect both deficient and excessive levels of tree N. Leaf nitrate levels in excess of 180 ppm were consistently found in trees supplied with greater than optimum soil N. Trees with total leaf N less than 2.5% may be deficient. The presence of excess N cannot be reliably determined using total leaf N. In nectarine, total leaf N is the best available index of tree N status and adequately reflects both N deficiency and toxicity. A total leaf N of 2.7% resulted in optimal yield; higher total leaf N indicated excess soil N application.

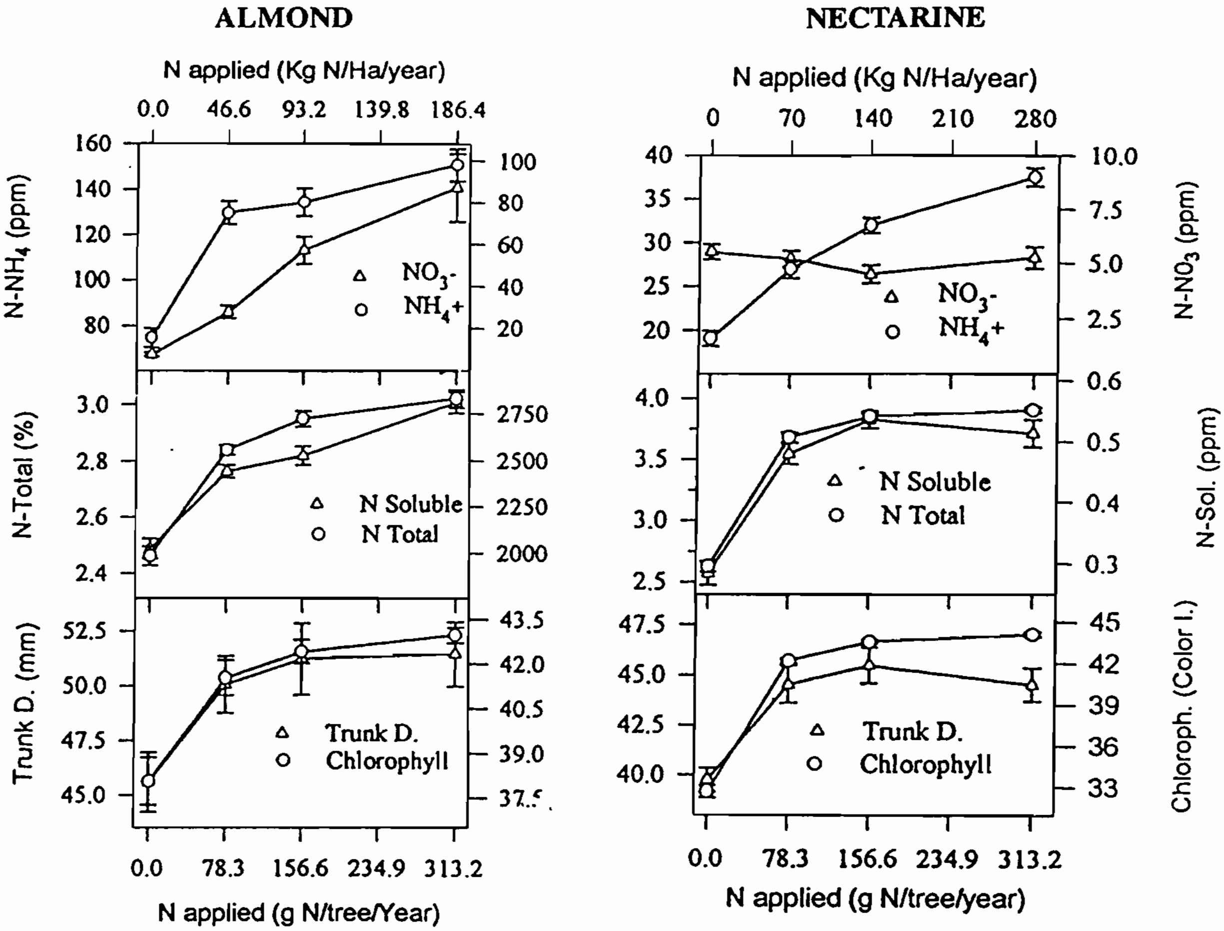

Figure 1 and 2: Effect of nitrogen application on nitrogen conpounds, total nitrogen, chlorophyll and growth in Almond (left) and Nectarine (right).

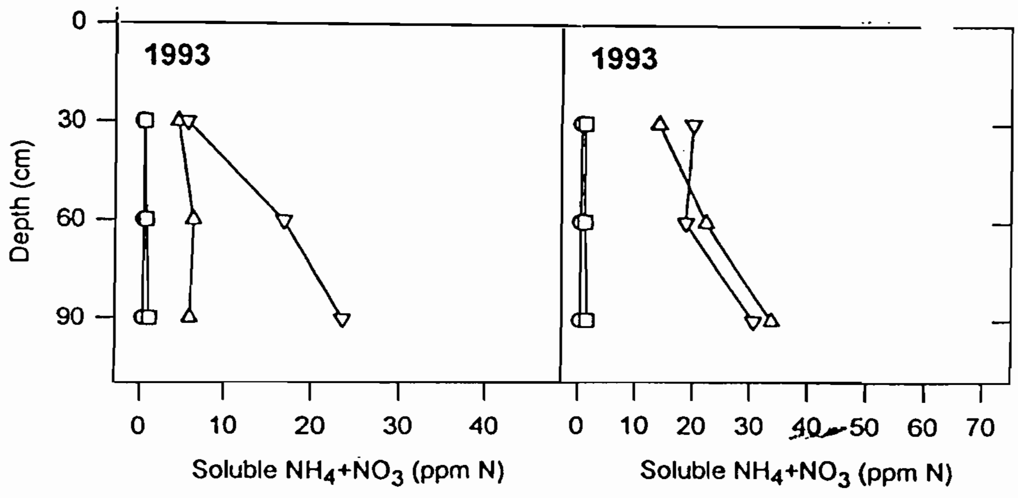

Figure 3: Effect of nitrogen application (NO=0, N1=79, N2=156, N3=235, N4=313 g N/tree/year), on residual soluble nitrogen in the soil at various depths. Left Nectarine, right Almond.

Efficient Nitrogen Management for Desert Vegetables

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Over 80% of the leafy salad vegetables produced in the United States during the winter months are grown in the low desert region of southern Arizona and southern California. Relatively large areas are also under production in the adjacent States of Sonora and Baja, Mexico. The area of land utilized to produce winter vegetables has increased over the past 10 years. For example, in Yuma county, Arizona, vegetables harvested from 13,000 hectares in 1980 had a farm gate value of approximately 63 million dollars. By the 1990, vegetables were produced on 26,000 hectares, and had a farm gate value exceeding 130 million dollars. However, with this increased production of salad vegetables, concerns about nitrate contamination of ground water have also increased. Land cropped to salad vegetables often receives more N fertilizer than land cropped to agronomic crops because of rigid produce quality standards enforced by the market, more frequent cropping, inadequately calibrated soil and plant tissue test, and generally poorer irrigation efficiencies.

Over the past five years, we have implemented a research and outreach program aimed at improving N fertilizer use efficiency for desert vegetables. The first component of the research program involves water quality monitoring to obtain a understanding of the scope and magnitude of nitrate-N ground water contamination. The second component involves studies of solute transport using biologically conserved tracers (Br) and ^{15}N to assess the potential for N leaching. The third component of the research program involves a number of studies aimed at developing management practices which achieve efficient N utilization. This program includes evaluation and calibration of soil and plant testing criteria for low desert vegetable crops. Diagnostic approaches being evaluated include pre-sidedress soil nitrate-N tests, the traditional dry midrib nitrate-N test, the sap midrib test using the Cardy Meter, absorbance using the chlorophyll meter, and various reflectance technologies including digital computer analysis of aerial images. This program also includes evaluation of alternate N management strategies involving variables of rate, placement, timing, and source. Furthermore, we have recently began to evaluate the impact of irrigation practices on N utilization efficiency.

In addition to our research effort, we are conducting an interactive outreach program. In this program we demonstrate promising technologies to growers and solicit feed back on their logistical concerns. Our objective is to direct our research and development efforts toward technologies growers would by inclined to incorporate into their management program. During my presentation I will briefly summarize results obtained during the first four years of study.

IMPACT OF MICROBIAL PROCESSES ON CROP USE OF FERTILIZERS FROM ORGANIC AND MINERAL SOURCES

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Cooperator:
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OBJECTIVES:

Efficient use of fertilizers resulting in maximum plant productivity and minimal environmental harm is desirable both to the agricultural community and members of the general public who rely on groundwater as a source of drinking water. The successful functioning of agricultural systems depends on the timely delivery to plants of nitrogen and other nutrients from mineral fertilizers and from decomposition of organic residues, both of which are strongly influenced by microbial activity in soils. Soil microorganisms are both a significant reservoir of plant nutrients and are responsible for the transformation of nutrients into forms available for crop uptake. The microbial community is typically treated as a "black box," and measurements of the consequences of its activities are made without an understanding of underlying mechanisms. Knowledge of the mechanisms involved, however, is essential if recommendations such as for fertilizer inputs are to be truly predictive, and thus useful to growers. Also, with an understanding of the synchrony between crops and microorganisms in nutrient cycling, it may be possible to increase fertilizer use efficiency by managing the microbial biomass through specific farming practices.

The primary objectives are to determine relationships among: a) microbial biomass and activity; b) soil fertility parameters, particularly N pools; c) crop tissue levels over the growing season; and d) crop yield and quality at the end of the growing season. Studies are conducted in tomato and corn under three different N management systems: N from mineral sources only; N from cover crops and manure; and N from cover crops supplemented with mineral sources.

DESCRIPTION:

The study site is the long-term Sustainable Agriculture Farming Systems Project, located at the Agronomy Farm at UC Davis, and now in its seventh year of study (funded by USDA, EPA and UC). The project measures changes in soil fertility, crop, pest and economic parameters in four farming systems: conventional 2-yr rotation, conventional 4-yr rotation, organic 4-yr rotation, and a low-input 4-yr rotation. All 4-yr rotations follow the sequence: tomatoes, safflower, corn, and wheat or oats-vetch/ beans. The 2-yr rotation alternates between tomatoes and wheat/beans. Table 1 gives an example of typical production practices for tomatoes, in this case for 1992.

Table 1. Tomato Production Practices, 1992.

Operation	Organic	Low input	Conv. 4 yr	Conv. 2 yr
Planting	transplants	transplants	seeds	seeds
N Fertilizer				
Preplant & starter	cover crop manure	cover crop 8-24-6	6-20-20	6-20-20
Sidedress & topdress	fish powder seaweed	30 lb ammonium nitrate	120 lb ammonium nitrate	120 lb ammonium nitrate
Pesticides	--	--	Roundup Devrinol Asana XL	Roundup Devrinol Asana XL

Measurements in soil have included: a) microbial biomass, both as C (MBC) and N (MBN), b) microbial activity: arginine ammonification (ARG) indicating the potential for mineralization of organic N and substrate induced respiration (SIR) indicating the potential for respiration of carbon dioxide, and c) nitrogen pools: nitrate, ammonium, potentially mineralizable N (PMN) which is an estimate of available nitrogen from organic matter. Emphasis in this project has been on organic and conventional tomatoes, with less frequent sampling of low input and conventional two-yr tomatoes and all systems of corn.

In 1994 (which was similar to 1993), nitrogen fertilizer application to tomatoes in the different farming systems was as follows:

Conventional: 8-24-6 applied as starter at 15 gal/ac in March; fertilizer side-dress with 46-0-0 at 304 lbs/ac in May.

Low-input: Purple vetch planted in November, incorporated in April; starter fertilizer 8-24-6 applied at 15 gals/ac to transplants in April.

Organic: Purple vetch planted in November, incorporated in April; poultry manure of 3.4% N applied at 2.15 t/ac; starter fertilizer of fish powder (12-0.25-1 at 4 lbs/ac) and seaweed (3-0.25-0.15 at 1 gal./ac) applied to transplants in April. Top-dress of fish powder (12-0.25-1 at 4 lbs/ac) and seaweed (3-0.25-0.15 at 1/2 gal./ac) applied in July.

Nitrogen fertilizer application to corn in the different farming systems was as follows:

Conventional:	6-20-20 applied as starter at 100 lbs /ac on April 2; fertilizer side-dress with 46-0-0 at 261 lbs/ac on April 22; fertilizer side-dress with 34-0-0 at 235 lbs/ac on May 12.
Low-input:	Purple vetch planted in November, incorporated in April; starter fertilizer 6-20-20 applied at 100 lb/ac in April; fertilizer sidedress with 34-0-0 at 235 lb/ac on May 12.
Organic:	Purple vetch planted in November, incorporated in April; poultry manure (3.4% N) applied at 4.3 t/ac in late March.

RESULTS AND CONCLUSIONS:

Differences in microbial parameters among farming systems. Fairly consistently, microbial biomass and activity show greater values (up to double) in organic than in conventional tomato plots. Figs. 1 and 2 show differences between organic and conventional tomatoes in five microbial parameters during 1993. PMN levels are shown in Fig. 3. Similar differences were observed in 1994. Seasonal variations are considerable, with generally lower variability in conventional than organic plots. In addition, bacterial-feeding nematode populations are significantly higher in organic than conventional plots, which suggests their importance in the turnover of nitrogen contained in the microbial biomass. With regard to differences in microbial parameters among the other farming systems, levels of microbial biomass are sometimes, but not always, higher in organic than low input plots. Low input receives lower levels of carbon inputs (e.g., no manure) than the organic system. There is little difference in MBC between the conventional 2- and 4-year rotation systems.

Microbial parameters are sensitive to both temperature and soil moisture. In 1993, soil temperature varied from approximately 15° C at the beginning to the low 20's throughout the remainder of the growing season. Frequent irrigation maintains soil moisture in organic and conventional plots at levels between 12 and 30% in the top 15 cm of soil. Irrigation is more frequent and soil moisture was usually higher in the organic than conventional system. Correlation analyses indicated positive relationships ($p<0.0001$) between soil moisture and either MBC or MBN, but negative relationships ($p<0.0001$) with the C/N ratio of the microbial biomass, arginine ammonification, and SIR/MBC. Soil temperature was inversely related ($p<0.0001$) to MBN, SIR/MBC, and soil ammonium levels. Severe declines in microbial parameters in the mid growing season were evident in all systems and appeared to be related to hot and dry periods between irrigation events.

Relationship of microbial parameters to soil fertility. An important objective for this project has been to evaluate whether the striking differences in microbial parameters correspond to differences in soil fertility among the different farming systems. In previous years we have shown that soil nitrate levels during the growing season differ among farming systems. The pattern changed from previously higher (1989, 1990) to now lower nitrate levels in organic compared to conventional tomatoes. In 1993, the inputs into the organic system had considerably higher carbon to nitrogen (C/N) ratios than in previous years because a large portion of the cover crop was oats (rather than vetch) and because the manure had large quantities of straw. Soil mineral N levels in the organic system were low over the 1993 season and were below what would be "acceptable" plant nutrition levels based on conventional agriculture criteria (Fig. 4). In the conventional 4- year system, however, mineral N levels increased dramatically following application of sidedress fertilizer, NH_4NO_3 and levels remained relatively high for three weeks. Regardless of these differences in soil N, crop yields in the two systems were comparable in 1993. We believe this was due to high activity of the very large microbial biomass in organic soil in mineralizing nitrogen which, in turn, was immediately taken up by the tomatoes. Availability of mineral N also may have been stimulated by predation of microorganisms by bacterial-feeding nematodes, whose populations increased substantially over the growing season. These results suggest that organic inputs with higher C/N ratios than typically recommended may supply sufficient fertility to crops while at the same time potentially reducing nitrate leaching. The ability of organic inputs with different C/N ratios to supply fertility to tomatoes is being tested this year in sub-plots. Unfortunately, it was not possible in 1994 to confirm the 1993 field observations because the organic tomatoes, originally from transplants, had severely reduced yields due to a viral infection.

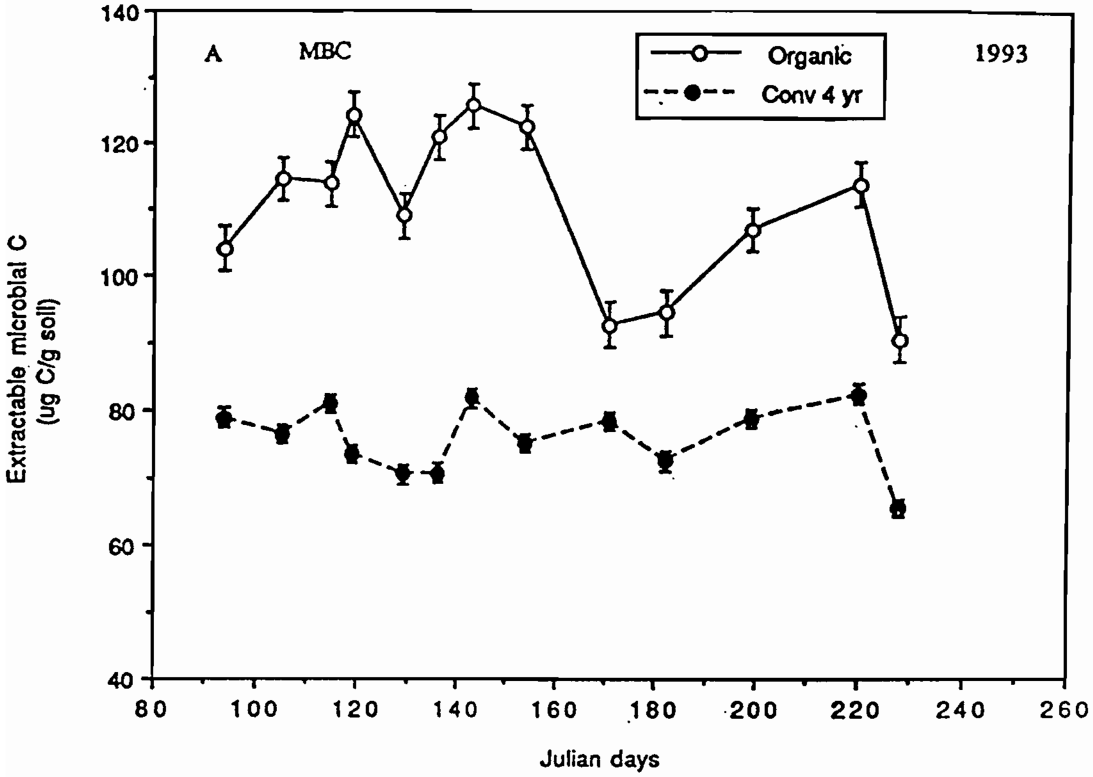
Determining relationships among microbial parameters and soil nitrogen is complicated because of short-term fluctuations in both types of measurements. In general, when looking at correlations among parameters in all farming systems combined or in the conventional system alone, there is a significant ($p<0.05$) negative relationship between microbial biomass and either soil nitrate or ammonium. Analysis of data from the organic system alone, however, shows a positive relationship between MBC and soil nitrate and ammonium. In all systems, there is a strong correlation between most of the microbial parameters and PMN, the latter being an estimate of the pool of available organic nitrogen.

An important issue for farmers converting to farming systems using organic inputs is whether microbial populations in previously conventional soils are, during the first few years of transition, able to break down organic residues rapidly enough to serve as a nutrient source to crops. To test whether rates of cover crop decomposition were slower in conventional than organic managed plots, soils from both farming systems were collected in the field at five different times throughout the year and incubated in the laboratory with alfalfa residues. On all occasions, there was little or no difference between the soils in their rates of cover crop decomposition as measured by weight loss in litter bags and carbon dioxide evolution. Cover crop decomposition is only the first of several microbial processes that ultimately lead to release of mineral nitrogen from organic sources. Therefore the lack of significant difference in cover crop decomposition does not necessarily mean that organic and conventional managed soils are equivalent in their ability to supply crop nutrients from organic sources.

A commonly held, but largely untested, belief is that it is not possible to increase organic matter contents in California agricultural soils. After six years of farming, total organic matter contents have increased significantly, by approximately 15-18%, in the organic system compared to the conventional systems. Organic matter decreases among farming systems in the following order: organic > low input > conventional 4-year > conventional 2-year. Total organic matter content is not as accurate representation of the nutrient pool available from organic matter as is microbial biomass (itself, part of organic matter). As discussed above, we have demonstrated the available organic matter pool (MBN) is now significantly higher in the organic than conventionally managed soil under tomatoes.

In 1994, tomatoes and corn plots showed marked differences in soil nitrate levels. In corn, levels ranged between 10 and 20 µg/g, whereas in organic and low input, levels ranged between 20 and 65 µg/g. By the end of the season, levels in organic were significantly higher than in low input and conventional soils. With respect to microbial parameters, MBC and MBN were often, but not always, significantly higher in organic than conventional soils. SIR was never significantly different and PMN was significantly different on only one date. Future work will be aimed at better understanding the differences in microbial and soil fertility dynamics in corn versus tomato plots.

Figure 1. Changes in A. extractable MBC and B. extractable MBN in conv 4 yr and organic systems in 1993. Vertical bars = standard error (n=4).



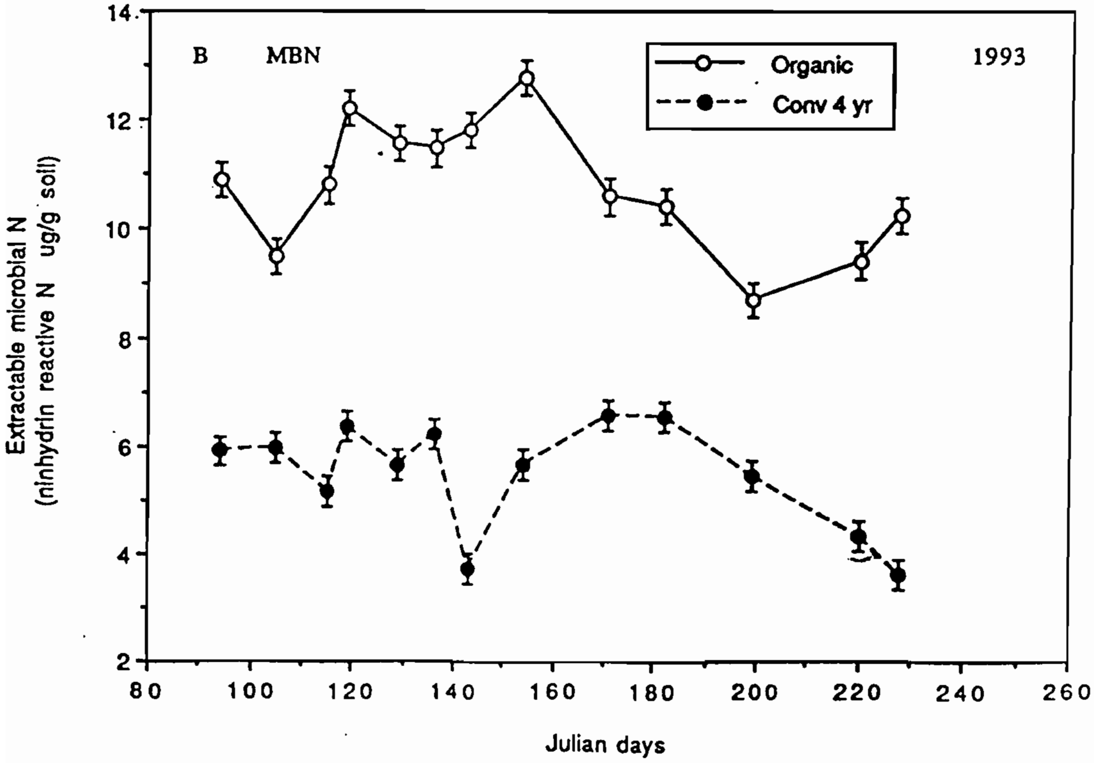


Figure 2. Changes in A. substrate induced respiration, B. uninduced respiration and C. arginine ammonification in conv 4 yr and organic systems in 1993. Vertical bars = standard error (n=4).

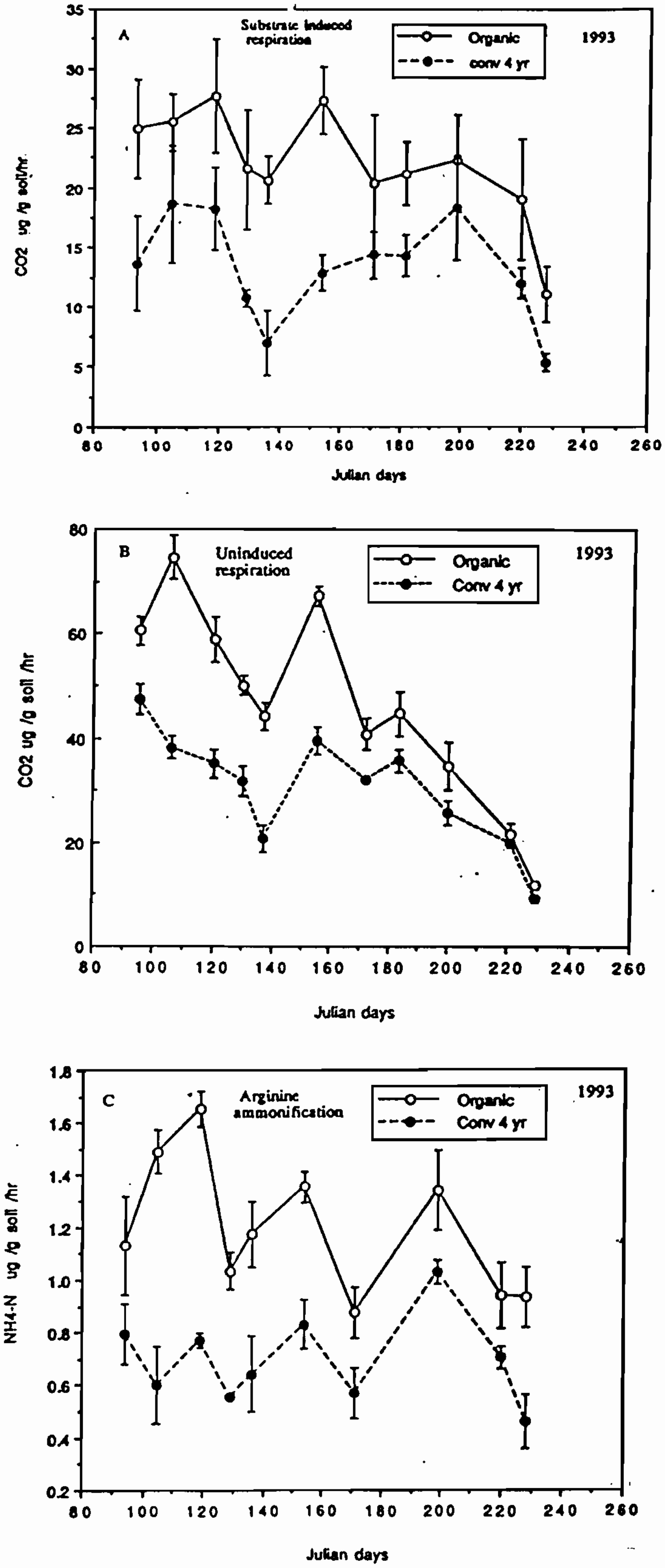


Figure 3. Changes in PMN in conv 4 yr and organic systems in 1993. Vertical bars = standard error (n=4).

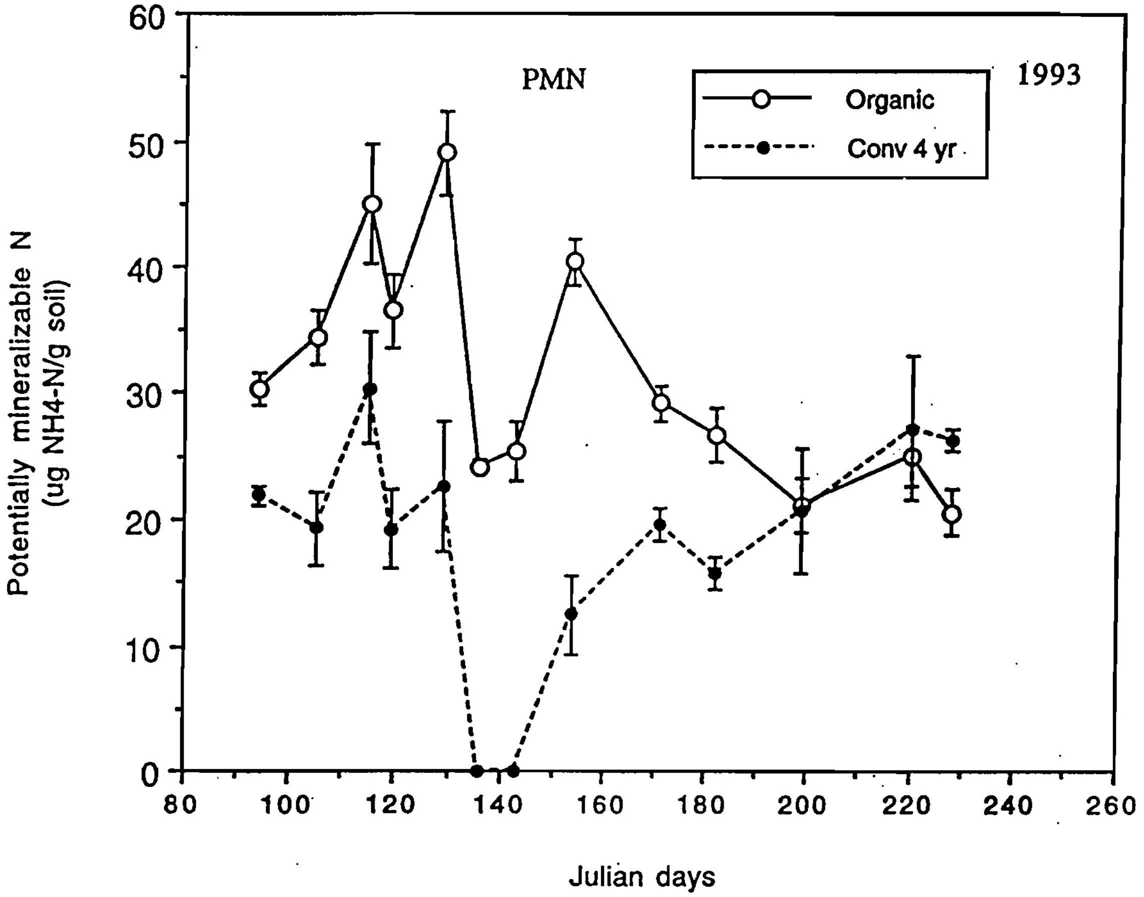
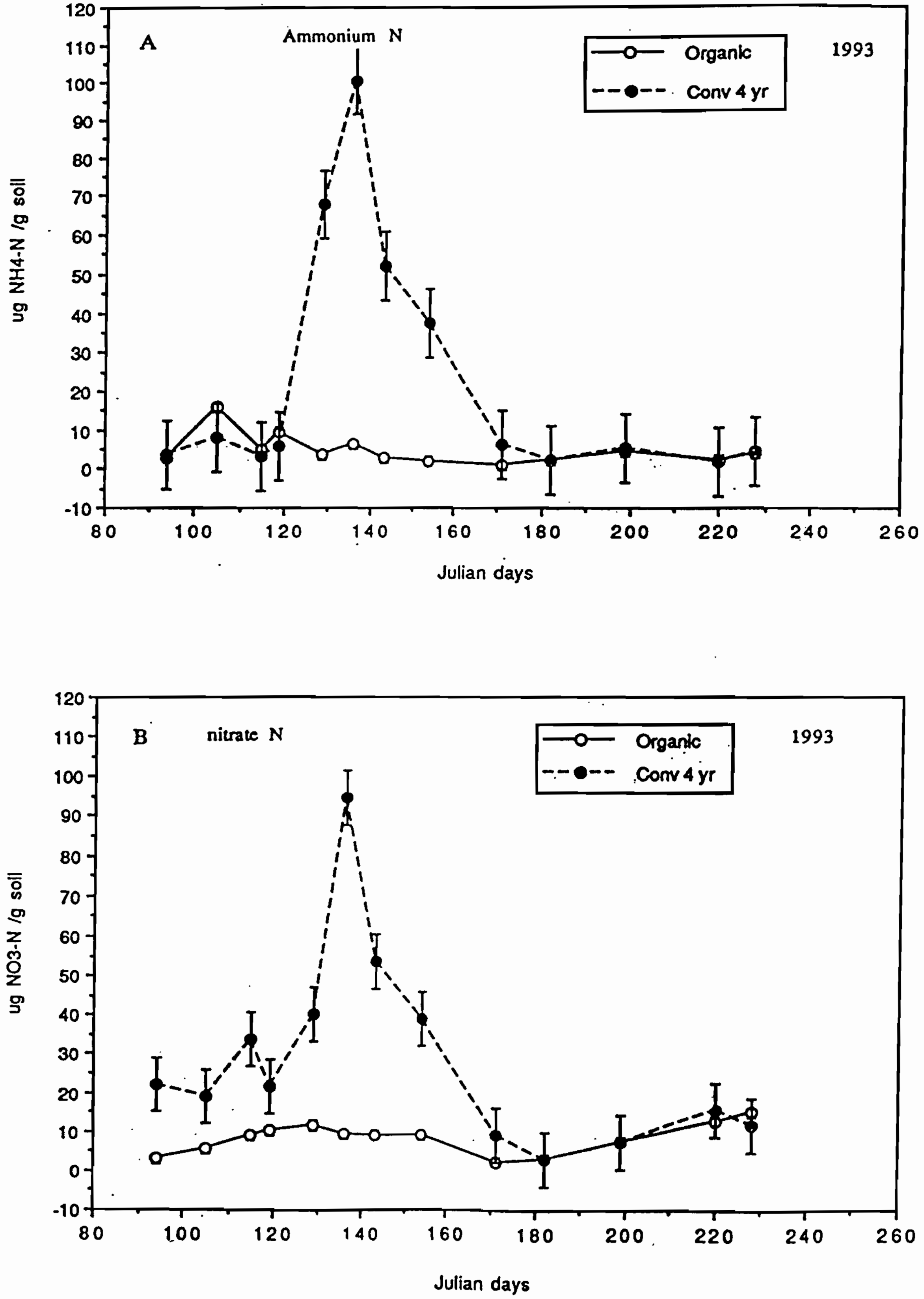


Figure 4. Changes in A. soil NH_4-N and B. soil NO_3-N in conv 4 yr and organic systems in 1993. Vertical bars = standard error (n=4).



Nitrogen management through intensive on-farm monitoring

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It is generally acknowledged that intensive vegetable production as practiced along California's central coast is a significant contributor to the nitrate pollution of groundwater; the Salinas Valley, Santa Maria Valley and the Oxnard plain are all considered to be nitrate-sensitive areas. Typically, vegetable land in these areas is double-cropped, with per-crop N applications of >200 $kg{\bullet}ha^{-1}$ common, particularly for broccoli, cauliflower and celery. Nitrogen removal with the harvested product usually accounts for only a small fraction of N applied. The cool-season vegetables produced in this area are shallowly rooted and intensively irrigated. These circumstances suggest substantial opportunity for nitrate leaching.

Past cropping history and the mild Mediterranean climate have resulted in the development of soils that are extremely active in nitrogen cycling. Large soil mineral N pools and rapid N mineralization have been reported by several researchers. Recently developed on-farm monitoring techniques for soil- and plant N status are now available which can enable a grower to more fully exploit soil mineral N and limit additional fertilization. Furthermore, the increasing use of drip irrigation provides a vehicle for efficient water delivery (minimizing leaching losses) as well as delivery of fertilizer N independent of cultural constraints.
This project, conducted in commercial vegetable fields in the Santa Maria Valley, sought to document the utility of intensive on-farm monitoring of soil- and crop nitrogen status in fertility decision-making. The specific objectives were:

a) Document the accuracy, labor intensity and cost of on-farm monitoring techniques for soil and crop N status.

b) Develop baseline data on N uptake rates and tissue N sufficiency levels for the important cool season crops.

c) Demonstrate the effect of "best management practices" (drip irrigation and fertigation, intensive monitoring) on crop yield, and water- and nitrogen use.

Materials and Methods:

In cooperation with Betteravia Farms of Santa Maria, eight drip irrigated fields were selected for study in spring, 1994. They were followed through normal crop rotations (including lettuce, broccoli, cauliflower and celery) until fall, 1995. At the beginning of each cropping cycle, each field was divided into quadrants; in each quadrant a 4-row plot was fertilized with 110 kg N•ha^{-1} in the form of a slow-release fertilizer. These plots, which also received all N fertigation applied to the whole field, served as an N sufficiency reference against which the remainder of the field was evaluated with respect to crop yield and N status.

After the establishment of each crop, composite soil samples (0-30 cm) were collected and analyzed for mineral N (NH_4-N + NO_3-N) concentration; a subsample of that soil was incubated aerobically at constant moisture at 20°C for 4 weeks, then retested for mineral N. The increase in mineral N during incubation estimated net N mineralization, the net rate at which soil organic N was converted to plant-available forms.

Four times during each cropping season plant tissue and soil samples were collected by farm personnel and analyzed on-farm by the following methods:

a) soil NO_3-N by a 'quick test' technique which used a volumetric extraction of moist soil, with nitrate measurement by colormetric test paper (Hartz, 1994).

b) petiole sap NO_3-N analysis with the 'Cardy' portable nitrate selective electrode (Hartz, *et al* 1993)

These tests, performed on-farm, provided information to help guide N fertigation decisions. The accuracy of these methods was monitored by comparison with standard laboratory analysis of paired samples. At each sampling date, whole plant samples were taken for determination of total plant biomass and biomass-N. At first commercial harvest, crop yield and quality was evaluated in the reference plots and matching sections of the field.

Results and Discussion:

The study revealed a consistent pattern regarding soil mineral N content. All fields planted in summer and early fall showed high soil NO_3-N concentration (> 30 mg/kg). Despite generally conservative fertilization (usually < 200 kg N•ha^{-1}) substantial NO_3-N levels were maintained throughout the growing season; in some fields soil NO_3-N at harvest equaled or exceeded that measured at crop establishment, despite the accumulation of > 200 kg N•ha^{-1} in crop biomass. This was an indication of significant N mineralization; indeed, aerobic incubation techniques confirmed that these soils were capable of maintaining net N mineralization rates of 1.5-2.5 kg N•ha^{-1} day^{-1} over extended periods. The other factor working to maintain soil NO_3-N level was the efficiency of drip irrigation. Seasonal irrigation volume on summer and early fall planted fields averaged approximately 18 cm, at least 1/3 less than typical with conventional irrigation techniques.

Following the extraordinary rainfall amounts received over the winter, crops planted in spring 1995 began the season with relatively little residual mineral N (< 15 mg•kg^{-1}). For early spring planted fields exposed to continued leaching rains, soil mineral N levels remained low despite high N fertigation rates, which in some fields exceeded 350 kg N•ha^{-1} seasonally. However, at the establishment of the summer, 1995 crops, soil residual NO_3-N had rebounded to levels roughly similar to 1994, again indicating the rapid N mineralization in these soils.

Crop yields showed that, in these nitrogen-rich soils, heavy N application was not necessary for maximum productivity; representative are the results of the cauliflower fields monitored (Table 1). In no case did the reference plots (which received an additional 110 kg N•ha^{-1} in slow-release form) significantly outyield the rest of the field. In fact, at no time during the season could the reference plots be visually distinguished in any field. As expected, the reference plots had higher soil NO_3-N levels, but this did not lead to greater crop N uptake; the only effect of the extra N was to enlarge the pool of NO_3-N susceptible to leaching.

The soil NO_3-N quick test and petiole sap NO_3-N analysis, although not as accurate as conventional laboratory analysis, proved to be valuable on-farm monitoring tools, consistently able to document high nitrate levels in both soil and plant tissue. On a commercial scale, monitoring as done in this study was an economically justifiable practice, with seasonal labor and equipment costs below $50 per 10 ha field. Reducing fertilizer application only 10 kg N•ha^{-1} based on the results of monitoring, would more than offset costs.

Judging by the results of this and other recent studies, N fertilizer input in coastal vegetable production can be reduced considerably without affecting crop productivity. In-season monitoring can help a grower effectively utilize residual and mineralized N, more effectively targeting fertilizer applications.

We acknowledge and thank Craig Reade and Lynn Wierdsma of Betteravia Farms for their cooperation in this study.

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Table 1. Performance of drip-irrigated cauliflower under varying N application.

Field	Seasonal N applied[z] (kg•ha^{-1})	Seasonal irrigation (cm)	Soil NO_3-N (mg•kg^{-1})[y] Establishment	Harvest	Relative crop yield[x] (%)
A	183	14.7	41	25	94 ns
B	191	15.0	52	48	137 *
C	194	17.0	67	45	119 ns
D	197	14.7	48	67	96 ns
E	214	18.7	31	24	96 ns
F	331	24.9	61	75	103 ns

[*, ns] field and reference plots significantly different, or not different, at p=0.05

[z] amount of N fertigation; reference plots received an additional 110 kg N•ha^{-1} in preplant slow-release form

[y] top 30 cm; establishment sample collected after transplanting and initial irrigation

[x] (field plots/reference plots) x 100

INTEGRATED RESOURCES MANAGEMENT: AN OVERVIEW

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For many agricultural scientists, the term "integrated resources management" is closely associated with several related ideas. One has to do with improving the efficiency of resource use in agriculture. A second has to do with reducing the undesirable environmental consequences of farming, or possibly with the management of agricultural lands and crops to benefit wildlife, and a third with the enhancement of biotic diversity in agricultural areas. Much agricultural research has been and will continue to be carried out as single factor or simpler, factorial experiments. This traditional approach allows for the identification of cause and effect and advances agricultural science in clear ways. Thinking about agricultural management in a more inclusive way, however, can require new ideas about experimentation, analysis and management.

Many different approaches to integrated resource management are possible. Cropping systems, farming systems, or even entire agricultural systems may be the focus of management or research. There are several examples of extension programs that focus on farm management as a whole. For the most part, these programs have originated where farming involves fewer crops than in California and where owner-operator labor is the rule. Iowa State's *Integrated Crop Management* program is an example (Brown, et al., 1994). Farmers must keep a field by field record of all crops, inputs, and yields, and are asked to set management goals on a yearly and multi-year basis focused on improving their resource use efficiency overall, but also on compliance with new or evolving environmental regulations. Individual crops and fields are organized into an integrated, long-term farm management plan. Help is provided with record keeping and farm planning.

Systems research can take many forms in agriculture including: quantitative farm descriptions, surveys of farms, decision case analysis, economic modeling, simulation modeling, on-farm research, complex experiments, and other approaches that can be referred to as integrative methods . Two are worth emphasizing. On-farm research can be linked to integrative farm management programs by allowing farmers to carry out well-designed research related to their own or society's longer-term management objectives. For agricultural scientists, on-farm research provides the opportunity to evaluate management practices under actual farm conditions, taking into account the cumulative effects of previous farm management decisions and the limitations faced by farmers who attempt to carry out new practices.

Complex experiments are being carried out in a number of locations, but the most advanced efforts to date are occurring in western European countries. Results from several projects are further integrated by a consortium of researchers from several countries and several institutions. These projects each have multiple goals, with input reduction, economic viability and environmental enhancement forming the co-equal objectives. They involve complex crop rotations and the comparison of different sets of management practices. They are guided by the principles that:

1. there is a negative correlation between the intensity of tillage and the stability of the soil ecosystem,
2. diversified crop rotations are have multiple advantages not otherwise available to farmers,
3. crop genetic diversity can be used more effectively in many instances, and
4. species diversity on farmland is largely beneficial and can be consciously manipulated (El Titi, 1995).

Some of these concepts are well-know, but others are hypothetical and await demonstration or proof.

New methods of research have potential pitfalls, including the search for ever-elusive "emergent properties" of farming systems, confounding of demonstration and research goals, and the difficulty of optimizing simultaneously, multiple objectives (Kaffka, 1995).

Agriculture affects the environment primarily through resource use, including land, water, fossil energy and secondary effects. Since food must be produced, the most environmentally sound systems in general are those that produce the highest yields for the lowest cost per unit yield. Such systems involve the careful and improving integration of all production resources, such that increasing returns are achieved to total factor use. Research that aims to improve resource use efficiency should focus not on diminishing marginal returns to limiting resources, but rather on the minimization of each necessary production input, while allowing for the best possible use of all other resources (de Wit, 1992).

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Conventional, Low Input and Organic Farming Systems of the Sacramento Valley: The Transition Phase and Long Term Viability

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Project Overview

The Sustainable Agriculture Farming Systems Project (SAFS) is an interdisciplinary research project initiated in 1989 at the University of California, Davis to compare conventional, low-input and organic farming systems over a 12 year period. The goal of the study is to analyze and quantify the complex environmental and economic consequences of the transition from conventional to low-input and organic farming systems. As the project completes its seventh year, the focus has expanded to include analysis of the long-term environmental sustainability and economic viability of all systems.

The research plots are located on 20 acres of the Agronomy Farm at UC Davis, Yolo County. The main experimental area is divided into 56 plots, each 1/3 acre in size (60 by 220 feet) to allow for use of large scale farm machinery for all operations, including planting, ground preparation and harvesting.. The four farming systems (main factors) are arranged in a split-plot randomized complete block design with four replicates of each system. For each season, all crop-system combinations are present, each representing a different point in the rotation. The experiment is conducted on Yolo silt loam, a medium to heavy soil. The soils are fairly representative of the Sacramento Valley, as are the crops grown in the rotation.

The four year, five crop rotation consists of processing tomatoes, safflower, field corn, and a cereal/bean double crop for all systems. The conventional system is managed using materials and practices typical of the northern Sacramento Valley, such as mineral fertilizers and synthetic pesticides. The low input system utilizes practices typical of both conventional and organic systems; cover crops are grown for fertility, yet mineral fertilizer is used to supplement when deemed biologically necessary and economically feasible. Pesticides are also used as needed. Low-input management is also defined by efforts to reduce system dependency on nonrenewable inputs. The organic system is farmed according to standards outlined by California Certified Organic Farmers, and includes use of manures and cover crops for fertility, and mechanical control for weeds. No mineral fertilizers or synthetic pesticides are used in this system. A fourth system, a two year conventional tomato-wheat rotation, is also included to represent growers who have short term economic constraints.

Farming practices for each system each year are determined by 'best farmer' management rather than by a prescribed set of guidelines. For example, insect and disease management decisions for all systems are based on periodic monitoring of pest levels and no pesticides are applied until threshold levels are exceeded. Quantities of supplemental fertilizer for the low input system are determined each year based on estimated cover crop and soil nitrogen each spring. Emphasis in decision making is placed on the effects of crops and weeds on subsequent crops, the logistics of equipment compatibility and competing demands on management, and a long-term view of whole farm economics.

All farming decisions are made by an interdisciplinary project team of researchers, farmers and farm advisors through regular meetings and e-mail discussions. All important decisions are made by consensus, giving special weight to the recommendations of grower participants.

General Project Results

After 6 years, safflower, bean and wheat continue to yield equivalently in all systems, while tomato and corn yields have shown consistent differences among systems (Table 1). Although tomato yields for all systems have been at or above county averages for the course of the experiment, the organic tomatoes have not been able to produce as well as the other three systems. While corn yields were essentially equivalent the first years of the experiment, the low-input corn has consistently outperformed either the conventional or organic corn for the last three years.

The transition period was clearly important for the soil microbial community. It took at least three years for microbial populations in the organic and low-input systems to reach consistently higher levels of biomass, and activity, presumably making them better able to turn over organic material and generate nutrients for the crops, than populations in the conventional systems. Beneficial nematodes have been consistently greater in the organic and low-input plots in the last few years, most likely as a result of cumulative additions of organic matter.

Insect and pathogen pests have fluctuated primarily by season, crop and system, and are much more weather dependent than system driven. Weed pressure has also fluctuated considerably over the six years, showing more significant seasonal than system differences. Shifts in weed species have occurred in the systems, most likely as a result of differences in herbicides used and longer fallow periods in the conventional systems, leading to greater invasion of perennial species in the conventional plots, and an increase in grass species in the organic and low-input plots.

The conventional systems continue to return a higher profit than the organic or low-input systems (unless organic returns are calculated based on premium prices), although the year to year variability of costs and returns is very high in all systems.

For an extensive review of the results from the economic, pest, agronomic and soil research consult Klonsky and Livington, 1994; Lanini et al. 1994; Scow et al. 1994; and Temple et al. 1994;

Corn Yields and Nitrogen Utilization

Of special significance are the consistently high yields of the low-input corn. Extensive soil fertility and plant tissue data have shown that lower yields in the conventional system may be due to lower nitrogen use efficiency resulting from decreased water uptake. Stalk nitrate collected at harvest for all three systems has shown that the conventional corn consistently has excess levels as determined by Binford (1992). (Figure 1). Water application rates have been consistently lower in the conventional corn than the organic and low-input systems despite attempts to ensure that all three systems receive the same amount of water. Differences in water penetration are probably related to divergent physical and chemical properties in the systems resulting from different management practices such as cover crop and manure applications. Efforts to quantify these differences are currently underway.

Yields in the organic corn appear to be directly related to nitrogen availability. In 1994, with a seasonal average of 50 ppm of NO_3-N at 0-6 inches, organic corn yields were above 6 tons/acre. During the 1993 growing season, soil NO_3-N averaged approximately 25 ppm and organic corn yields were considerably decreased. Deficient stalk nitrate in 1993 and adequate stalk nitrate in 1994 at the V8 (8 leaf) stage and maturity support this observation.

Corn grown using low-input management appears to be the most stable of the three systems. Low-input corn has outperformed conventional corn most likely because of better water penetration, and low-input yields have exceeded those of organic corn probably because nitrogen fertilizer additions are well coupled with plant requirements. The low-input corn has also provided the highest economic returns for the last three years, indicating that this system has a high potential for widespread use in conventional systems.

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Table 1. Effect of farming system on yields of all crops for 1989-1994.

	System				
Crop	Organic	Low-input	Conv-4	Conv-2	Yolo County Average
Tomato (tons/acre)					
1989	24.50 b[1]	30.92 a	34.33 a	34.18 a	30.20
1990	30.70 c	36.28 b	36.82 ab	39.56 a	28.79
1991	28.20 c	34.85 b	45.58 a	37.42 b	30.50
1992	42.66	42.87	47.70	41.25	33.84
1993	28.10	32.6	26.60	25.68	29.17
1994	24.39 b	27.97 b	41.49 a	37.95 a	33.66
Safflower (lbs/acre)					
1989	1,358 b	1,343 b	2,058 a	- -	2,320
1990	2,070	2,350	2,160	- -	2,100
1991	1,990	1,879	2,155	- -	1,740
1992[2]	- -	- -	2,575	- -	1,920
1993	2,373	2,011	2,455	- -	1,820
1994	2,308	2,266	2,567	- -	2,100
Corn (tons/acre)					
1989	4.18	5.21	5.08	- -	4.51
1990	5.20	5.00	4.91	- -	4.87
1991	4.07 b	4.09 b	5.06 a	- -	4.59
1992	4.92 b	5.92 a	4.76 b	- -	4.90
1993	3.87 b	5.72 a	4.76 ab	- -	5.21
1994	6.38 a	6.55 a	5.16 b	- -	5.21
Wheat (lbs/acre)					
1989	- -	- -	4,507 b	4,916 a	5,200
1990	- -	- -	4,615	4,961	4,660
1991	- -	- -	5,273	5,485	5,380
1992	- -	- -	4,694	4,498	4,440
1993	- -	- -	5,335 a	4,811 b	4,780
1994	- -	- -	6,837	6,789	5,740
Beans (lbs/acre)[3]					
1990	Y 2,218 a	Y 2,330 a	S 1,934 b	- -	1,980
1991	RK 1,592	RK 1,457	RK 1,140	- -	1,780
1992	Y 2,830	Y 2,716	Y 2,442	- -	1,780
1993	MB 1,473	MB 1,584	MB 1,529	- -	1,660
1994	MB 1,929	MB 1,687	MB 1,717	- -	1,820
Oats/Vetch (lbs/acre)					
1991	1,783	2,093			
1992	659	- -[4]			
1993	1,870	2,364			
1994	1,756	3,127			

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[1] Means within a row followed by different letters indicate significant differences among systems at 5%.

[2] Organic and low-input safflower in 1992 were plowed under early in the season and Yolano beans were planted. Bean yields were 2,193 and 2,273 lbs/acre for the organic and low-input systems respectively.

[3] Varieties of beans as follows: Y=Yolano; S=Sutter; RK=Red Kidney: MB=Midnight Blacks

[4] Low Input oats/vetch harvested for green chop in 1992; no seed yield.

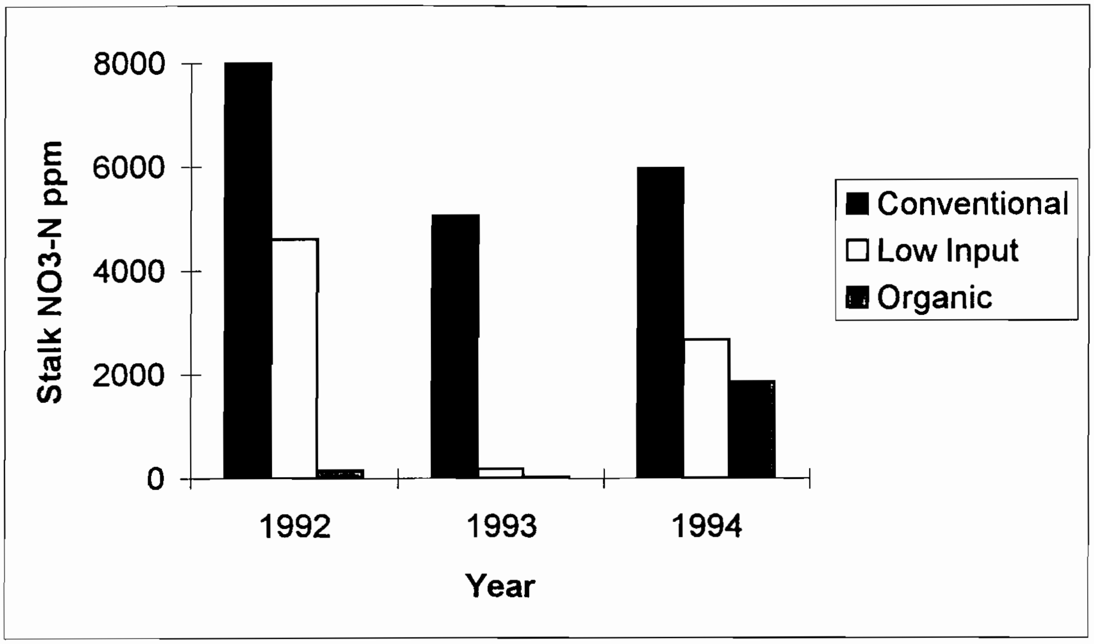

Figure 1. Stalk Nitrate at Maturity 1992-1994.

INTEGRATING RICE CULTURAL PRACTICES AND WATERFOWL HABITAT

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California's central valleys once contained 2 to 4 million acres of seasonal and semi-permanent wetlands, now mostly converted to anthropogenic uses, including agriculture. Only 300,000 acres are estimated to remain in natural wetlands. Rice (*Oryza sativa*) was introduced to the Sacramento Valley before the turn of the century and became established commercially in 1912. It is produced mostly on former wetlands—heavy, poorly drained clay soils of the valley floor which are relatively unsuited for other crops. The clear, warm summer days and dry growing season are highly favorable for rice production, making California the highest yielding rice area in the world. Statewide average yields have exceeded 9.5 t ha^{-1} (8,500 lbs $acre^{-1}$) with maximum yields exceeding 12.3 t ha^{-1} (12,000 lbs $acre^{-1}$).

California's Central Valley was estimated to have concentrated 40 to 50 million migratory waterfowl in the late 1800s, and as recently as the 1970s 10-12 million birds migrated through the state. Even today, it supports 3 to 5 million waterfowl, the largest concentration in North America. These populations are increasing as habitat is restored both in their northern nesting grounds and in their southern over-wintering habitat. Emerging evidence suggests that when populations are low, nesting areas are most important, but when populations are high, the quality of over-wintering habitat is critical to subsequent reproduction. Thus, in recent years wildlife biologists have given increasing emphasis on the quantity and quality of winter habitat.

In the early years of rice production, grain depredation by waterfowl made ducks and geese a major pest of rice farmers. In 1917, only five years after the first commercial rice crop in California, grain losses due to ducks totaled $1 million. In the 1940s, both the U.S. Fish and Wildlife Service and the California Department of Fish and Game expanded and developed the wildlife refuges, effectively reducing the problem of grain depredation by waterfowl. In the decade of the 1970s, semidwarf, lodging resistant cultivars were introduced to California rice culture. Not only were these cultivars high yielding, but they were largely photoperiod insensitive, shortening the growing season from 160-170 days to 135-145 days. Furthermore, soil leveling with laser-directed equipment was widely adopted, greatly improving water management during critical periods of seedling development as well as for field drainage and soil drying prior to harvest. With erect (nonlodged), short-season rice, uniformly dry soils and larger combines, harvest is now completed largely before migratory waterfowl arrive. Although primarily aimed at the improvement of agronomic efficiency in rice, these events greatly enhanced the possibilities for environmental stewardship with respect to the conjunctive use of rice production and overwintering waterfowl.

California rice fields have long been a source of food and habitat for a large number of waterfowl species. An average of 350 lbs acre^{-1} of unharvested rice grain coupled with 250 lbs acre^{-1} of small invertebrates, tubers, edible shoots and seeds provide a food value nearly equivalent to that produced by natural wetlands. Thus, waterfowl have become highly dependent on rice fields (and other grain fields) for food. While some farmers and hunting clubs have managed rice fields in the fall and winter to attract ducks and geese, only recently has the industry as a whole proactively embraced the idea of postharvest management of rice fields for their unique qualities as a waterfowl habitat.

The Rice Straw Burning Reduction Act (AB 1378) of 1991, mandated the phase down of rice straw burning in the Sacramento Valley by the year 2000. Traditionally, rice farmers disposed of straw by burning, leaving about 70 percent of the unharvested grain readily available to waterfowl on the soil surface. Excepting in very high rainfall years, most burned fields remained essentially unflooded in the winter although 7-10 percent were estimated to have been flooded for duck clubs. With changes in straw burning regulations, growers have coupled straw disposal to management for winter waterfowl habitat.

Without burning, two options remain for rice growers: 1) in-field incorporation of straw and 2) straw removal for other uses. While the latter would be preferable, the markets for rice straw are poorly developed and currently not competitive with other stocks for industrial uses. For the short term, growers have settled on methods for *in situ* disposal, varying widely in expense, but all more costly than burning. With the need to develop novel approaches to in-field disposal came the realization that moisture is essential to straw decomposition, especially in the warmer postharvest period of early fall. But flooded fields may become anaerobic, thus retarding decomposition. Initial proposals from the environmental community included the suggestion to flood all 500,000 acres of riceland to a depth of two feet, creating not only wetlands, but stored water to flush the delta and alleviate water shortages in general. This was impractical for several reasons: 1) diversion of limited water in the fall when moisture is most needed to enhance straw decomposition was at odds with the needs of river fisheries, most notably winter-run Chinook salmon; 2) the proposed high water depths were not suited for waterfowl use (most ducks forage in six inches or less floodwater and geese prefer unflooded fields); and 3) this depth of water could not be contained by the current rice field water management infrastructure. The dialogue between environmentalists, waterfowl conservationists, farmers and researchers led to an increased awareness of the potential for coupling waterfowl friendly winter flooding with innovative experimental techniques to manage rice straw. Most notable is the concept of "straw rolling," whereby fields are reflooded after harvest and the standing straw is mashed into the soil surface by large tractor-pulled cage rollers. Advantages of this method are that it is less costly than dry incorporation, most of the unharvested grain remains at or near the soil surface as compared to conventional incorporation with a stubble disc or plow, and the continuous flooding creates a habitat for invertebrate organisms which serve as high protein food for overwintering waterfowl.

The long-term agronomic consequences of nearly year-round anaerobic soils created by the combination of winter flooding for straw disposal and in-season flooding for rice cultivation is largely unknown in temperate rice production, but so-called long-term yield declines are now widely recognized in the continuous rice cropping systems (2 to 3 crops y^{-1}) of tropical Asia. Considerable long-term research is currently in progress to assess and improve the sustainability of rice cropping systems in conjunction with the concept of managed wetlands. Meanwhile, California rice growers are experimenting with various methods of straw chopping, light incorporation, rolling and winter flooding to dispose of rice straw. Water suppliers, environmental groups and rice growers have clearly made a difference in improving winter waterfowl habitat and rice fields have become a highly visible and viable extension of managed wetlands and a public relations coup for the value of agricultural land.

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COVER CROP SELECTION AND MANAGEMENT IN ORCHARDS AND VINEYARDS

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Potential Benefits of Cover Crops

Addition or conservation of nitrogen
Reduced soil erosion
Addition of organic matter to soil
Weed suppression
Improved soil structure and water pen.
Improved traction
Increased beneficial arthropods

Potential Problems with Cover Crops

Increased costs and management, but benefits may outweigh costs
Depletion of soil moisture
Increased frost hazard
Increased weed problems
Increased pests

Tree and vine crop growers have several cover cropping systems from which to choose. The choice and performance of cover crops often depends on site-specific factors, so they should first be tested in a few rows before planting large acreages. The main factors to consider when selecting a particular species or mix are costs vs. benefits, irrigation method, tillage practices, nitrogen needs, frost concerns and harvesting practices (for nut crops). Understanding the basic cover crop types and management strategies can greatly improve the chances for success.

COVER CROP SPECIES AND BLENDS

Monocultures of sown cover crops are frequently used, but problems may occur with the use of the same species year after year. For example, continual plantings of Cahaba white vetch may be affected by soil diseases; also, in some areas alfalfa weevil can be a serious pest of bur medic. Localized environmental niches, such as sand streaks or areas with differing soil nutrient availability, may also provide unfavorable growing conditions for a single species. Providing different species in a mix may enable one species to thrive in areas where another might be weak, increasing the chances for a healthy stand throughout the orchard or vineyard. Polycultures also attract a diversity of beneficial arthropods which may aid in pest management, although research in this area has provided mixed results.

Resident vegetation is naturally-occurring vegetation, or "weeds." While not sown, this ground cover is inexpensive to manage and has some of the benefits of sown cover crops, such as providing traction, improving soil tilth, and attracting some beneficial insects. However, resident vegetation can be highly variable among farms and even within a single orchard or vineyard. It usually contains little or no nitrogen-contributing legumes, which are essential on organic farms. Also, it can contain undesirable weeds which may compete excessively with the trees or vines. Of course, many growers use resident vegetation successfully.

Reseeding Winter Annual Cover Crops. With the increasing trend towards nontillage, many growers sow winter annual species that reseed and die in the spring and regenerate each fall--preferably with irrigation, but often with rainfall alone. Such species include clovers, medics, many vetches, oats, barley, 'Blando' brome, and 'Zorro' fescue. Species that do not effectively reseed include bell (fava) beans and field peas. In addition, many species will only reliably reseed if supplemental irrigation water is supplied in the spring. Blends of burr medic (burr clover) and subterranean, crimson, and rose clovers are common and can be quite productive when properly maintained. Where no supplemental irrigation is available (i.e., under drip irrigation), the following species that will reseed in most years: burr medic, early and mid-season varieties of subterranean clover, rose clover, 'Blando' brome (soft chess), and 'Zorro' fescue. If not replanted or if neglected, however, in time these species may simply become minor components of the ground cover. Periodic replanting every 3 to 4 years can ensure dominance by these species.

Burr medic is well adapted to California's climate and grows well only in neutral to high-pH soils; it is occasionally a major component of resident vegetation. It effectively reseeds even under fairly close mowing and, because of its high percentage of hard seed, it usually reestablishes well even when tillage is used. For these reasons, it is an excellent cover crop for raisin vineyards. Burrless varieties, such as 'Santiago,' are available commercially. Subterranean clover, or subclover, usually performs best in acid to neutral soils. It forms a dense, spreading mat which can effectively suppress weed growth, especially with periodic mowing. Early-maturing varieties, frequently used on range land, include 'Nungarin' and 'Dalkeith.' 'Blando' brome is often used in monocultural stands, although it is useful as a low-growing, mowable grass when combined with clovers and medics. 'Zorro' fescue is very expensive and is used mostly on hillside, serpentine, low fertility soils or where initial erosion control is required on cleared land.

High Biomass Mixes. Where supplemental irrigation is available, mixes which produce large amounts of biomass, or plant matter, can be used to add organic matter to the soil. The periodic addition of organic matter enhances soil microbial populations, improving soil structure and nutrient cycling. High biomass mixes contain large seeds and are usually quite easy to grow. In general, they are sown each fall and either disked or mowed in the spring. Two basic types of high biomass mixes are often available from seed companies: pure legume and legume/grass blends.

Pure legume blends, usually containing bell beans, vetch, and field peas are used to add the maximum amount of readily available nitrogen to the soil. They are usually disked in late March or April during peak flowering; this is referred to as a "green manure" cover crop. Where furrow irrigation is used, they are disked before the soil dries excessively to enable the disk to penetrate the soil. Bell beans produce vigorous, upright growth. Field peas are shallow rooted and therefore subject to drought on sandy soils; they also produce the far majority of their biomass and nitrogen in the spring. Vetches are frequently used, but may twine up vines, trees, or sprinklers if planted too close. Also, if allowed to reseed they may become a weed problem in the rows. Among the vetches, purple vetch usually produces the greatest amount of biomass by late winter/early spring, but it is also the least winter hardy. When maximum biomass production is desired before disking in March, purple vetch is may be the best vetch species to use in most areas of California, although mixing vetches is also advantageous. 'Lana' woollypod is one of the most vigorous vetches in the spring and flowers and matures earlier than purple

vetch. Common vetch has extrafloral nectaries on the stipules, which provide nectar to beneficial insects. Cahaba white vetch has been shown to suppress root knot nematodes.
Various legume/grass blends are also available. The addition of grasses, such as barley, oats, or cereal rye in a mix imparts several benefits. The fibrous roots of grasses greatly enhance soil tilth and water penetration. Grasses also take up excess nitrogen from the soil, improving the growth and nitrogen-fixing ability of the legumes. Lastly, grasses provide structural support for the twining vetches and peas. Legume/grass cover crop blends can be disked, but are often simply mowed; the clippings form a moisture-conserving mulch through much of the growing season. Typical blends often consist of bell beans, one or more vetches, peas, and oats. Because bell beans and peas do not tolerate mowing, they are sometimes omitted; barley/vetch or oat/vetch blends are relatively inexpensive and are used in many orchards and vineyards.

Perennials. Perennial grasses and legumes provide a permanent cover that offers year-round traction and ease of management. Perennial clovers, such as white and strawberry, are low growing and add nitrogen, but are invasive and compete with trees and vines for water. Birdsfoot trefoil, a legume, is slow to establish but forms a low-growing, dense cover. Vigorous, summer-active perennial grasses, such as 'Berber' orchardgrass and tall fescue, devigorate trees and vines and should only be planted where vigor is excessive.

Drought tolerant and drought avoidant perennial grasses, most of which are native to California, are currently popular among many grape growers, especially in the North Coast and the San Joaquin delta area. Drought tolerant species survive dry periods by developing large root-to-shoot ratios--i.e., extensive, spreading root systems. Drought avoidant species, such as meadow barley and California brome, deal with dry periods by going dormant when water is scarce, and are most appropriate under drip irrigation. While both types can be useful, the latter species are the most appropriate in order to avoid excessive competition with vines. Under drip irrigation they will almost completely shut down growth during the summer, and thus will not compete with the vines. The seed is quite expensive initially, but can be relatively inexpensive over the life of the cover. It is important to select species that are adapted to the climate. Special care must be used in planting and establishment of these species, but once established they often effectively outcompete weeds. Low-growing mixes are available that require only one mowing per year; in any case, springtime mowing of these grasses should be avoided until after seed has matured.

Insectary Blends. Many cover crop blends are available which are sown for the purpose of attracting beneficial insects. These mixes vary greatly among seed companies, but usually include members of the carrot and sunflower families. Insectary blends are usually sown in the fall every 3 to 10 rows and treated as perennials; they are allowed to flower and reseed in order to be effective and to persist. While insectary blends do attract a diversity of predators and parasitoids, their role in pest management is unclear. Some growers have encountered problems with these blends, usually arising from poor establishment from planting too deeply (they should be only about 1/4 in. deep). Summer annual insectary species, such as buckwheat, are occasionally planted in orchards and vineyards.

MANAGEMENT STRATEGIES AND CONSIDERATIONS

Planting. Winter annual and perennial cover crops perform best when sown by mid-October, but can also be successfully grown if planted by mid-November. It should be noted that establishing small-seeded cover crops in years with little fall rains may be very difficult, especially on sandy soils. In general, lower rates can be used for early seeding, and higher rates should be used for later seeding. For example, vetch sown in late September or early October may be seeded at 30 to 40 pounds per acre, while an early November seeding would require 40-80 lbs. Good seedbed preparation is essential, especially with native grasses. Legume seeds must be inoculated with nitrogen-fixing *Rhizobium* bacteria to ensure nitrogen fixation. Small-seeded legumes are usually preinoculated, however large-seeded legumes (bell beans, vetch, and peas) must be inoculated by the grower, at least the first time they are sown. Use about one 8-ounce bag of inoculant per 100 pounds of seed. The most reliable method is the "wet" method, where a slurry of inoculum and adhesive are added to the seed and then allowed to dry before planting. However, the inoculant can also simply be layered (dry) with seed in the hopper. Inoculant or inoculated seed should be kept out of direct sunlight, so broadcast seed should be incorporated as soon as possible.

Mowing. Because cover crops can increase frost hazard, they are often mowed in late winter. Bell beans and peas do not perform well if mowed. Vetch should be mowed high (no lower than 8-10 in.), but must not be mowed after about late March if reseeding is desired. High biomass blends can be killed in spring if mowed close to the ground. Nontillage clover mixes should be mowed in late winter to suppress tall weeds and encourage spreading. Subclover and burr medic can usually reseed even under fairly close mowing, while crimson and rose clovers flower above the foliage and therefore must not be mowed after about late March to allow for reseeding.

Nutrition. As with trees and vines, soil fertility is critical to cover crop production. Legumes fix nitrogen, so nitrogen should not be applied shortly before or during their growth. However, legumes do require adequate sulfur (which is plentiful in most vineyards) and phosphorus for good growth. Annual grasses require nitrogen additions if grown alone, and will respond well to up to 50 pounds of nitrogen per acre. Perennial grasses may require even more than this amount. In general, grasses predominate on highly fertile sites, while legumes will usually grow best in soils with low nitrogen content. Many poor solid legume plantings (especially clovers and medics) that are overtaken by grasses and mustards may be a result of excessive soil nitrogen, so broadcast fertilization should be avoided from fall until late spring. The end result of cover cropping should be optimum crop nutrition and productivity, so tissue nutrient analyses should be conducted regularly.

In general, vetches and peas can fix far more nitrogen than clovers and medics. A green manure cover crop disked in April can add 150 pounds or more of nitrogen per planted acre, which may cause excessive vigor in grapevines, especially on highly fertile soils. Nitrogen production in orchards may be reduced due to shading and the use of wide herbicide strips. Management options in vigorous vineyards include alternate row planting, perhaps with native perennial grasses in alternating rows, and mowing instead of disking. When residues are mowed and left on the soil surface, a portion of the nitrogen will volatilize into the atmosphere. With about 80 percent of the nitrogen in leguminous cover crops contained in the above-ground portion, volatilization losses can be high--perhaps as much as half. Nontillage clovers and medics may add only about 30 to 40 pounds of nitrogen per planted acre. Perennial clovers may add substantial amounts of nitrogen, while perennial grasses use soil nitrogen and may require supplemental fertilization.

Cover Cropping in Almond and Walnut Orchards. Because almonds and walnuts are harvested picked up from the orchard floor, excessive cover crop debris at harvest could be problematic, particularly in nontilled orchards. However, most winter annual cover crops can be grown successfully if properly managed. Legume cover crops have a low carbon-to-nitrogen (C/N) ratio and therefore break down fairly rapidly after mowing, usually causing no residue problems at harvest. Grass residues have a high C/N ratio and can persist until harvest, but they are usually not a problem if mowed closely by June, followed by periodic mowing until harvest. Under drip or microsprinkler irrigation, breakdown of residues is slower, so mowing should start in late spring.

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AN INTEGRATED APPROACH FOR WATER QUALITY
THE PAM CONNECTION

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USDA conservation and education agencies in partnership with a resource conservation district have successfully met water quality objectives the past five years through a comprehensive, integrated, locally managed watershed project in Stanislaus County, California. The West Stanislaus Hydrologic Unit Area (HUA) project is one of 36 HUA's nationwide established by USDA's 1991 "Water Quality Initiative."

Irrigation-induced erosion has been studied in the West Stanislaus Watershed area for 15 years and these studies have contributed greatly to developing predictive tools statewide. Many Best Management Practices (BMPs) have been evaluated during this period and are highlighted in this paper. The innovative evaluation and use of PAM (polyacrylamide) by HUA agencies is a more recent practice that has great potential for reducing significant amounts of sediment and pesticide residues from entering the impaired San Joaquin River.

The West Stanislaus Resource Conservation District (RCD) serves as the local, grass-roots sponsoring agency. RCD's are special districts formed for the purpose of addressing local resource conservation needs under Division 9 of the California Public Resources Code. The are 116 RCDs statewide that establish local conservation priorities and seek technical and financial assistance from a wide variety of local, state and federal agencies. RCD Directors are elected or appointed and volunteer their time to improve the resources in their respective communities.

The primary USDA agencies "working together" on the HUA are the Natural Resources Conservation Service - NRCS (formerly the Soil Conservation Service), the Farm Service Agency - FSA (formerly the Agricultural Conservation and Stabilization Service), and the University of California Cooperative Extension. Since the HUA began in 1991, over 25 additional local, state and federal agencies are participating or cooperating in varying degrees to implement their objectives in a coordinated manner.

HUA agencies have coordinated a comprehensive information and education program through newsletters, magazine articles, journals, tours, videos, brochures, fact-sheets, meetings, seminars, steering committees, formal and informal presentations throughout the western states and one-on-one discussions with growers. The February 1996 issue of National Geographic Magazine will contain an article on nonpoint source pollution with a segment on the West Stanislaus HUA.

A comprehensive "West Stanislaus Sediment Reduction Plan" (February 1992) was published by the NRCS and funded by the Central Valley Regional Water Quality Control Board at the request of the RCD. This plan established the base-line in the watershed and acknowledged that over one million tons of sediment could potentially be lost by irrigation-induced erosion annually in the HUA. It had been previously documented that DDT pesticides legally applied in the HUA over two decades ago still persist in these soils and were negatively impacting the San Joaquin River.

Developed by an multi-disciplinary team of engineers, biologists, soil scientists, agronomists, water quality specialists, soil conservationists, farm advisors, geologists, economists and sociologists, the plan listed 17 conservation practices that when used in combination or with managerial practices, would significantly reduce the volume of sediment leaving irrigated fields in the HUA. The plan "emphasizes that the best solution is a local solution" and established an implementation plan consistent with the 1991 Inland Surface Water Plan with 3 levels of implementation; (1) voluntary implementation of BMPs, (2) institutional-based encouragement of BMP implementation, and (3) regulatory implementation, such as waste discharge requirements or discharge prohibitions.

The team concluded that BMPs (structural and managerial) can significantly reduce sediment loss from irrigation-induced erosion processes in the HUA. The RCD concluded from previous pilot-projects and reports that a goal of 80-85 percent reduction in sediment goal was economically feasible and achievable by growers in the HUA with adequate technical and financial assistance. The RCD established a 300 mg/l goal (opaque in color) for all HUA cost-shared projects (down from an average drain with 1500 mg/l - chocolate brown in color).

In 1991, the HUA to began promoting and implementing BMPs using an integrated approach of (1) information and education, (2) technical assistance, and (3) cost-sharing of BMP installation. Five years later, the result of these efforts have been documented in comprehensive "resource management plans" with the highlights from the "West Stanislaus Hydrologic Unit Area 1995 Progress Report listed below:

Approximately 24% (30,568 acres) of the total area in the HUA have adopted structural and managerial BMPs documented in Total Resource Management Plans and LTAs. Cumulative savings as a direct result of HUA assistance:

960 pounds of DDT isomers from offsite impacts.
525,945 tons of sediment from offsite impacts.
30,560 acre/feet of irrigation water.
13,495 acres of Irrigation Water Management Practices.
19% average absolute improved irrigation efficiency.
Controlled drainage practices have been implemented on 9,717 acres

Cost-sharing under Agricultural Conservation Program (ACP) and Long Term Agreements (LTA) and Water Quality Incentives Program (WQIP) were utilized ($332,919) to reduce sediment load in streams. An additional 42% (54,180 acres) of the total area in the HUA had previously utilized structural BMPs from prior technical and financial assistance, and/or non cost-shared implementation of BMPs. Therefore approximately 66% of the HUA has been adequately treated. Some of the remaining 34% (43,860 acres) have minimal BMPs installed and need significant treatment to meet the HUA objective of 300mg/L. All irrigated lands need managerial BMPs on an annual basis.

HUA leaders have estimated that over 90% of the farmers are aware of the HUA goals and most are implementing some BMPs. New FSA cost-shared practices, such as Integrated Crop Management (SP-53) have been promoted in the HUA to reduce the use of pesticides and nutrients along with Shallow Water Areas for Wildlife (WL-2).

Significant wetland enhancements have been implemented since the HUA began including restorations on prior converted cropland (PC). Numerous sediment basins provide temporary habitat for wildlife in the HUA. UCCE has tracked the location of all sediment basins (installed with or without cost-share) and this map could easily be converted to a Geographical Information System (GIS) format.

In 1992, the first ever "National Irrigation-Induced Erosion and Water Quality Conference was conducted in Boise, Idaho. NRCS and UCCE collaborated on a technical paper and poster presentation to share the California perspective. This was a significant event that has led to the National Survey on Irrigation-Induced Erosion as part of the National Resource Inventory.

At that conference, HUA leaders learned of significant research being conducted by the Agricultural Research Service (USDA-ARS) in Kimberly, Idaho on soil conditioners; specifically water soluble anionic polyacrylamide (PAM). Professor John Letey from the University of California, Riverside had simultaneously been conducting laboratory research on PAM and collaborated with UCCE in late 1992 to conduct field trials in the HUA to evaluate reductions in soil loss, pesticide residues (DDT) in tail-water runoff and improvements in irrigation infiltration rates.

How does PAM Work? USDA-ARS, Kimberly, Idaho states *"Water-applied PAM increases soil cohesion and strengthens aggregates it contacts in the furrow by binding exposed soil particles together more securely. This greatly reduces detachment and transport of sediments in irrigation runoff. Soil erodibility at the soil/water interface is reduced by improved inter-aggregate bonding and by better maintenance of surface roughness. PAM also acts as a settling agent. It flocculates (clumps together) the fine particles dispersed by and carried in the flow, causing them to settle to the furrow bottom. Fewer dispersed fine particles remain in the infiltrating water to block pores and reduce infiltration rates. Pore structure is maintained, preventing the usual infiltration rate reduction. This decreases runoff rate and amount, which further reduces stream force, carrying capacity and transport volume."*

Field trial results in the HUA indicate a 95-98 percent reduction in soil loss and a corresponding reduction in pesticide residues leaving the fields through furrow irrigation. Additionally, a 10-40 percent increase in infiltration was observed in treated furrows compared to non-treated furrows. PAM maintains existing soil structural units (peds or clods) reducing crusting (silting over) by silts and very fine sands of existing pores. Therefore, initial infiltration rates are maintained resulting in a net increase of infiltration. Non-treated furrows degrade to the point where up to 75 percent or more of the applied irrigation water may runoff the end of the field carrying significant loads of sediment and soil-adhered pesticide residues into man-made drains and intermittent streams and ultimately to the San Joaquin River.

UCCE continues to conduct additional field trials in cooperation with growers and PAM manufacturers All soils in the HUA have responded favorably to PAM applications resulting in water (<10 mg/l) with very high clarity.

The HUA has been the California test site for purposes of evaluating PAM for NRCS Field Office Technical Guide standards and specifications. The Central Valley Regional Water Quality Control Board requested NRCS's "assistance in evaluating the potential impacts of utilizing polymers as a best management practice on a widespread basis." . The HUA has coordinated two seminars that brought scientists from across the nation (and England) to discuss the widespread use of PAM in agriculture. Chemists, microbiologists, agronomists, soil scientists, toxicologists and other disciplines met June 8, 1995 at the NRCS State Office to share the latest science on PAM. A video tape is available of this historic meeting.

In a letter to EPA, USDA-ARS scientists state, *"PAM use for erosion control is at the heart of the concept of agricultural sustainability. It provides a potent environmental benefit without negative impact on flora and fauna. It halts erosion (about half a ton per ounce of PAM used). It increases infiltration, thus enabling conservation of water (California's scarcest resource). It allows changes in furrow irrigation management that provide more uniform water application, reducing the potential for nitrate leaching. It removes substantial amounts of sediment, phosphorus and pesticides from return-flows, and greatly reduces return flow BOD. Because furrow reshaping and sediment pond or ditch cleaning are needed less frequently with PAM use, it also conserves fuel, lessens air pollution, and reduces equipment wear and labor."* PAM has clearly generated a lot of interest and is part of an integrated approach for water quality in the West Stanislaus Hydrologic Unit Area Project.

As a result of the experience gained in the HUA and scientific support from university researchers, government researchers and industry researchers, California NRCS approved the NRCS West National Technical Center's Interim Conservation Practice Standard 201, Irrigation Erosion Control (Polyacrylamide - PAM). This standard enables NRCS field offices to include this practice in their on-farm planning.

HUA leaders have envisioned a full scale demonstration farm, perhaps located on the NASA-AMES Crows Landing Facility in the HUA. The agricultural outlease property has been extensively studied and monitored by the NRCS, RCD and UCCE. This is the same site as the recently completed "Crows Landing 319 Demonstration Project" which the RCD evaluated BMPs in controlling the off-site movement of pesticides and sediment. Contractual incentives and controls are in place to assure HUA goals are achieved. Additional contractual agreements could be established to provide a "safety net" for expenses and/or losses over and above those which may be reasonable in any given crop year.

The goal of the full scale demonstration farm is to provide a commercially farmed study area to compare science-based applications of organic soil amendments (manures, green waste compost and perhaps biosolids) and soil conditioners (PAM) to maintain or improve aggregate stability and soil quality. A science-based approach could provide valuable answers to alternative approaches to solving irrigation-induced erosion. All of the cooperating agencies contacted to date have been supportive of this idea. A meeting of interested agencies was conducted November 21, 1995 to share progress and future objectives. We acknowledge the need to maintain existing partnerships and develop new ones.

The HUA was the focus of a US General Accounting Office (GAO) report to the Committee on Agriculture, Nutrition, and Forestry, U.S. Senate titled "AGRICULTURE AND THE ENVIRONMENT: Information on and Characteristics of Selected Watershed Projects" (GAO/RCED-95-218). The GAO Project Manager wrote: *"As you will see, the West Stanislaus County watershed project plays a prominent role in this report. The project is cited several times in the body of the report and is the focus of Appendix II."*

The resulting GAO report to the US Senate states *"participants in all 9 (watershed projects evaluated) echoed two key lessons learned: the need for (1) flexibility in the kinds of financial and technical assistance provided by federal agencies and (2) local tailoring of approaches to watershed management. Because watershed projects differ in characteristics such as the type and source of pollutants, local agricultural practices, and the community's attitudes, participant's believed that a prescriptive, one-size-fits-all approach would be inappropriate (pp 1-2)."*

The HUA has had a presence in the community with favorable local and regional newspaper articles, and with the RCD's mobile irrigation lab truck with signs that clearly display all HUA cooperating agencies, and with RCD Directors who are recognized by other farmers in the community as leaders of a successful, grass-roots voluntary effort. NRCS Economists determined that $1.8 million dollars in annual, direct economic benefits in the HUA because of partnerships developed by the HUA project.

Benefits and Challenges of Integrating Wildlife in an Agricultural Operation

George Work, Farmer/Rancher, Paso Robles, CA

Paper not submitted in time for inclusion in Proceedings.

GRAPEVINE NUTRITIONAL STATUS AND LEAFHOPPER POPULATIONS

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INTRODUCTION:

It would probably be wise to begin with a few remarks about the broader context into which this presentation fits. As an academic researcher, I have always had tremendous respect for farmers and agricultural consultants. For years, many farmers have been miles ahead of some conventional researchers in exploring innovative approaches to successful farming. I certainly have no interest in attempting to prove or disprove something about a production system that the farmer and/or consultant already has observed is working. On the other hand, I feel we must be very cautious in suggesting that simple cause and effect or predictive relationships can be delineated from single, although easily monitored, parameters in our complex agricultural ecosystems.

I should also mention that for several years now I have enthusiastically promoted the advantages of practicing integrated pest management (IPM) with a "Plant Positive" rather than a "Pest Negative" perspective. As outlined by Eliot Coleman and many other capable deep agricultural thinkers, this Plant Positive perspective allows us to approach pest outbreaks with an emphasis on their basic causation, instead of simply treating the same old symptoms. Recent research in the IPM Program at CSU Fresno (Mayse et al. 1991, Roy 1991, Garcia 1993) on the effects of fertilizer type and amount on leafhopper population dynamics is partial evidence of my interest and commitment to the "Plant Health" approach to IPM. Results of a three-year field project showed that *Erythroneura* leafhopper densities were significantly greater on vines fertilized with synthetic ammonium nitrate compared with vines receiving compost fertilizer. We further pursued this line of research by investigating effects of irrigation on leafhopper populations. Higher leafhopper densities were found on vines receiving greater amounts of irrigation water. These results have been corroborated in related research conducted recently by various University of California scientists (e.g., Kent Daane, Jeff Dlott, Larry Williams, Ted Wilson).

Just before the start of our irrigation studies (i.e., around 1991), I first became aware that several successful and high-profile organic agriculture consultants in California were promoting the use of Brix readings from leaf sap in trying to predict potential leafhopper problems. In short, low Brix levels would supposedly indicate leafhopper danger, while high Brix would suggest the plant is well-protected against sucking insects. In fact, the current issue of the Peaceful Valley Farm Supply Main Catalog (p. 54) states that "a Brix reading above 12 indicates plant resistance to sucking insects." Consultants were further suggesting that to raise Brix levels, application of foliar nutrient solutions should be made.

This Brix / leafhopper story was naturally intriguing to such a self-professed proponent of the "Plant Health" perspective as myself. Thus, as part of our irrigation study in 1992, M.S. student Antonio Trias Trueta gathered some preliminary data for both leaf sap Brix levels and leafhopper populations (Trueta 1993). We found that the Brix readings stayed well below 12 throughout the season, but also that leafhopper nymph densities remained under 5 per leaf during the entire study. It seemed very clear that it was possible to have relatively low Brix levels in leaf sap, and to still have very low numbers of leafhoppers in the vineyard.

These preliminary findings prompted me to become somewhat skeptical about the Brix / leafhopper story which was circulating through various channels in the industry. Additional reservations I had related to several important issue areas: 1) Applying foliar fertilizers to solve low sap Brix "problems" (i.e., < 12) is a chemical product approach rather than a biological process type of solution, which is starkly inconsistent with the fundamental principles of organic farming systems; 2) In some cases, proponents of this Brix / leafhopper story would derive direct financial benefit from sales of the foliar nutrient solutions, injecting some conflict of interest potential into the consulting arena; and 3) Most importantly from a scientific viewpoint, there appeared to be little if any solid empirical evidence (as contrasted to anecdotal observations) which supports this predictive Brix / leafhopper story.

PROCEDURES:

In 1994, we initiated a research project in Fresno-area vineyards to rigorously investigate any apparent relationship between leaf sap Brix levels and leafhopper population dynamics. Field data were collected primarily by William O'Keefe (research associate) and Kip Green (M.S. student), and the research project was supported by grants from the California Agricultural Technology Institute and the Organic Farming Research Foundation. Results here will be limited to the 1994 season, since data for 1995 are currently undergoing final analysis.

Five vineyards were sampled for leaf sap Brix levels and leafhopper densities from mid-June to early October during 1994. Brix data were collected using temperature compensating refractometers to evaluate soluble solids in leaf and petiole tissues, in young and old leaves, and for vines located in the edge and middle sections of each vineyard. For leafhopper data collection, standard direct observation leaf sampling for detecting nymphal numbers was conducted. Although leafhoppers were distinguished by species (i.e., variegated leafhopper *Erythroneura variabilis* and western grape leafhopper *E. elegantula*), data were combined for this presentation due to time and space constraints.

RESULTS AND DISCUSSION:

Brix data for plant sap extracted from leaf tissue and from grapeleaf petioles are compared in Figure 1. Leaf sap yielded consistently higher values for Brix, and the range of Brix levels for leaf tissue (approx. 6 to 12 = 6) was twice the range found in petiole sap (4 to 7 = 3). Although the sampling procedures recommended by proponents of the Brix / leafhopper story expressly suggest that either leaves or petioles may be sampled, our results for 1994 (Figure 1) clearly reveal that leaf and petiole Brix readings can differ substantially.

Although not so distinct a difference as found with leaves vs. petioles, Brix levels detected in young leaf tissue were consistently higher than in older, more mature leaves (Figure 2). Results suggest that numerically higher Brix values, as well as a wider diversity of readings throughout the season are likely to be associated with younger leaf tissue.

Season-long comparison of leaf sap Brix readings with leafhopper nymph counts in a Thompson seedless vineyard at the California State University, Fresno Farm Laboratory is shown in Figure 3. One might consider the low Brix readings coincident with intermediate densities of leafhoppers during July as lending credence to the purported Brix / leafhopper story. However, data in Figure 3 also reveal that for late June and early July, as well as from mid-August through September, leafhopper trends directly mirrored patterns of Brix levels. These findings contradict the inverse relationship which would otherwise be expected from the alleged Brix / leafhopper relationship.

Leafhopper vs. Brix data from a Barbera vineyard (Figure 4) further undercut the notion that low soluble solid levels predict high pest numbers. In this vineyard, leafhopper densities closely mirrored Brix readings throughout the entire 1994 sampling season (June-August). It should further be noted that even though Brix levels remained well below the so-called indicator level of 12 throughout the 1994 season in both the vineyards illustrated here (Figures 3 and 4), leafhopper counts in fact stayed much lower than the generally recognized economic threshold of around 25 nymphs per leaf (densities were in fact frequently under 6 nymphs per leaf).

Another way to examine the alleged relationship between leaf sap Brix levels and leafhopper densities is to factor out sampling date and to simply compare Brix values sorted numerically against average leafhopper nymph numbers per leaf (Figures 5 and 6). If one could reasonably predict leafhopper population numbers based on soluble solid readings from leaf sap, then the general shape of the curves on graphs laid out like these would roughly start high on the left side (low Brix =? high leafhoppers) and gradually drift lower toward the right-side portion of the graph (high Brix =? low leafhoppers). Data presented here in both Figures 5 and 6 clearly demonstrate precisely the opposite trend from what one would expected with the "story." That is, 1994 data from the Barbera and Carignane vineyards in this study conversely demonstrated a general increase of leafhopper nymph densities as Brix levels became elevated.

CONCLUSION:

Results compiled in the 1994 study thus appear to provide essentially no consistent support for the alleged predictive Brix / leafhopper relationship as it is currently being promoted. Although most researchers, consultants, and farmers are beginning to recognize that grapevine nutritional status most definitely can affect leafhoppers and other pests, the evidence that leaf sap Brix levels alone can be used to reliably predict herbivore population changes is by no means compelling at this time. Additional results from the 1995 study (currently being analyzed) will be essential in either further supporting this conclusion, or alternatively in suggesting new directions for additional investigation.

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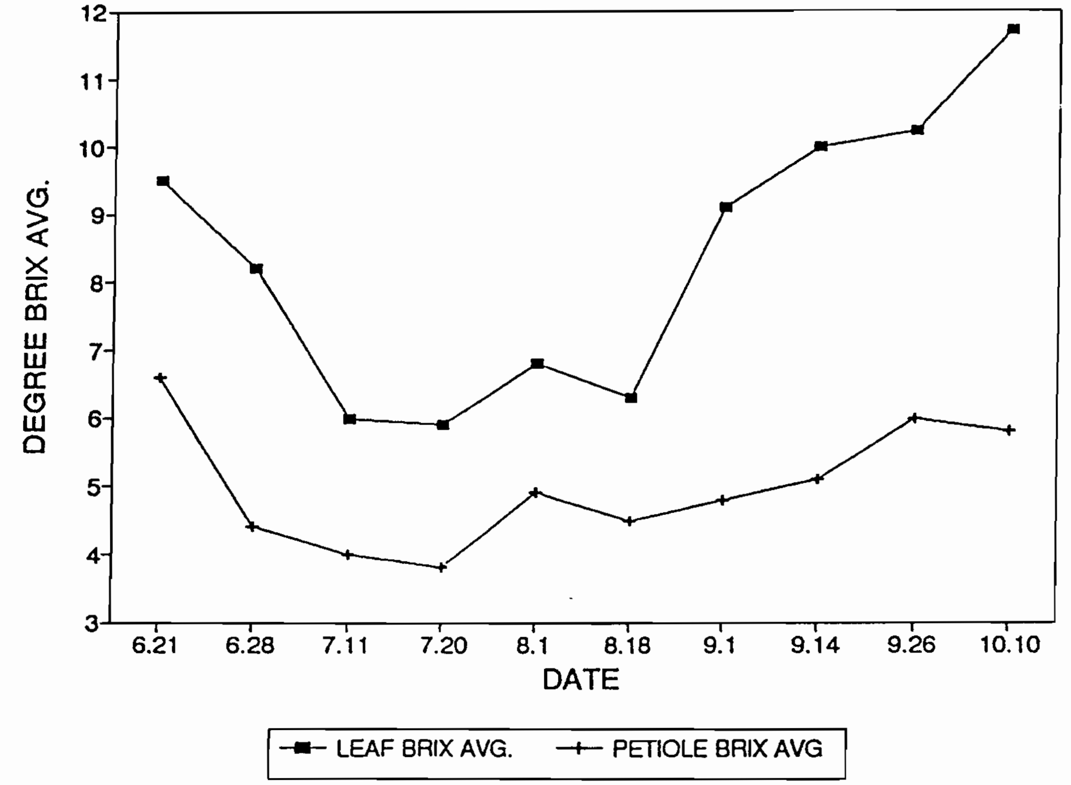

Figure 1. Comparison of Brix values for sap extracted from leaf tissue and from grapeleaf petioles in a Thompson seedless vineyard at CSU Fresno during 1994.

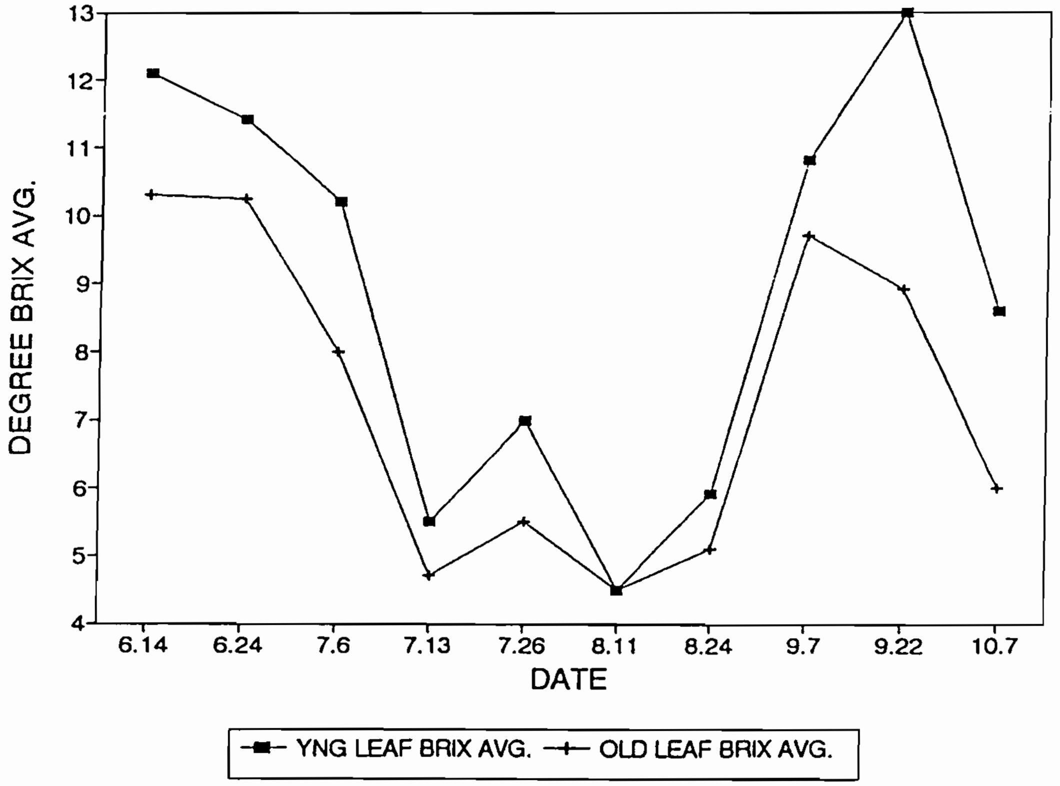

Figure 2. Comparison of Brix values for sap extracted from young / new leaves and older / more mature leaves in a Grenache vineyard near Ripperdan, CA during 1994.

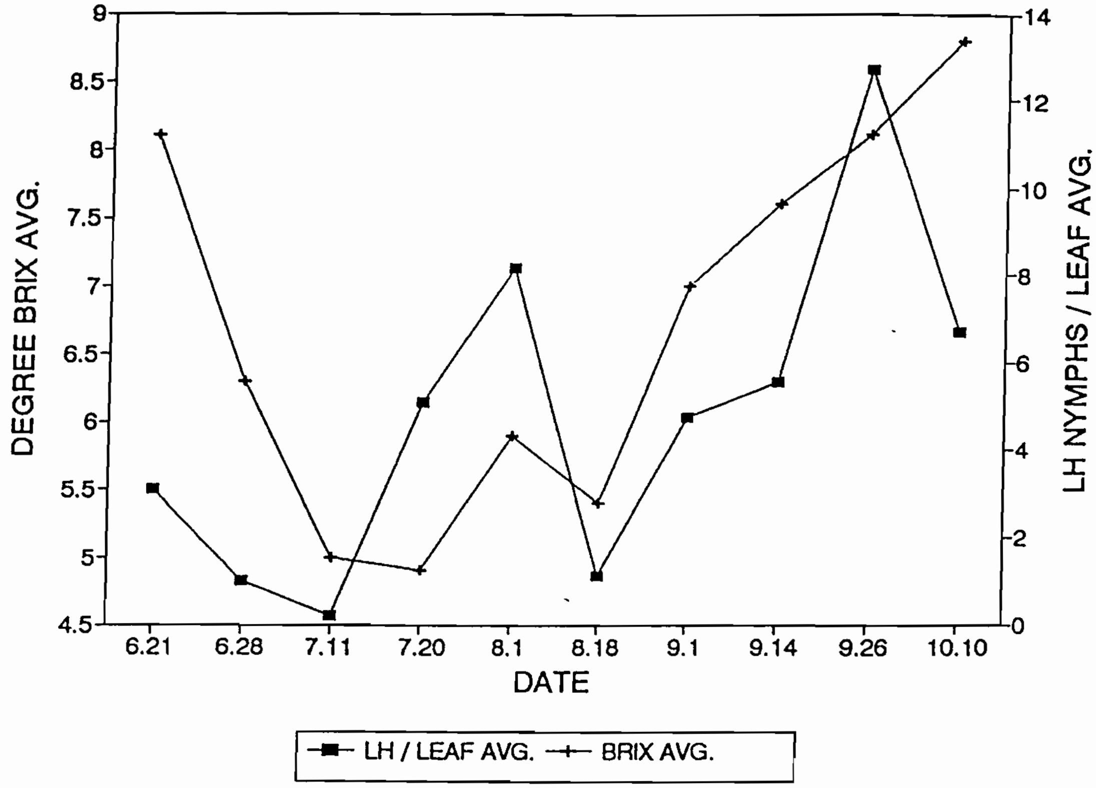

Figure 3. Patterns of leaf sap Brix levels and *Erythroneura* leafhopper nymph densities in a Thompson seedless vineyard at CSU Fresno during 1994.

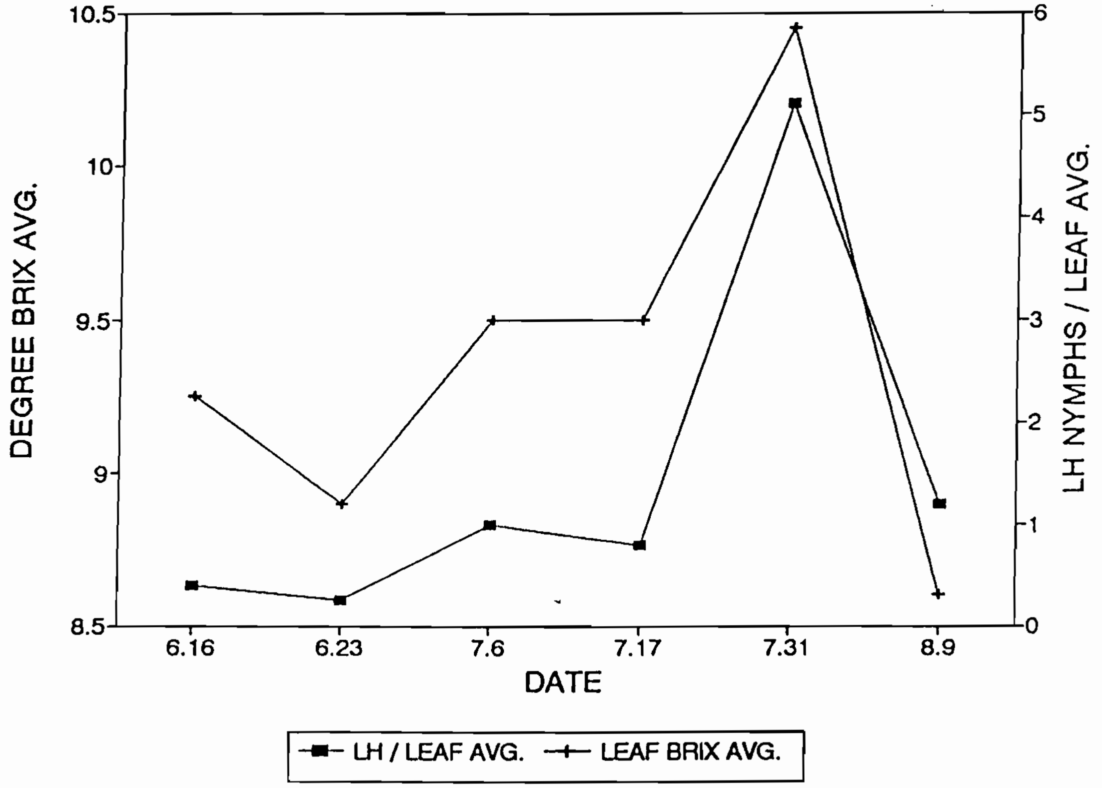

Figure 4. Patterns of leaf sap Brix levels and *Erythroneura* leafhopper nymph densities in a Barbera vineyard near Fresno, CA during 1994 .

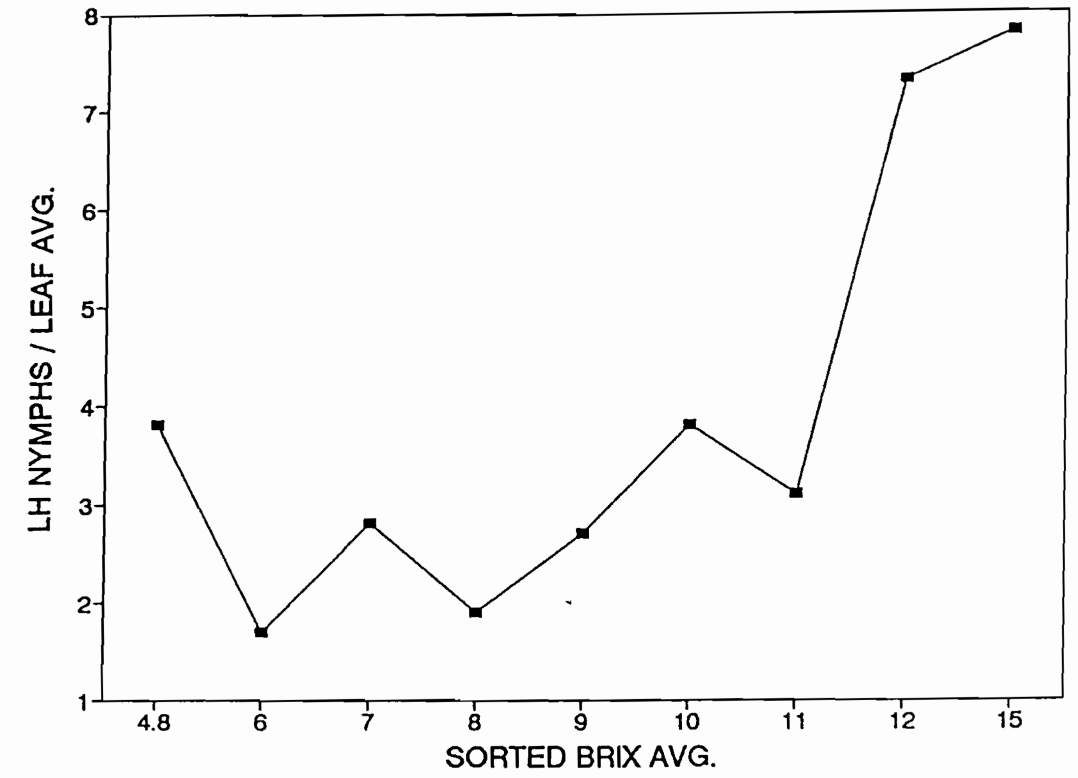

Figure 5. Leaf sap Brix readings sorted numerically (independent of date) compared with *Erythroneura* leafhopper nymph densities in a Barbera vineyard near Fresno, CA during 1994.

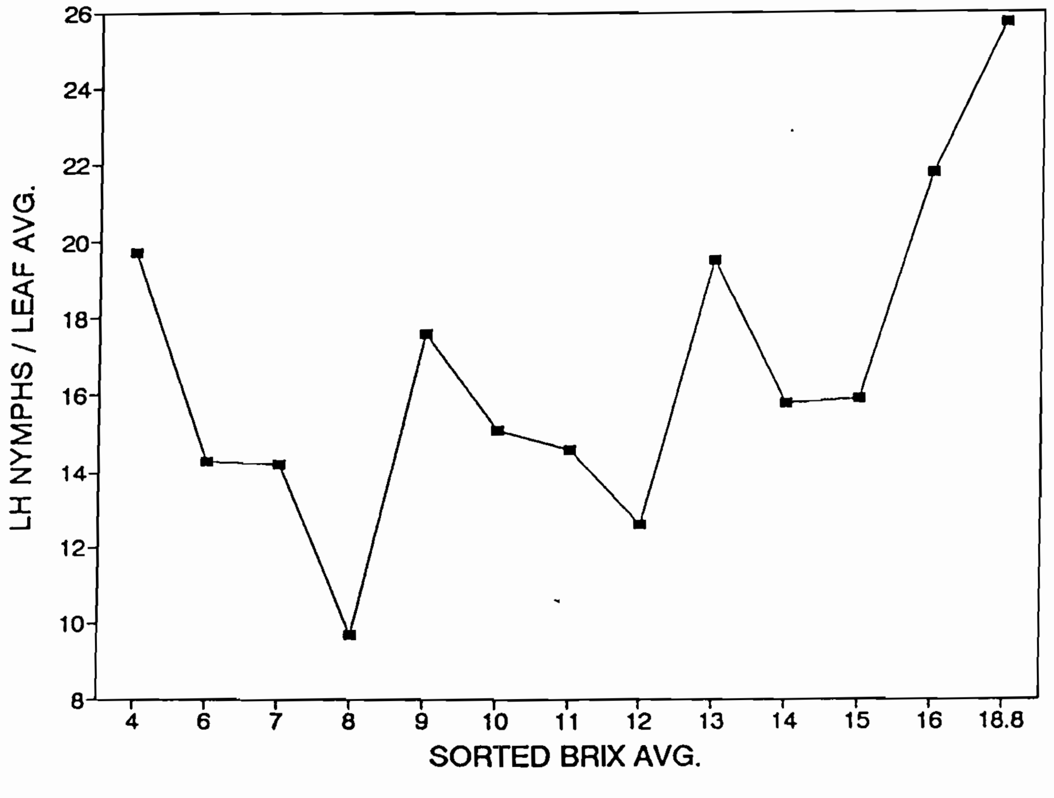

Figure 6. Leaf sap Brix readings sorted numerically (independent of date) compared with *Erythroneura* leafhopper nymph densities in a Carignane vineyard near Fresno, CA during 1994.

NITROGEN FERTILIZATION AFFECTS SUSCEPTIBILITY OF NECTARINE FRUITS TO BROWN ROT

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INTRODUCTION:

It has long been recognized that fertilization practices affect levels of plant disease (Huber & Whatson, 1974). Although a number of studies have shown the relationship of nitrogen fertilization and root and cortical rots, vascular wilts (Fusarium and Verticillium wilts), foliar diseases (powdery mildews, rusts, and smuts), canker diseases, and even virus diseases, studies on the effects of nitrogen fertilization on blossom and fruit diseases are very limited. For instance, excess nitrogen application to apples can cause softer fruit, poorer fruit color, reduced storage and shelf life, and more bitter pit (Micke, 1991). In addition, high levels of nitrogen correlated with susceptibility of pear trees to fire blight (Van der Zwet et Keil, 1979). In contrast, fertilization with nitrogen reduced the severity of anthracnose caused by *Gnomonia leptostyla* in walnut (Neely, 1986). For postharvest diseases, increased nitrogen resulted in more Rhizopus rot of sweet potato caused by *Rhizopus stolonifer*.

In the summer of 1988, we observed a natural resistance to brown rot infections of nectarine fruits (of both Flavor Top and Fantasia cultivars) collected from underfertilized trees or trees from the unfertilized controls. In contrast, nectarines collected from trees that received higher levels of nitrogen fertilization were severely infected by brown rot. These observations prompted us to study the effects of nitrogen fertilization on resistance of nectarine fruits to brown rot. All fruit used in the experiments in this study were from a Fantasia nectarine block planted in 1975.

Because only a few good examples exist on the effects of nitrogen fertilization on brown rot, a major disease of stone fruits caused by *Monilinia fructicola,* we conducted a series of experiments to study the relationship between nitrogen and brown rot. These studies were performed on nectarine blossoms, green fruit, and mature fruit from a Fantasia nectarine block located at the Kearney Agricultural Center (see details under the **Procedures** section of this report).

PROCEDURES:

Experimental plot. To study aspects of nitrogen fertilization on the susceptibility of blossoms and fruit of Fantasia nectarines to brown rot, a nitrogen (N) fertilization rate experiment was initiated in a 2-acre block of Fantasia nectarines at the Kearney Agricultural Center in Parlier. The trees were planted on a 20-feet-by-20-feet spacing and were trained to an open vase system. We organized five fertilization treatments in a randomized block design, with three replicates each and five trees per replicate. Treatments were an unfertilized control and four N treatments: 100, 175, 250, and 325 lb N/acre/year. The four N treatments received 100 lb N as ammonium nitrate broadcast in early September. The latter three treatments then received supplements of ammonium nitrate or calcium nitrate in the spring. All fertilizer events were followed immediately with furrow irrigation (about 30 lb N/acre/year was added by the irrigation water). The fertilizer treatments were initiated in 1983 and have been maintained since then.

Blossom inoculations. To determine the effect of N fertilization on brown rot in blossoms, on March 1, 3, 5, and 11, 1992, shoots from each treatment replicate were sprayed with a suspension of $2x10^4$ or $3X10^4$ spores/ml of *M. fructicola* and covered with both a plastic and a paper bag for 3 days to increase relative humidity and induce disease. These inoculum doses may be higher than field rates, but were used to obtain a controlled environment response. Spores (also called conidia) are the infective stage of *M. fructicola.* Inoculated shoots were pruned 3 days after inoculation and the incidence of infected stamens was recorded, using a dissecting microscope in the laboratory.

Green fruit inoculations and latent infections. To determine the effects of N fertilization on green fruit infection by the brown rot fungus, three shoots bearing several green fruit from each treatment replicate were flagged and inoculated by spraying to runoff with a 10^5 spores/ml suspension of *M. fructicola.* The shoots with inoculated fruit were covered with a plastic bag inside and a paper bag outside. Bags were removed 24 to 48 hours later. The inoculations begun on April 4 and continued until July 1, at 14- to 20-day intervals. All inoculated fruit were harvested on 13 July, surface disinfected, and incubated in plastic containers to induce decay development. Severity of disease was determined by counting individual lesions per fruit.

Natural infection and inoculation of mature fruit. During the commercial harvest time, mature nectarine fruit were collected and incubated under high relative humidity (greater than 95%) for 3 days. Lesions of brown rot per fruit were counted. Other batches of mature fruit from each treatment replicate were surface disinfected with chlorinated water (400 µg/ml), allowed to dry, and then spray-inoculated with 10^4, $2x10^4$, or $4x10^4$ spores/ml of *M. fructicola.* Inoculated fruit were incubated at 75 °F in plastic containers and the incidence and severity (number of lesions per fruit) of the disease were determined after 3 days.

Nitrogen and fruit cuticle characteristics. To examine the cuticle thickness of mature fruit, 10 fruit in each treatment replicate were collected at harvest time and, using standard histological procedures, fixed in paraffin, thin-sectioned (approx. 10 µm) with a microtome, and stained with Sudan Black (a stain specific for plant cuticles). Thin sections were observed with a compound microscope and photographed. In addition, the weights of cuticle sections (1 cm in diameter) from 50 fruit in each treatment replicate were determined. A chemical procedure was used for isolating the cuticles (Holloway, 1968).

Nitrogen and brown rot on dropped fruit and overwintering mummies. Brown rot incidence on fruit dropped on the ground was recorded on 8 July and on hanging mummies on December 9, each on three trees per nitrogen treatment replicate.

RESULTS:

Blossom inoculations. Inoculations of blossoms on March 1 showed a trend towards increased levels of stamen infection with increased nitrogen fertilization levels (Table 1). However, inoculations at full bloom (on 3 March 1992) definitely indicated that great numbers of stamens were infected in blossoms from the high nitrogen levels (175-325 lbs/acre) than in blossoms from trees fertilized at lower rates (100 lbs/acre) or not fertilized at all. Blossoms from unfertilized trees always showed the lowest levels of infection. Not much infection occurred in stamens after inoculation on 11 March. Blossoms contained 2.93, 3.13, 3.15, 3.06, and 3.05% nitrogen and 0.35, 0.28, 0.26, 0.29, and 0.29% Ca, respectively, from trees fertilized with 0, 100, 175, 250, and 325 lbs ammonium nitrate per acre.

Green fruit inoculations and latent infections. Results of green fruit inoculations, combined over all dates, showed a positive correlation between incidence of infected fruit and N fertilization. Fruit from trees treated with high N rates, inoculated on April 4 and 24, May 1 and July 1, had significantly higher incidence of brown rot. Fruit inoculated on May 21 and June 3 and 16 showed trends toward higher incidence of brown rot on fruit from trees with higher N treatment levels, but the differences were not significant. Analysis of variance for overall results of inoculations showed a curvilinear relationship between incidence of infected fruit and nitrogen fertilization (Fig. 1).

Inoculations of mature fruit. Increased nitrogen fertilization also resulted in increased levels of brown rot incidence in mature fruit (Fig. 2). Regardless of the N levels, the highest spore concentration resulted in the greatest number of lesions per fruit.

Effects of N fertilization on fruit cuticle characteristics. The cuticle weight of fruit from the unfertilized control was greater than that from trees fertilized with 100 to 225 lb N/acre/year. In addition, thin sectioning indicated that cuticle thickness decreased as N fertilization increased. High N fertilization results in denser tree canopies, which shade fruit. Shading has been reported as the cause of thinner cuticles in many plants. It is possible that excessive shading of nectarine fruit in the high N treatment trees prevented the development of nectarine fruit cuticles.

Nitrogen and brown rot on dropped fruit and hanging mummies. Tests using overwintering mummies showed similar results, with positive correlations between higher N treatments and infections of *M. fructicola* in both dropped fruit on the ground and numbers of mummies hanging on the trees. The smallest number of mummies hung on unfertilized trees (Fig. 3).

DISCUSSION:

Our results suggest that N fertilization affects incidence of brown rot disease at all stages of the disease cycle (blossom infection, green fruit latent infection, mature fruit infections, and postharvest infections). Because reduced levels of N fertilization in general reduced brown rot disease, it could be possible that stone fruit growers to reduce brown rot with the a proper, conservative fertilization schedule. This study could serve as an incentive for growers to reduce the amount of N fertilizers applied to stone fruits. In accompanied studies in the same Fantasia block, Drs. R. Johnson (horticulturist) and K. Daane (entomologist), both at Kearney Agricultural Center, showed that applying higher rates of N fertilization did not increase yields but it increased levels of peach twig borer damage. Furthermore, the higher rates of N reduced fruit red color and increased the possibility of leaching nitrates into the groundwater. Reducing disease with reduced N fertilization is an alternative approach to conventional fungicide control.

Although levels of disease in the field are influenced mainly by spore inoculum present in the orchard and environmental conditions, this study showed that incidence of disease can also be affected by nitrogen fertilization. Levels of infected fruit increased linearly with increasing nitrogen fertilization. Similarly, N fertilization affected levels of postharvest brown rot of both inoculated and noninoculated fruit in 1991, 1992, and 1993 (Michailides et al, 1993). Therefore, the shelf life of stone fruit can be affected by N fertilization rates applied in the field.

The mechanism of blossom susceptibility with increasing N rates is not known. Analyses for nitrogen content of blossoms showed no clear relationship between N fertilization and percentage of N content in blossoms. Although increased rates of nitrogen amended in agar media increased the growth, sporulation, and spore germination of *M. fructicola* pathogen (Michailides & Johnson, 1991, Michailides et al., 1993; Ramirez, 1993), such relationship was not found in inoculated blossoms. In contrast, the thinner cuticle of fruit from trees fertilized with the high N rates can explain their higher susceptibility to brown rot. Biggs and Northover (1989) and Adaskaveg et al. (1991) showed that susceptibility of stone fruit is affected by epidermal or cuticle characteristics of cherries and peach fruit, respectively. In addition, Michailides et al. (1994) showed that prune fruit are infected by *M. fructicola* in contact surfaces where cuticle of fruit is thinner (Michailides et al., 1994). Therefore, Fantasia nectarines from trees fertilized with high N rates were infected easier and decayed more by *M. fructicola* than fruit from trees not fertilized or fertilized with low N rates because the latter had thicker cuticles. Thick cuticle can act as barrier to penetration by *M. fructicola* in stone fruits.

Nitrogen fertilization can also influence the effectiveness of preharvest fungicide sprays in reducing brown rot in the field. In other studies, it was shown that, although the effects of preharvest sprays in reducing brown rot in the field were not clear when sprays were applied on trees fertilized with the high-nitrogen rates, all preharvest sprays reduced brown rot disease in trees receiving the low nitrogen rates (Michailides et al., 1993 & 1994). It is possible that less vegetative growth of trees fertilized with 0-100 N lbs/acre allowed for a better coverage of the fruit by the sprays. However, all the sprays significantly reduced postharvest brown rot on both inoculated and noninoculated fruit.

In conclusion, nitrogen fertilization influences the biology of the brown rot pathogen, the overall disease development in the field and postharvest, and the effectiveness of fungicide applications.

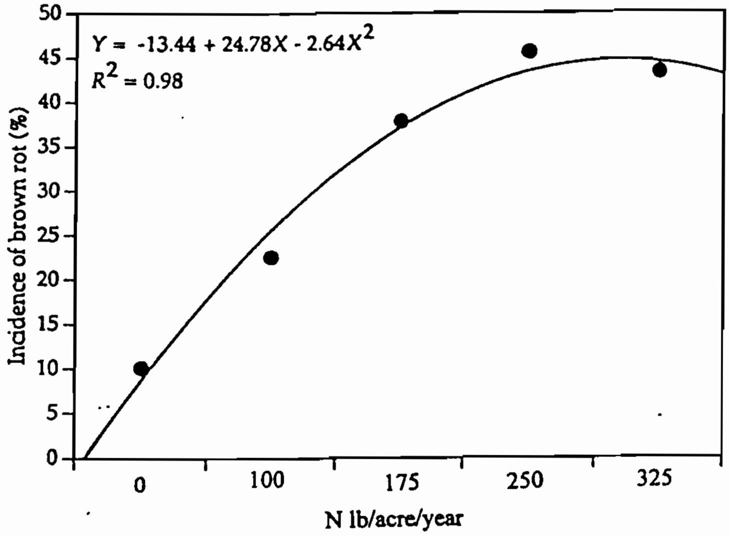

Figure 1. Effects of nitrogen fertilization on brown rot incidence of mature fruit from the development of latent infections after inoculation on 4 and 24 April, 1 and 21 May, 3 and 16 June, and 1 July. Points represent the average of 315 replicate fruits.

Fig. 2

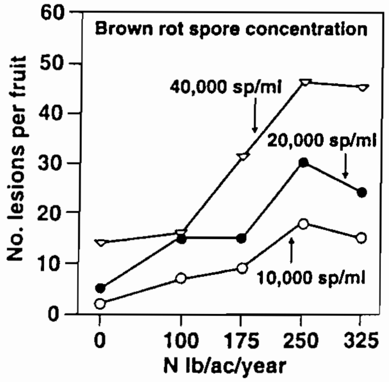

Fig. 3

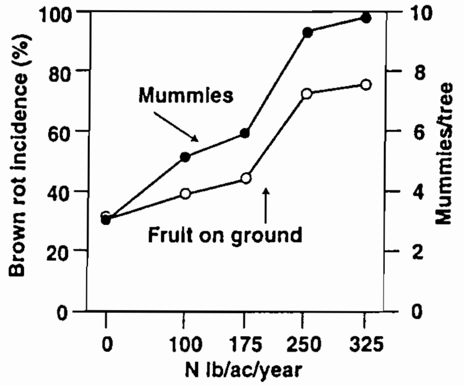

Figure 2. Effects of nitrogen (N) fertilization treatments and spore concentration of *Monilinia fructicola* on infection of mature 'Fantasia' nectarines.

Figure 3. Effects of nitrogen (N) fertilization treatments on brown rot developed on fruit dropped on the ground and the number of overwintering mummies hanging on 'Fantasia' nectarine trees.

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FIELD OBSERVATIONS OF CROP PRODUCTION UNDER PEST PRESSURE - GROWER STANDARD VERSUS CONTROLLED RELEASE NITROGEN

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INTRODUCTION:

Crop fertility programs dealing with source, placement, rate and timing of a practice, can have a profound effect on plant vigor, yield and quality. In some cases, observation and/or measurement of changes in pest populations as a result of a fertilizer practice have resulted in a change in yield. It is the purpose of this presentation to site a few examples of pest and fertility interaction and to present some general observations from controlled release soil applied nitrogen compared with growers standard practice in field.

Pest populations have reported to have been altered with either soil or foliar application of urea to a crop. Dr. Michael McKenry (et al.,1992, 1995), Nematologist at the University of California Kearny Agricultural Field Station, has measured reductions in nematode populations when soils were drenched with a urea solution. A soil drench three times per year on Cabernet Sauvignon Grapes with urea solution significantly reduced Root Knot, Dagger and Citrus Nematode populations compared with un-treated areas(1). An integrated crop management project on citrus (California Agriculture 1990) with more than thirty (30) university personnel in association observed interaction of foliar nitrogen in (a) reduction in mite populations (b) reduction in phytophthora incidence and (c) increased thrip populations(2). Dr. Carol Lovatt, Associate Professor of Plant Physiology at U.C. Riverside, (et. al., 1994) found a high degree of variability in population of citrus thrip among foliar low-biuret urea treated citrus versus untreated to be non-significant(3). However, in two years of studies, with May foliar urea sprays, resulted in a significant (10% level) reduction in citrus thrip scarring.

FIELD OBSERVATIONS

Measurements of crop response with soil applied controlled release nitrogen from both small plot subplot replicated harvest and large scale commercial harvest have shown controlled release nitrogen to generally out yield grower standard nitrogen programs. As a “side light” in the past four years, controlled release nitrogen has shown positive increases in yield under pest pressure. The controlled release nitrogen is a polymer coated urea, trade name Duration® manufactured by Sherritt, Inc. of Canada. The primary factor which controls nitrogen release from the polymer coated urea is temperature. This factor often follows growth as temperature increases, release growth rate increases as generally does crop need for nitrogen.

The controlled release nitrogen is applied as a dry product, usually preplant banded at approximately 80% of the growers standard nitrogen program. Depending on tissue levels of nitrogen and/or crop appearance additional nitrogen as a water run is applied late season to finish the crop.

Well over 300 tests infield side by side comparisons, many several acres in size, have been completed. The controlled release nitrogen was compared to growers standard nitrogen program evaluating yield and quality in replicated subplot harvest and comparative commercial harvest.

While evaluating controlled release nitrogen on lettuce, differences in *Sclerotinia spp.* damage were noted. *Sclerotinia sclerotiorum* is a fungus which causes a severe wet rot of lettuce. It reproduces in soil planted to susceptible crops (ie. lettuce, tomatoes, cabbage and celery). During wet conditions the disease increases with the development of rotted plant parts. Percent wilt was the only measurement of disease incidence in these tests as the main thrust was yield and quality. Table (1) contains the results from ten (10) field trials indicating reduced *Sclerotinia spp.* in lettuce with controlled release nitrogen versus grower standard nitrogen. Percent wilt was the only measurement of disease incidence in these tests, as the main thrust was yield and quality. There was a 68% reduction in *Sclerotinia spp.*

In the Santa Maria California area 1992, increased lettuce yields were noted with controlled release versus grower standard nitrogen in a field severely infested with "Corky Root" along with a light infestation of *Sclerotinia spp.*. Corky root disease is caused by a bacterium *Rhizomonar suberifaciens* (infectious corky root). Symptoms include roots with yellow discoloration and broad corky areas. The Duration (C.R.F.) Was applied 7/7/92 at 300 lbs. N/acre preplant. When the "Corky Root" incidence was noted to be severe both the grower standard and Duration area received additional water runs of nitrogen. Frequent applications of nitrogen is often practiced as a rescue treatment for severe conditions. A "side line" observed to the original purpose of the study was a reduction in *Sclerotinia spp.* incidence (Table 2) and an increase in larger heads probably due to some improvement in N feeding a restrictive root system ("Corky Root") (Table 3). Conflicting reports exist in the literature as to the relationships between certain forms of nitrogen and corky root disease in lettuce. There have been reports of corky root disease increases under high nitrogen.

Chardonnay Grapes in the Paso Robles California area were sidedressed banded to 8" depth on 3/11/94 with Duration at three rates of nitrogen. The established vineyard was at least 12 years old, grown on a clay soil under drip irrigation. A high incidence of phylloxera in the field reduced growth substantially. Phylloxera is an aphid like insect that attacks grape roots and causes stunted growth and vine death. A rescue treatment of a total of 240 lbs. Nitrogen per acre as UN-32 applied periodically through the drip irrigation system became grower standard for this problem field. In late August at harvest percent sugar, clusters of grapes per vine and pounds of grapes per vine were compared (Figures. 1,2,3). An increase in yield from Duration resulted from 103 lbs. N, 192 lbs. N, 240 lbs. N as Duration, a 95% to 155% increase over standard grower soluble nitrogen. The increase in yield from Duration may be due to nitrogen being present in higher quantities in the root zone (reduced root effectiveness due to phylloxera). Soil samples taken 38 days after application at 1,2 and 3 foot depths and analyzed for nitrate nitrogen displayed higher soil levels in two of the three Duration treatments (Table 4).

A two year study was conducted in King City on Chardonnay grapes to determine the effect of high rates of controlled release urea nitrogen on the control of grape phylloxera applied in the month of March in 1994 and 1995. The product was applied using a Clamco side-dress applicator.

In March of 1994, two different release rates of Duration were applied to reduce the population of grape phylloxera in a vineyard in the King City area. The three treatments are as follows:

1. Duration T-180 at 240 lbs. Nitrogen/acre, 18" from vine banded 10"-12" depths.
2. Duration T-270 at 240 lbs. Nitrogen/acre, 18" from vine banded 10"-12" depths.
3. Growers Standard Practice.

Presamples of grape roots were taken to determine if similar pest pressure were present among treated areas. The samples were taken by digging up 12" of a live grape root, the diameter for all roots taken ranged from .25" to .50". The roots were then examined for phylloxera using a hand lens and all phylloxera were counted and recorded. In the month of October, a second sample was taken using the same methods. All samples were then recorded and analyzed using the statistical analysis according to Little and Hills. The results from the 1994 data showed a significant reduction (P=0.0031 of phylloxera in treatments 1 and 2 over the GSP. The study was conducted again in 1995. The same treatments were used and laid over the previous years treatments. The same design was used and sampled accordingly to the previous years test. The results were analyzed and reported. In 1995, the treatments of 1 and 2 were numerically lower than the GSP, but no significant differences were found (Figure. 4).

In conclusion, this two year study shows that heavy populations of phylloxera can be reduced by heavy applications of urea based fertilizer, but it is felt by the researcher that control was not obtained. Yield results are pending for 1995.

SUMMARY

As a side line to controlled release nitrogen field studies, increased yields under pest pressure was noted. Duration controlled release nitrogen has preformed well in over 300 field tests under "more normal" field production conditions (low or no soil pest pressure), and is currently marketed by Western Farm Service on a number of crops.

Table 1. Summary of percent wilt of lettuce as a measure of Sclerotinia damage. Coastal California - 1993-1994.

*PERCENT WILTED LETTUCE HEADS

TEST	DUR	GSP	RATIO GSP/DUR
Watsonville Test 1	7.1	11.8	1.66
Watsonville Test 2	7.1	13.9	1.96
Watsonville Test 3	2.0	4.0	2.00
Salinas Test 1	4.6	6.1	1.33
Salinas Test 2	1.8	5.5	3.05
Salinas Test 3	21.1	24.4	1.16
Salinas Test 4	4.0	7.8	1.95
Santa Maria Test 1	4.8	8.4	1.75
Salinas Test 5	1.1	7.7	7.00
Santa Maria Test 2	2.1	4.3	2.05
Average	**5.6**	**9.4**	**1.68**

* This represents 68% higher incidence in grower's standard fertilizer programs than in Duration fertilized fields; Duration demonstrating an advantage in 100% of the tests with an incidence of *Sclerotinia.* 1000 heads counted per treatment, 4 replications.

Table 2. Number of lettuce heads displaying symptoms of *Sclerotinia.* Santa Maria 1992.

*REP	1	2	3	4	5	6	7	8	9	10	**Tot/1000**
GROWER STANDARD	4	4	9	16	4	4	7	8	5	7	**68**
DURATION	7	5	4	4	9	8	7	4	4	6	**58**

* 100 heads counted per rep.

Table 3. Lettuce head size distribution in severe corky root infestation - 1992 Santa Maria.

TREATMENT	24'S	30'S	BULK	24'S + 30'S
Duration	33.3	60.0	6.7	93.3
GSP	6.7	73.3	20.0	80.0

Table 4. Soil Nitrate Levels Chardonnay Grapes - Sampled 4/21/94

	PPM NO3-N IN SOIL			
DEPTH	GSP 240 #N/A	DUR 240 #N/A	DUR 192 #N/A	DUR 103 #N/A
12"	8 L	13 M	9 L	6 L
24"	6 L	15 M	11 L	6 L
36"	7 L	16 M	9 L	6 L
TOTAL	**21**	**44**	**29**	**1**

Figure 1.

PRGR94.01
Percent Sugar
Chardonnay Grapes

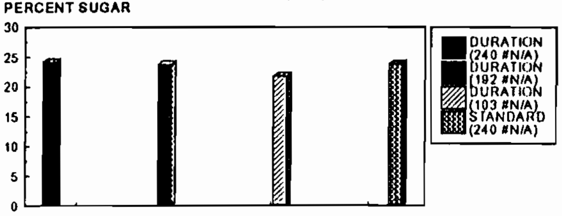


Figure 2.

PRGR94.01
Grape Clusters Per Vine
Chardonnay Grapes

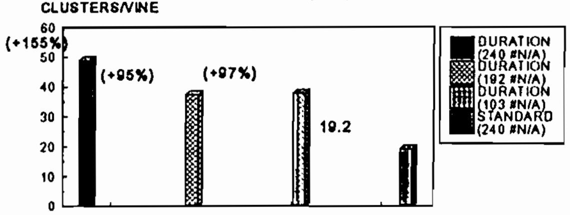


Figure 3.

PRGR94.01
Pounds Grapes Per Vine
Chardonnay Grapes

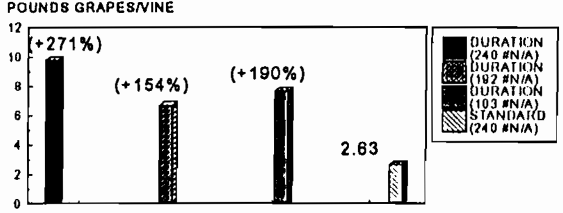
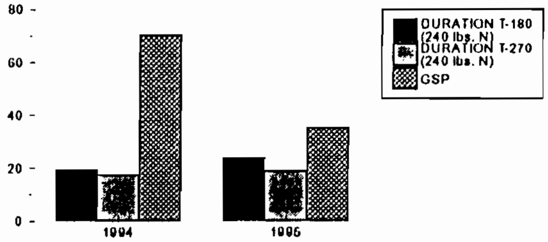


Figure. 4

PHYLLOXERA STUDY 94' & 95'



The presample average was 75 phylloxera per 12" root. The study was a Randomized Complete Block design, three treatments with 10 replications per treatment. Each replication consisted of five 12" roots. Results followed by different letters are significantly different (DMRT P=0.05)

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BENEFICIAL WEED CONTROL IN COLE CROPS, ONIONS, GARLIC AND OTHER CROPS USING VARIOUS NITROGEN FERTILIZER MATERIALS

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INTRODUCTION:

Various fertilizer materials have been used to aid in crop management in ways other than strictly as nutrient sources. Zinc sulfate with and without liquid nitrogen solutions has been used as desiccant/defoliant in trees and vines to induce early leaf fall while at the same time providing an infusion of zinc, sulfur, and/or nitrogen into fruit wood for the following season. Ammonium thiosulfate, and urea sulfuric acid have been successfully used as bloom thinners on both stone and pome fruits with relatively good success as replacements or alternatives to dinoseb (DNOC) containing materials such as Elgetol. Urea, ammonium sulfate, UAN Solution, phosphoric and urea-sulfuric acids are regularly included in pesticide sprays as acidifiers and carriers which enhance uptake and/or activity of herbicides, fungicides and insecticides. Perhaps the most common and widely practiced, is the use of nitrogen or nitrogen-phosphorus-sulfur fertilizer materials for desiccation of seedling weeds in row crops including onions, garlic, broccoli and cauliflower, more occasionally in dormant alfalfa, orchard floors, and for potato vine desiccation.

Much of the development work is attributable to University and Extension researchers and farm advisors in their efforts to optimize inputs and find alternatives to use of pesticides which may be hazardous to the environment and/or workers, and to replace pesticides which are no longer available; a good example being substitution of 20% ammonium nitrate solution for nitrofen (Tok) for weed control. Pioneering work using ammonium thiosulfate and urea-sulfuric acid for bloom thinning of pome and stonefruits has been carried out by researchers including R.E. Byers, Virginia Polytechnic Institute and State University, S.C. Myers, University of Georgia, Athens, and M.W. Williams, USDA/ARS/PWA, Tree Fruit Research Laboratory, Wenatchee, WA. Development and perfection of using ammonium nitrate solution in row crops is largely attributable to work by H. Agamalian and others associated with the University of California, Cooperative Extension Service. Development of the use of urea-sulfuric acid on onions, garlic and potatoes, was the result of modification of use of sulfuric acid, which dates back as one of the earliest chemical desiccants used in modern agriculture. Credit for development of use of such materials under localized regional conditions also goes to various industry agronomists and of course, the growers themselves.

The focus provided here is review of use parameters, performance of nitrogen containing solutions as desiccants, as well as review regulatory requirements and interpretations of those uses, and consideration of the approach by basic manufacturers and local suppliers.

Regulatory Considerations:

The intent in using fertilizer materials as herbicide/desiccants was to achieve the desired effect(s) in the absence of available registered pesticides, or as alternatives to highly regulated and potentially hazardous materials such as concentrated sulfuric acid, paraquat and dinoseb. The assumption often made has been that products not registered or recognized as pesticides did not fall under regulatory authority. Such an assumption is inconsistent with Federal USEPA FIFRA (7 U.S.C. 136-136y), 40CFR Part 152.15 and others, and California 3CCR sections 6000 and 6145 and others, addressing "economic poisons" and pesticides which include the definition as; "...(1) any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest, and (2) any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant...", and consistent with State regulations which define a pesticide or economic poison as stated above take the position that "a substance is considered to be intended for pesticidal purpose, and thus to be a pesticide requiring registration".

Federal and State definitions of pesticide and requirements for registration are consistent, specific, and intended to include any material used for pesticidal purposes. However, with respect to fertilizer materials which may impart pesticidal activity, this author's practical interpretation after discussions with CalEPA, Department of Pesticide Regulation (DPR) is that if the PRIMARY intent of material use is appropriate and consistent with good agronomic (fertilizer use) principles, then incidental additional benefits of pest control are not of significant concern as long as worker and crop safety are not compromised. However, ANY promotion, advertising, written recommendation or claim of pesticidal performance made by a manufacturer, supplier, Pest Control Advisor, etc. of a fertilizer product for pesticidal purposes will trigger regulation under the above listed Federal an State pesticide regulation codes.

Several examples are relevant. The use of ammonium nitrate 20% solution (AN 20) sprayed on bed tops of row crops during appropriate fertilizer application periods, at rates consistent with good agronomic practices and with accompanying ancillary vegetation suppression is generally considered acceptable. Similarly, surface application of sulfuric acid, urea-sulfuric acid, phosphoric acid or combinations of those to row, field, orchard or vineyard crops for the purpose of fertilizing, improving water penetration, or reducing surface crusting with ancillary vegetation suppression appears acceptable. The primary purpose of such applications is other than weed control. Examples of questionable "fertilizer" uses include foliar application of hydrogen cyanamide on dormant trees or vineyards, or use of phosphorus acid as foliar nutrient sources. The primary intent of use of such materials has been interpreted as pesticidal in nature and of little plant nutritional value.

Several attempts have been pursued by manufacturers to acquire registration of fertilizer materials where clear pesticidal activity has been observed. Those attempts have generally resulted in long, expensive, and often unrewarding intercourse with regulatory agencies, with the end result being imposition of inappropriate and extreme toxicological testing and highly limiting restrictions on material use, and no viable means to extract a premium for the product to recoup the incurred expenses of registration.

The following examples of appropriate surface applications of fertilizer materials are provided with the admonition that those uses may or may not fall within realm of regulated materials, and performance other than as a nutrient source is not recommended, guaranteed or acknowledged by producers or suppliers. Such uses are under the sole purview of growers who may be without recourse if incidental results are less than or different from the expected.

Materials:

Fertilizer liquids including urea ammonium nitrate (UAN 28, 30 and 32% N), ammonium thiosulfate (12-0-0-26S), urea-sulfuric acid (15-0-0-16S), ammonium nitrate (20% N), and even aqua ammonia (20% N) have been evaluated for use as vegetation desiccants. Of those, the most commonly used material in certain cole crops including cauliflower and broccoli is ammonium nitrate solution (AN 20), while urea-sulfuric acid (USA), is commonly applied to onions and garlic for weed control, and to potatoes for vine desiccation. It should be noted that outside California, USA is EPA registered on certain crops as a herbicide/desiccant. Probably the most significant use of ammonium thiosulfate is for blossom thinning in stone and pome fruits at relatively high dilution and low per acre application rates. Bloom thinning of Rosaceaus fruit has also been accomplished with USA which is an EPA registered product, again outside California. EPA Registration of fertilizer based products further obfuscates the issue of the definition of fertilizer and pesticide and make intention of the user paramount in evaluation of the need for regulatory or enforcement actions.

Ammonium nitrate 20% solution (AN 20):

The use of AN 20 has become quite common where directed band application treatments are made to broccoli and cauliflower when plants are a minimum of two to three true leaves in size. Application is made at 50-70 gallons per acre, applied at low pressure (10-15 psi) with flat fan nozzles, directed into the drill row and toward the base of the plants. Over the top broadcast applications have resulted in unacceptable crop damage due to collection of fertilizer in the developing whorls and desiccation of sensitive bud tissue. Irrigation in such plantings is by sprinkler usually following within 48 hours of treatment, with the result being application of 100-150 pounds of readily available nitrogen in the planted row. Such applications are in place of rather than in addition to alternative nitrogen applications and are considered to be good agronomically sound practice.

Susceptible seedlings (of both crops and weeds) contacted by the AN 20 solution are desiccated with a variable percentage not surviving the treatment. Succulent broadleafs are more susceptible to desiccation while grasses, plants with protected growing points and species with waxy cuticles are not controlled (Table 1).**

A significant consideration is degree and condition of the cuticular layer. Selective activity is dependent upon variable plant resistance to wetting and osmotically induced desiccation. Crops normally containing a waxy cuticle such as broccoli and cauliflower may be damaged by fertilizer spray if the cuticle has been altered by the recent (within 72 hours) application of surfactant, mechanical abrasion (wind blown soil) or insect damage (thrips). Degree of protection provided by the cuticular layer varies depending on season, with cool season plantings being more susceptible to spray damage than those treated during warmer periods.

Under most circumstances, some crop damage is caused by the fertilizer spray. Reduction in stand, vegetative growth, as well as damage to flowers or growing points may carry through as yield reductions and/or delayed maturity. There is often some tradeoff as is usual where chemical applications are made. In the case of broccoli and cauliflower topical in row application of AN 20 has been deemed to be an acceptable and efficient fertilizer practice as well as an alternative to hand weeding in the absence of available post emergence herbicide products.

Other materials including USA and ammonium thiosulfate (ATS) have been evaluated for use on broccoli and cauliflower with mixed results. While both have been successfully used for seedling weed desiccation, material availability, cost, and equipment compatibility considerations have resulted in AN 20 being the favored material. However, combinations of AN 20 and ATS have been successfully used to obtain greater flexibility of fertilizer type and rate while at the same time improving vegetation burn down. Several AN 20/ATS combinations are currently available from suppliers, which optimize fertility and weed burndown benefits.

Urea-sulfuric acid:

Urea-sulfuric acid (USA) has been commercially available in the western U.S. for approximately 15 years. Originally developed as an acid fertilizer for use on alkaline calcareous soils, it soon became evident that application to undesirable vegetation provided very rapid desiccant activity in addition to the residual benefits of the contained nitrogen and sulfur.

Temporary unavailability or termination of certain herbicides used in onions led to the resurgence of interest in sulfuric acid for herbicide purposes in the early 1980's. The inherent dangers associated with sulfuric acid led industry agronomists to evaluate USA as an alternative. Selectivity of mineral based acidic materials is similar to AN 20 in that resistance to damage from exposure is based on the presence of a waxy cuticle and growth habit, such as is found in members of the onion family and certain brassicas as mentioned above. It was discovered that USA could be used in a manner similar to sulfuric acid for vegetation management in onions and other waxy crops without the same degree of hazard.

Combining urea with sulfuric acid substantially reduces the danger of the contained acidity making USA significantly safer to handle and apply. The combination of increased safety of handling and vegetation burn down features led to extensive testing of various formulations of USA for herbicide, desiccant, anticrustant, irrigation water treatment, and fertilizer uses. Among the most successful has been use in onions for weed control and on potatoes for vine desiccation prior to harvest.

A significant difference between USA and AN 20 is that USA requires lower use rates but higher application pressure to obtain adequate coverage. With either product, activity is based on coverage of the target species, since neither material provides systemic activity. Effective use of USA requires application of 15-25 gallons per acre (as compared to 50-70 gal/a for AN 20) applied at a nozzle pressure of 40-50 psi. Dilution is necessary only to the extent that treated foliage is adequately covered, with the usual total spray volume being in the range of 25-40 gal/a.

The high application pressure requirement needed to achieve coverage precipitated two problems. The growth habit of broadleaf crops such as broccoli could trap the spray solution in whorls and other sensitive tissues resulting in excessive crop damage. However, onions were not similarly affected to the extent that use was considered excessively risky. Also, equipment requirements for applying a corrosive material at high pressure were such that commonly available spray equipment was not usually compatible or suitable.

Use of USA as a pre-harvest desiccant on potato vines has also been quite successful. Nonselectivity of USA can be enhanced by the use of nonionic surfactants to increase the rate and broaden the spectrum of tissue desiccation. Rapid and thorough desiccant activity under both warm and cool weather conditions allows precise scheduling of harvest. Since many potato growing regions have historically applied sulfuric acid as a desiccant, equipment compatibility has been a manageable issue. Increased safety and a lower degree of regulation, combined with residual fertilizer value have led to significant use for desiccation of vines and weeds. It should be noted that one manufacturer of USA was successful in obtaining EPA and state registrations for use as a herbicide/desiccant on onions, potatoes and several other crops. California however, is not included in those registrations.

There are numerous other potential and realized uses of fertilizer materials in crop management. It is unfortunate that regulatory definitions rather than practical considerations have limited the promotion and wider use of fertilizer products as substitutes for often more toxic and environmentally offensive pesticide materials. If the political and regulatory pendulum swings back toward less rigidity and greater practicality, perhaps the use of fertilizers which do more than fertilize may become a more common and less restricted practice.

**Table 1. Weed susceptibility to liquid ammonium nitrate at two stages of growth--summary of 13 field experiments.

Weeds	Control*	
	1-4-leaf	5-7-leaf
	%	%
Annual bluegrass	0	0
Barnyardgrass	0	0
Black mustard	92	47
Burning nettle	5	65
Chickweed	97	51
Common groundsel	98	68
Hairy nightshade	96	72
Lambsquarters	0	0
Little mallow	99	77
London rocket	95	54
Nettleleaf goosefoot	0	0
Pineapple weed	98	62
Purslane	0	0
Redroot pigweed	96	58
Shepherds-purse	95	41
Sowthistle	32	0

* Determined from counts of weed per 2 square feet.

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CEPRAP, Using Biotechnology to Improve and Protect Plants

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Paper not submitted in time for inclusion in Proceedings.

COMMERCIAL TRANSGENIC PLANT PRODUCTS, FOOD SAFETY

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In the past two years, we have seen transgenic varieties move from research and development to the market place. As of October 1995, at least eight transgenic plant products have been commercialized, and an additional number will be introduced in 1996. What steps must their developers take to demonstrate safety and obtain regulatory clearances needed for commercialization? One of the key requirements is evaluation of food and feed safety, in compliance with the 1992 FDA Statement of Policy: Foods Derived from New Plant Varieties. The FDA policy states that regulation of new food varieties will be the same as they are for all other foods, with no routine premarket approval; however, the developer of the new variety remains responsible for ensuring safety, and consultation with FDA is strongly encouraged. The policy also establishes the concept of substantial equivalence: demonstration of equivalence with known characteristics of the plant which has been modified, or "a genetically engineered tomato is still a tomato." This presentation describes elements of the FDA policy and provides examples of how the policy has been applied to transgenic plant products.

Consumer Perception and Acceptance of Biotechnology

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Biotechnology is a general term for several techniques which use living organisms to make or modify products for a specific purpose. Consumer attitudes toward biotechnology are generally positive, however some questions and concerns exist.

A United States nationwide study found that 67% of the public believe they will benefit from biotechnology in the next five years (Hoban and Kendall, 1992). Among Canadian consumers, about two-thirds expect society will receive benefits from biotechnology, and the same proportion believe that society will also be at increased risk (Walter, 1994). Most Australians believe genetic engineering is a "good idea" with as many as 90% supporting medical and environmental and about two thirds supporting food and nutritional applications (Kelley, 1995)

It is natural to express concern about potential risks from a new technology. In 1906 Luther Burbank expressed concern about the technique of cross-breeding considered routine today:

> "We have recently advanced our knowledge of genetics to the point where we can manipulate life in a way never intended by nature. We must proceed with utmost caution in the application of this new found knowledge."

Similarily today some people don't want change, don't realize plant and animals have changed over the centuries, and are skeptical of a technique they don't understand. Consumers are not familiar with the concept of transferring genes from one organism to another and therefore view it as potentially risky. Other people trust scientists and regulators, and embrace change if there are personal or environmental benefits.

Acceptance of the concept of gene transfer is much lower when not tied to a specific goal. People consider risks and benefits in making decisions. In the United States over 60% of consumers considered acceptable the use of biotechnology to make cotton plants resistant to damage from weed control chemicals. Use of biotechnology to help farm animals resist disease was acceptable to about 50% of the sample, and was more acceptable than the general use of crossbreeding to improve animals. People are most aware of the potential positive effect of rDNA technologies on farm economics, food quality, nutrition, and the environment.

People want assurance that human safety, specially potential risks from food allergies, have been addressed and product safety is assured. FDA has proposed a policy which addresses the safety of biotechnology-modified products, including allergens, however this is seldom presented in media reports. Some consumers fear this policy may not be adequate because they believe they are allergic to a food the FDA does not recognize as an allergen.

The belief that a person suffers from food allergies is greater than actual occurrence, according to Dean Darrel Metcalfe, National Institute of Allergy and Infectious Disease. He notes that about one person in three thinks he/she has food allergies, however in double-blind tests, less than three percent of children and less than one percent of adults actually have food allergies. Scientists believed the allergy issue is pertinent to food in general, not just food modified by biotechnology. They recommend that allergens be addressed by the scientific community.

The transfer of genetic material from a food known to cause allergies is strictly regulated. Actually, techniques of biotechnology offer the long term potential of producing new allergen-free versions of common foods. Rice without a common allergen has been developed through these advanced techniques.

Environmental quality is also a consumer concern. About 20% of consumers fear that modification by biotechnology disrupts nature and unforeseen consequences could ensue. Many people do not recognize that humans have modified nature for centuries and all domestic plants and animals today have been modified by selective breeding.

Surveys indicate people are more accepting of plant to plant transfers, than animal to animal transfers and are most concerned about cross-species transfers. People are not familiar with the details of rDNA technology and do not recognize that living organisms use the same code chemicals and many of the same code sequences. They do not understand how much is transferred when genetic material is taken from one organism and inserted into another. People are most uncertain about cross species transfers because they fear that essential, unique characteristics are being transferred.

Ethical concerns relate to applications of biotechnology to animals. People are concerned about treating other creatures humanely and are sensitive to allegations that animals may be exploited to serve human demands. There are numerous applications of rDNA which will enhance animal health and well-being, but these are seldom discussed in the media and never mentioned by those opposed to biotechnology.

Response to products modified by rDNA technology and available in the United States market is positive:

Chymosin

Produced by rDNA technology, this enzyme is used for 50% of more of the cheese produced in the United States. Consumers are generally not aware of this enzyme, however in some areas it is marketed as vegetarian.

rBST in milk production:

- Sales of milk appear to be unaffected by adverse publicity generated by activist groups. During the last year, per capita milk consumption has increased 1.2%. (Carlson, G., 1994)
- Sales of milk labeled "BST-free" in Wisconsin are slow, according to retailers (Carlson, 1994). Sales of Land-O-Lakes certified rBST free product, priced 10 to 12 cents more per half gallon, are 5% of their fluid market. (Personal communication)
- Consumers Union withdrew its claim that milk from treated cows poses a health risk to humans. (March 22, 1995)

- It is estimated that 15% - 18% of cows nationally received rBST in 1994. The increased production efficiency made possible by use of rBST is estimated to give dairy producers a profit of $90 to $250 per cow per lactation, with the amount varying by dairy region. (Fetrow, 1995)
- In California in 1994, 20% of producers reported they were currently using rBST, 4% had used it in the past year and stopped. Another 22% indicated they would consider using rBST in the future. This usage represents 8.4% of the cows treated with a potential increase of 4.5%. (Butler, 1995)
- Half of the farms in New York were using or planned to use rBST within one year. (Lyson et al, 1995)

Flavr-Savr tomato

Distribution was limited due to relatively small supply. The Pure Food Campaign protested this product, but with limited press coverage. Sales in Davis, California and Chicago, were very strong. James Corrigan, owner of the Chicago establishment, Carrot Top, stated that despite the company policy of getting the best tomato available, his customers expressed a significant preference for the Flavr Savr. The product was not widely available in the winter of 1995 due to limited planting. Market penetration is slowly increasing.

The key for success is benefits. Consumers say they are supportive of environmental benefits. Less interest is expressed for improvements in flavor, however taste is the primary factor which motivates purchase. Also important to the public is the belief that those developing a technology consider its consequences.

Surveys indicate people are interested in receiving additional information about biotechnology, particularly the effects on human health. People get most of their science information from television, newspapers, and other people, and place the greatest trust in health professionals. University scientists are in the upper third on credibility and only about 5% consider activists, chefs, and supermarkets credible.

Continued acceptance of new products modified by biotechnology is great if products deliver their promise and the public continues to receive information which explains benefits and safeguards.

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EXOTIC GERMPLASM OR ENGINEERED GENES: A CASE STUDY OF GENETIC MANIPULATION IN TOMATO

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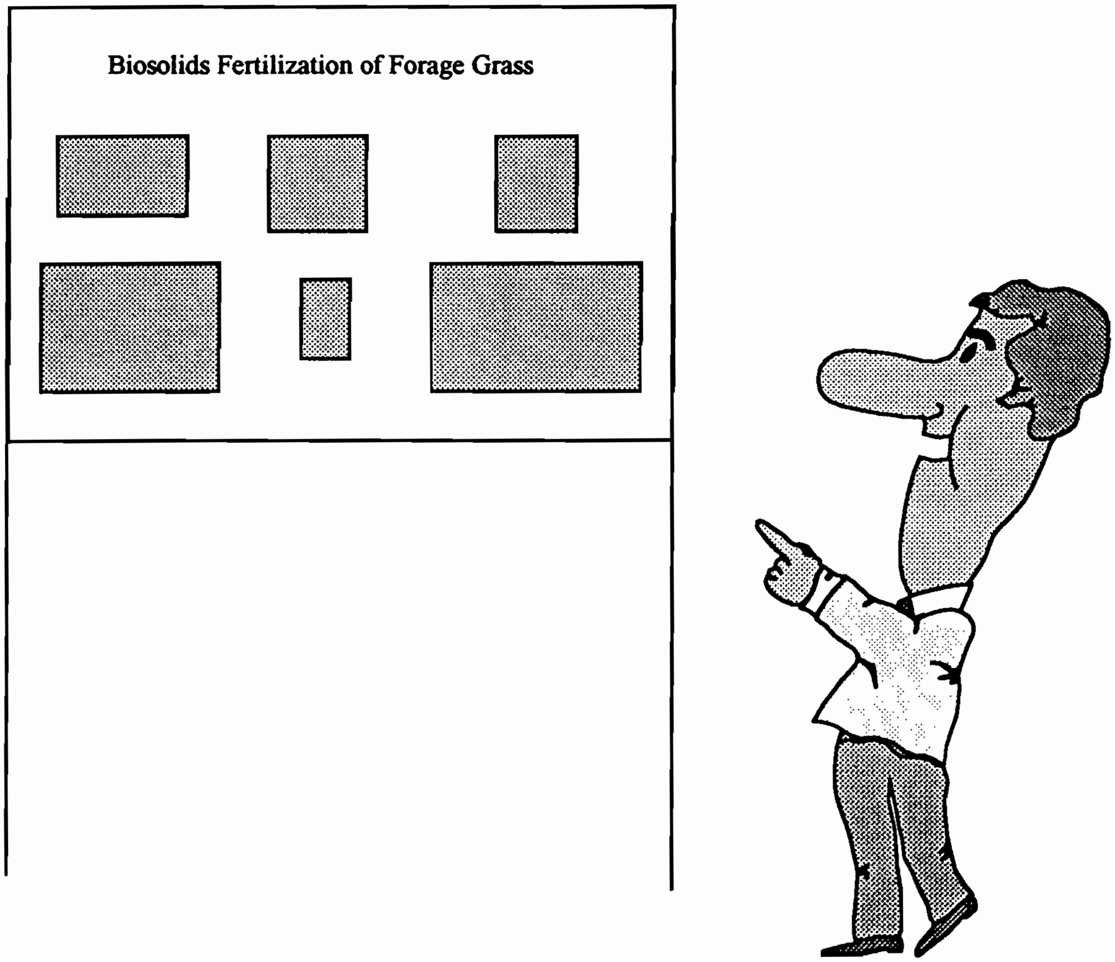
Tomato has a long history of genetic manipulation, since its first domestication in Central America and its more recent intensive breeding using wild tomato relatives to introduce new and important traits, especially as related to disease resistance. Tomato improvement is currently the focus of a great deal of molecular genetic research and, indeed, several of the first commercial genetically engineered foods will be tomato products. The most notable products have been engineered to alter ripening or carbohydrate metabolism to confer improved consumer quality.

One interesting case study in tomato improvement involves a gene which modifies sugar composition and may improve fruit quality. We introduced genes which conferred this trait by classical breeding from a wild relative of tomato or by a direct genetic engineering approach, thus providing an example to assess the extent of genetic modification that was due to the process rather than due to the trait itself. In each case, the tomato genome undergoes significant modification and in each case there is a degree of uncertainty in the structure of the final changes. The comparison suggests that genetic engineering can be legitimately viewed as an extension of classical plant breeding approaches, which greatly expands the germplasm resources available to modify crops, but which also carries its own limitations.

POSTER SESSION



Biosolids Fertilization of Forage Grass: Plant Available Nitrogen and Forage Yield

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A field study was conducted to study forage yield and plant available N content of tall fescue fertilized with biosolids (municipal sewage sludge). Biosolids were from two different urban treatment plants that meet "Class A" regulations for pathogen reduction and "Exceptional Quality" standards for unrestricted land application under EPA Part 503 rules. One was produced using a pilot drying facility (50 g/kg moisture content) and the other was produced through an aerobic/ anaerobic digestion (750 g/kg moisture content). Biosolids were broadcast after 3 cuttings for a total of 7, 13 and 20 dry Mg/ha/yr and compared with N fertilizer at 269 kg N/ha/yr. No differences were found in forage yield, N concentration, N uptake and residual soil N between biosolids sources. Under the conditions of this study, forage response and N uptake were still increasing at the highest rate. Residual soil NO_3 was low for all treatments, indicating little accumulation in the soil.

1994 Strawberry Fruit Yields as Affected by Various Control Release Fertilizers

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Control release fertilizers are used in strawberries to provide a uniform amount of nitrogen throughout the growing season. Excessive or poorly timed nitrogen applications may lower the strawberry yields and quality.

These experiments were designed to evaluate the yield potential in 1993-94 and 1994-95 of eight and twelve control release fertilizers. These trials were conducted on the variety Chandler in a strawberry field east of Santa Maria. The experimental plots received the same irrigation, pest control, and picking schedules as the commercial field.

The size of each fertilizer plot was 2 beds wide (40" per bed), and 23 feet long in 1994, and 28 feet long in 1995. The fertilizers were placed 5.5" below the bed surface in the planting slot. The fertilizer was applied on November 2 and 3, 1993, and October 28 and 29, 1994, and the strawberries planted on the same days.

The first strawberry harvest date was March 18, 1994, and the last harvest date was July 27, 1994. The 1994 for fresh fruit was picked from March to May, and yields ranged from 37,643 lbs./acre to 33,393 for the fertilized treatment, compared to the plots receiving no controlled fertilizer yielding 24,587 lbs./acre. Freezer fruit harvested in June and July for the control release fertilizers ranged in yields from 15,313 to 13,481 lbs./acre. The plots receiving no fertilizer yielded 10,198 lbs./acre. The total season yields for the control release fertilizer treatments ranged from 52,465 to 47,001 lbs./acre. The plots receiving no fertilizer yielded 34,785 lbs./acre.

The first 1995 strawberry harvest date was March 25. The fruit was picked for fresh fruit from March to early June. The 1995 fresh fruit yields ranged from 44,838 lbs/acre to 27,476 lbs/acre for the fertilized treatments, compared to the plots receiving no control fertilizer yielding 20,966 lbs/acre. Freezer fruit harvested from mid-June to July 24, 1995, for the control release fertilizers ranged in yields from 26,814 to 21,539 lbs/acre. The plots receiving no fertilizer yielded 8,204 lbs/acre. The 1995 total fruit yields for the control release fertilizer ranged from a high of 71,652 to 49,015 lbs/acre. The plots receiving no fertilizer yielded 49,015 lbs/acre.

Mycorrhizae in Weed Control and Crop Enhancement

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Vesicular-arbuscular mycorrhizal (VAM) fungi colonize the roots of most crop and weed plants. These obligately biotrophic organisms facilitate the transfer of mineral nutrients and carbon compounds between plants and soil organisms: an exchange important to sustainable agriculture both in terms of plant yield and soil stability. While the VAM-fungal soil mycelium is the major interface between plant and soil, it also serves to interconnect the root systems of adjacent plants and effects a flux of substances between them. In the past, interest in such VAM-mediated inter-plant fluxes centered on a transfer of N from legumes to nonlegumes, but sink-driven fluxes from senescent to surviving plants have also been documented. This phenomenon may be utilized to enhance herbicide effectiveness by VAM-mediated nutrient transfer from susceptible weeds to resistant crop plants.

We therefore tested the hypothesis that: 1. Weeds become sources of nutrients to crop plants in a herbicide-treated VAM crop-weed association, 2. Transfer is measurable by a movement of label from weed to crop plant, and 3. this flux results in crop growth enhancement and weed inhibition.

Soybean [*Glycine max* (L) Merr.] plants were grown in association with cocklebur (*Xanthium strumarium* L.) in high-P soil (1.5 L pots) inoculated with VAM fungi (*Glomus* sp.), or were left nonVAM as controls. A solution of 98 atom % ^{15}N (1 mL of 100 mM $^{15}NH_4NO_3$) was applied to the cocklebur leaves (7-leaf stage) to be assayed at harvest in the soybean leaves. Four days after ^{15}N application, all plants were sprayed at the rates of 0, 1/3, 2/3, 3/3 and 4/3 of field recommendation (FR, 1.1 $kg \times ha^{-1}$ active ingredient) of the herbicide Bentazon, a Hill-reaction inhibitor. Nonassociated VAM or nonVAM soybean or cocklebur plants were also tested for Bentazon effects at the rates of 0 and full FR.

Inhibition of biomass production by Bentazon was >70% in nonassociated cocklebur at full FR and <8% in soybean. VAM growth enhancement was low due to high soil P, but was higher in treated (cocklebur 22%, soybean 14%) than in nontreated (cocklebur 15%, soybean 4%) plants. In associated VAM and nonVAM soybean and cocklebur plants, the VAM vs. nonVAM difference was not significant at the 0 and 4/3 FR rates of Bentazon application, but at intermediate rates VAM soybean shoot biomass was significantly higher and for cocklebur lower than that of nonVAM plants. The plot of percent change [100x(VAM - nonVAM)/nonVAM] peaked for soybean (+15%) and bottomed for cocklebur (-20%) at 2/3 FR. This pattern held also for all leaf nutrient contents except for Mn. As with biomass, ^{15}N abundance was the same in VAM and nonVAM soybean leaves in the 0 and 1 RF Bentazon treatments and did not differ from natural abundance. At the intermediate Bentazon treatments (peaking at 2/3 RF), however, ^{15}N abundance was significantly higher in VAM than in nonVAM plants.

The results showed significant enhancement of VAM soybean growth at the expense of associated cocklebur when treated with Bentazon at or below the recommended rate. Movement of labelled N from cocklebur to soybean leaves in VAM plants indicated a direct (hyphal transport) or indirect (reabsorption of exudates) involvement of VAM fungi in the reallocation of cocklebur biomass to the soybean plants. This phenomenon may be conceptualized in terms of inter-plant source-sink relationships: 1. the resistant crop plant became a sink for biomass released by the herbicide-treated weed, 2. there was an optimal dosage (here 2/3 FR) that permitted maximum transfer and best crop enhancement and wheel control, and 3. an overdose (here 4/3 FR) resulted in a rapid necrosis of the leaves which prevented export. Appropriate crop-weed-VAM fungus combinations, along with optimal timing and dosage of system-compatible herbicides hold promise for the development of a synergistic bio-chemical technology to reduce herbicide utilization.

Mineralogy Comparison of Source Soil to Respirable Dust from Agricultural Operations in California

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After extensive measurements of respirable dust production from various agricultural operations, we determined the relationship between source soil and respirable particulate matter. The predominant soil is the Rincon soil series (fine, montmorillonitic, thermic Pachic Argixerolls). The texture of the uppermost horizon is clay loam. X-ray analysis of the source soil indicates that the 50-20 µm fraction consists of quartz, plagioclase, and traces of serpentine and kaolinite. The 20-2 µm fraction is composed of quartz, plagioclase, smectite/vermiculite, montmorillonite/vermiculite, vermiculite, kaolinite, mica and minor amounts of chlorite. The clay fraction includes smectite, vermiculite, kaolinite, and mica. Proton induced x-ray emission (PIXE) was used for non-destructive determination of the elemental composition of souce soil fractions. Under the scanning electron microscope, secondary x-rays emitted after electron bombardment of individual respirable dust particles show the composition to be mica, quartz, vermiculite, pyrophyllite, kaolinite, and orthoclase. Respirable particulate matter will be analyzed for constituents using electron diffraction, scanning electron microscopy, and PIXE. To further complete the comparison between source soil and particulate matter, total carbon analysis will be made.

Carbon Dynamics in Amended Soil with Compost

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California plans to compost most the majority of 5 million tons of urban yard trimmings by the year 2000 for use in agriculture. Since this material is substantially different from traditional organic amendements, there is a need to understand the mechanisms that regulate the processes of N mineralization and immobilization of yard waste compost in soils. Dissolved organic C (DOC) and dissolved organic N (DON) has been postulated as one of the most labile pools in soils. The hypothesis that DOC behaves as a source of available C for microbial activity and as an index for decomposition of organic matter and mineralization of N was tested. Dissolved organic C, dissolved organic N, microbial activity (evolution of CO_2 and basal respiration), microbial biomass C (SIR), NH_4^+ and NO_3^- were measured 8 times over 125 days from two yard waste composts (C:N=19 and 15.7), chicken manure compost (C:N=6.0), non- amended soil (C:N=7.2) and soil amended with compost. The treatments were incubated at constant moisture FC and temperature (25°C). The effect of the composts on microbial activity and nitrogen mineralization, and the use of DOC and DON as an index for compost quality, will be discussed.

Optimizing Nitrogen and Water Inputs for Trickle-Irrigated Cauliflower

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Subsurface trickle irrigation offers almost unlimited flexibility in managing water and N applications to optimize crop production while minimizing polluting N losses. Two field experiments were conducted on a reclaimed Casa Grande s.l. (fine-loamy, mixed, hyperthermic Typic Natrirgid) in 1993-95 with cauliflower (*Brassica oleracea* L. Botrytis group) using subsurface trickle irrigation. The objective was to evaluate the agronomic, economic, and environmental response of this crop to a complete factorial arrangement of three soil water tension (SWT) treatments (16-4 kPa) and 4 N fertilizer treatments (60-600 kg ha^{-1}). For both seasons maximum predicted marketable yield averaged 28.8 Mg ha^{-1} at 14.2 kPa SWT and 492 kg N $ha^{-1.}$ Abstract spatial analysis of crop response surfaces for marketable yield, net return and postharvest unaccounted for fertilizer N predicted N losses ranged from >240 kg ha^{-1} where excessive rates of water and N were applied to negligible amounts when input levels were made in accordance with current BMP's.

Estimation of Field Water Balance Using Stable Isotope Techniques

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Irrigated agricultural practices in the western San Joaquin Valley (SJV) of California over the last century has caused soil and groundwater degradation. Types of degradation include elevated water tables and increased soil and groundwater salinity and trace elements. In order to control the problems associated with irrigated agriculture and shallow groundwater tables in the SJV, subsurface drainage systems have been installed in much of this region.

This study used Stable Isotope techniques in the identification of the contributions to drainage flow from locally applied irrigation water and that from regional groundwater. Drainage water quantity and quality has been measured from both furrow and sprinkler irrigated fields with a shallow water table during the spring and summer of 1994. Water samples taken from irrigation and drain water, the vadose zone and the deep and shallow groundwater were analyzed for stable isotopes D/H and O^{18}/O^{16} as well as salinity (EC). Differences in isotopic composition and salinity were found in all the water sources sampled. Vadose zone samples were found to have enriched D/H and O^{18}/O^{16} composition compared to the relatively unenriched groundwater. Drainage water was found to have isotopic compositions lying between those of the vadose zone and groundwater reflecting a mixing of the water draining from the field and that being intercepted from the shallow groundwater. Drainage water isotopic composition was also found to vary with time reflecting changes in contributions from the field and groundwater during the growing season. The isotope data was used in mass balance calculations to quantify the contributions to the drainage flow from the field and groundwater.

Water Flow and Virus Transport in Weathered Rock

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Shallow soils underlain by thick zones of weathered, fractured granitic bedrock are extensive in upland areas of California. The hydraulic properties of these weathered rock materials and the potential for contaminant transport through them is relatively unknown. Bedrock joint traces may serve as preferential flow paths for contaminants contained in septic effluents in rural upland areas where soil adsorption systems are the primary means of wastewater treatment. K_{sat} values of weathered granitic rock profiles were determined using a compact constant head permeameter. An aqueous suspension/solution containing bacteriophage MS2, NaBr, and a blue dye (FD&C Blue #1) was applied to a weathered rock profile *in situ* to trace the extent and pathways of water and virus transport. Rock samples were taken using a modified grid pattern with higher sampling densities around morphological features suspected of contributing to preferential flow. K_{sat} ranged from 1 to 4 cm hr^{-1}. Preferential transport of the MS2 bacteriophage through weathered rock joint traces and fracture planes was extensive. Transport of water and bacteriophage through the weathered rock matrix was minimal.

Corn Yield and Nitrogen Utilization as Influenced by Conventional, Low Input and Organic Systems in California

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The Sustainable Agriculture Farming Systems Project, initiated in 1989, is a 12 year research-station based experiment comparing organic, low-input and conventional farming systems in a four year, five crop rotation (tomato/safflower/corn/cereal/beans). The low input corn has yielded the highest of the three systems for the last four years.Yields in the organic system are heavily influenced by the carbon to nitrogen ratio and nitrogen content of the organic inputs, and have fluctuated considerably during the experiment. Conventional yields have been very consistent but have not reached their potential. Crop nitrogen tissue data indicates that conventional yields are limited by some factor other than fertility, possibly water stress associated with poor water infiltration. Further work is underway to evaluate soil physical properties among the systems.

Purslane (*Portulaca oleracea*): A Halophytic Crop for Drainage Water Reuse Systems

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The drainage water reuse system, as proposed for the west side of the San Joaquin Valley of California, requires the identification of alternate species that will be useful as the final, most salt tolerant crop in the series. These crops must be productive when irrigated with waters that are typically high in sulfate salinity and may be contaminated with potentially toxic trace elements. This study was initiated to evaluate the interactive effects of sulfate salinity and selenium on biomass production and mineral content of purslane (*Portulaca oleracea*). Plants were grown in greenhouse sand cultures and irrigated four times daily. Treatments consisted of three salinities with electrical conductivities (EC) of 2.1, 15.2, and 28.5 dS/m, and two selenium levels, 0 and 2.3 mg/l. In the initial harvests, shoot dry matter was reduced by 10% at 15.2 dS/m and 89% at 28.5 dS/m. Regrowth after clipping above the first node was vigorous, and plants irrigated with 15.2 dS/m water were more productive than those at either low (2 dS/m) or high (28.5 dS/m) salinities. Purslane appears to be an excellent candidate for inclusion in saline drainage water reuse systems. It is (i) highly tolerant of both chloride- and sulfate-dominated salinity, (ii) a moderate selenium accumulator in the sulfate-system, and (iii) a valuable, nutritive vegetable crop for human consumption and for livestock forage.

Subsurface Drip and Furrow Irrigation of Alfalfa: ET, Salinity and Growth Responses

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Alfalfa was grown in the Imperial Valley of southern California's low desert in a four-year evaluation of yield response and evapotrranspiration (ET) requirements under subsurface drip and furrow irrigation regimes. Saline (electrical conductivity of 1.1 to 1.2 dS m-1) water from the Colorado River was used for all irrigation. During the first two years, drip laterals were installed 40 cm deep, while 65 cm deep laterals were evaluated during the third and fourth years. Two drip lateral spacings (1.02 m and 2.04 m) were evaluated in all years. The 40 cm deep lateral installation allowed surface soil wetting, causing problems with harvest, while the 60 cm deep laterals eliminated harvest problems with no loss in yield. Applied water and ET were similar (within 10%) across drip and furrow irrigation treatments; however, forage yields averaged over 30% higher in drip treatments. Salt distribution across beds and with depth were very different across irrigation methods and lateral spacings. With these irrigation methods and water quality, leaching for removal of root zone salinity will be required on at least a two-year frequency.

Water Quality and Agriculture in the Upper Klamath Basin of California and Oregon

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Conflicts between wildlife conservation and agriculture have developed in the Upper Klamath Basin. Irrigated agriculture is practiced on organic soils reclaimed from lake beds in a region of shallow, eutrophic surface waters that also provide vital waterfowl refuges on the pacific flyway. Two fish species endemic to the region's lakes are also listed as endangered. Algae are abundant in lakes, rivers and irrigation canals. High pH, low dissolved oxygen, unionized NH_3, and warm temperatures have been identified as important water quality problems. Agriculture and grazing are accused of worsening these problems. An initial assessment of the effects of irrigated agriculture on water quality was carried out using historical and current data. The salinity of waters draining farmed areas has declined over the period 1945 to 1990 from an average of 1200 $\mu S\ cm^{-1}$ to approximately 700 $\mu S\ cm^{-1}$. Average P concentrations in drainage waters were high (0.4 mg L^{-1}) but appear to have remained constant from 1980 to 1990. Average NH_3 concentrations were high but variable (0.1 to 1.2 mg L^{-1}). Crops act as a sink for N and P. Available data suggest that irrigated agriculture does not adversely influence water quality in the Basin.

Real-Time Mapping Systems Enhance Data Gathering and Productivity in Precision Agriculture

T. R. Lockhart, J.H. Kramer, and R.C. Dixon

Field data collection systems must be simple to operate, quick at processing information, and able to interface with data management software. Precision agriculture is data intensive, and along with the ability to generate large amounts of data comes the need to retrieve, process and analyze that data. Penbased field computers are new input devices for digitizing field information. Geographic Information Systems (GIS) are an excellent tool for analyzing digitized information. A data collection software that runs on penbased field computers is a critical link between data creation and analyses. Penmap software was used to collect vine stress information in a California grape vineyard. Lazer range-finding binoculars input location data onto the computer screen to verify field positioning. Contour information was downloaded in layers directly into GIS software (ArcView 2) to create maps showing exactly which vines were stressed. Management decisions will be based on annual progress of this mapped condition and a real-time, field generated database the documents the vigor of each vine.

Citrus Growers Can Reduce Nitrate Groundwater Pollution And Increase Profits By Using Foliar Urea Fertilization

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Cooperators:
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OBJECTIVES

The objective was to test the hypothesis that foliar urea applied within the period April 1 to June 1 can do triple duty as:

1. A "non-pesticide" to control citrus thrips and reduce fruit scarring.

2. A "growth regulator" to improve fruit set and increase yield without reducing fruit size or quality.

3. A nitrogen fertilizer by supplying a portion of the nitrogen to be applied in a given year thus reducing the amount applied to the soil.

The specific goal of our research was to determine whether there is an optimal time for cost-effective foliar application of urea that will successfully improve fruit set and yield and control citrus thrips to reduce fruit scarring. The results of our research will not only help improve citrus productivity and grower profits, but will also help reduce nitrate groundwater pollution and reduce the amount of chemical pesticides currently used to control citrus thrips.

DESCRIPTION

The research was conducted on 17-year-old `Frost nucellar' navel orange trees on Trifoliate orange rootstock under commercial production by Paramount Citrus in the Ivanhoe area of the San Joaquin Valley. The research was replicated for three years due to alternate bearing.

There were five treatments each replicated as eight randomized blocks (six rows wide by 15 trees long). Data was collected from six individual trees per block for a total of 48 data trees per treatment. Foliar low-biuret urea was applied each year on approximately April 7, April 21, May 5, or May 20 for treatments 1 through 4, respectively. Treatment 5, the control, was Paramount Citrus' best management practice.

RESULTS AND CONCLUSIONS

Our results suggest that urea will not have much impact in preventing scarring of fruit when thrips pressure is great. The performance of urea in reducing the percentage of fruit scarred by thrips in a light thrips year remains to be determined. The results provide evidence that a properly-timed spring (late May) foliar application of low-biuret urea significantly increased yield by increasing both the weight and number of large-sized fruit (packinghouse carton size 56) with some reduction in the degree of severe fruit scarring by citrus thrips. Trees receiving the late May foliar application of low-biuret urea averaged 11 kg more fruit than the control trees receiving soil-applied nitrogen over the two years of the study. This represents an additional 0.65 17-kg carton of fruit per tree. At a typical planting density of 96 trees per acre, the late May foliar application of low-biuret urea would yield 63 additional cartons per acre. A cost/benefit analyses showed that net return to the grower for the late May foliar application of low-biuret urea was an average of $318 per acre per year.

Relationships Between Crop Yield, Light Absorption, and Canopy Reflectance for Cotton in the San Joaquin Valley of California

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Assessment of crop condition and productivity on a regional scale is often not feasible using ground survey techniques. Satellite remote sensing can be used to periodically gather crop-related information from the fields in an agricultural region. In this paper, data obtained from 63 commercial cotton fields in the southern San Joaquin Valley were analyzed to identify correlatio ns between remotely sensed factors and observed crop growth. Remotely sensed canopy reflectance was determined from Landsat 5 Thematic Mapper images obtained on seven dates during the growing season and used to evaluate the Normalized Difference Vegetation Index (NDVI) . NDVI was correlated with ground measurements of leaf area index, plant canopy light absorptance, and percent ground cover. Correlations were sought between seasonal NDVI and light absorption and crop yield.

The Effect of Applied Water and Nitrogen Rate on Potato Yield and Petiole Nitrate Levels

D. B. Marcum and R. D. Meyer
University of California, McArthur and Davis

Highly significant Russett Burbank potato (Solanum tuberosum L.) yield differences were observed from a field trial in which a line-source irrigation delivered six water levels (33, 67, 100, 111, 122 and 133% ET_c) each having six planting time nitrogen rates (0, 56, 112, 168, 224 and 448 kg ha^{-1}). Water treatment yields were from 14.1 to 54.4 and 20.8 to 46.5 Mg ha^{-1} in 1992 and 1993 respectively with near maximum yields at 100-110 and 110-120% ET_c applied water. Nitrogen treatment yields ranged from 41.3 to 45.6 and 28.7 to 44.1 Mg ha^{-1} in 1992 and 1993 respectively with near maximum yields at 56-112 and 168-224 kg ha^{-1} applied nitrogen. Petiole-nitrate concentrations in samples collected 48-49, 63-64, 76-77, 90-91 and 104-105 days after planting the two years substantiated currently used guidelines to obtain optimum yields and utilize applied nitrogen efficiently.

Salt Accumulation and Crop Responses Under Four Levels of Subsurface Drip Irrigation

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A rotation of vegetable and field crops (lettuce, cotton, lettuce, onions) were grown under subsurface drip irrigation in a four-year evaluation in the low desert of southern California's Imperial Valley. Drip laterals were installed 40 cm deep on 1.52 m beds. Irrigation treatments consisted of four water application levels ranging from 50% to 125% of estimated crop evapotranspiration as measured using local weather station grass reference evapotranspiration and predetermined crop coefficients. Saline water (electrical conductivity of 1.1 to 1.2 dS m-1) from the Colorado River was used for all irrigation. In most crops marketable yields peaked at the 100% irrigation level. Growth and yield of onions were poor due to water deficits associated with a poor match of a shallow root system in the onions and deep drip lateral placement. Yields of other crops were moderate to high compared to yields on commercial fields in the same area. Patterns of salt accumulation were similar for each treatment, although the salinity levels in the bed area at the perimeter of the wetted zone from the drip laterals were higher with increasing water applications

The Effect of Applied Nitrogen and Water on Potato Yield and Nitrogen in the Soil.

Roland D. Meyer and Daniel B. Marcum
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Highly significant Russet Burbank potato (*Solanum tuberosum L.*) yield differences were observed from a field trial in which a line-source irrigation system delivered six water levels (33, 67, 100, 110, 120 and 130% ETc) each having six planting time nitrogen rates (0, 56, 112, 168, 224 and 448 kg ha^{-1}). Water treatment yields were from 14.1 to 54.4 and 20.8 to 46.5 Mg ha^{-1} in 1992 and 1993 respectively with near maximum yields at 100-110 and 110-120% ETc applied water. Nitrogen treatment yields ranged from 41.3 to 45.6 and 28.7 to 44.1 Mg ha^{-1} in 1992 and 1993 respectively with near maximum yields at 56-112 and 168-224 kg ha^{-1} applied nitrogen. Petiole-nitrate concentrations in samples collected 48-49, 63-64, 76-77, 90-91 and 104-105 days after planting the two years substantiated currently used guidelines to obtain optimum yields and utilize applied nitrogen efficiently. Soil nitrate- and ammonium-N concentrations were measured in 15 cm increments to 150 cms depth nine times over two potato growing seasons from four planting time nitrogen (ammonium sulfate) rates (0, 112, 224 and 448 kg ha^{-1}) each at three water levels (67, 100 and 130% ETc). Occasional high ammonium-N concentrations (>200 mg kg^{-1}) were observed in the 0-30 cms depth since sample cores were taken from the seed row between the two fertilizer bands. Ammonium-N concentrations exceeded 30 mg kg^{-1} for the 224 and 448 kg N ha^{-1} rates in the spring after above normal winter rainfall one year after application. Residual nitrate-N (10-40 mg kg^{-1}) at planting time the first cropping season was utilized, denitrified or leached from the top 150 cms by the end of winter rains the beginning of the second season. Little or very low nitrate-N concentrations were observed the end of the second growing season in the soil profiles receiving 0, 112 and 224 kg N ha^{-1}, whereas 10-50 mg kg^{-1} nitrate-N concentrations were found in the 0-60 cms depth of the 448 kg N ha^{-1} rate.

Western States Agricultural Laboratory Sample Exchange Program

Robert O. Miller and Janice Kotuby-Amacher
UC Davis, LAWR and Utah State University, USU Analytical Laboratories

OBJECTIVE

The Western States Agricultural Laboratory Sample Exchange Program was initiated in 1994 with the prime objective of developing an external quality control program for the laboratory industry. The program is based on the quarterly exchange of three soils and three plant material samples, on which standard agricultural analysis is conducted using standard methods. The program is being well-received by the industry and results have been published in the popular press and in scientific proceedings.

For the third quarter exchange (1994), 101 laboratories were enrolled and the exchange samples were shipped in September. Seventy-two laboratories completed the analyses. A high EC and

SAR soil was included, which provided a challenge for the laboratory industry. Overall proficiency results for the third quarter were similar to those of the two previous quarters. For the fourth quarter exchange (1994), 102 laboratories were enrolled in the program and the samples were shipped in November. Eighty laboratories completed the analyses and results were used in the quarterly report mailed December 28, 1994. Results for the fourth quarter were comparable with earlier quarters. The number of labs exceeding warning limits decreased, compared to the previous quarter.

During 1994, approximately 50% of the soil labs reported more than 90% of their values within the established warning limits. For plant analyses, approximately 65 percent of the labs reported more than 90 percent of the values within established warning limits. Of the analytical procedures evaluated, the soil bicarbonate P and plant extractable nitrate procedures appear to have precision problems. We are currently developing a plan to identify and address these problems.

For 1995, we have revised the program name to "Western States Proficiency Testing Program" to more accurately reflect its scope. Additional soil analyses have been added: SMP buffer pH, ammonium nitrogen and soil cation exchange capacity. Soil saturated paste carbonate has been dropped from the program. Currently we have selected, prepared and packaged 12 soil and plant samples for the 1995 program and have developed 5 soil and plant samples for the 1996 program. Version 2.00 of the method manual, containing new methods, was printed. We are currently reviewing alternative statistical methods for assessing proficiency based on ACOC and EPA protocols to effectively define the true value and level of precision for each analysis.

For the first quarter exchange of 1995, 85 laboratories were enrolled in the program and the exchange samples were shipped the week of February 1. Samples ranged in pH from 5.9 to 7.8. Seventy-five laboratories completed the analyses and results were used in the final report mailed March 15, 1995.

For the second quarter exchange (1995), 92 laboratories were enrolled and the exchange samples were shipped the week of May 1, 1995. Samples included a National Institute of Standards and Technology (NIST) certified reference solution which is being used to evaluate bias problems associated with the bicarbonate phosphorus method. Seventy-seven labs completed the analyses and results were included in the final report mailed June 20, 1995. Results indicated a high level of accuracy of the NIST sample by the lab industry for N, P, Ca, Mg, B, M, and Zn. Planning is underway for the third and fourth quarters exchanges of 1995. A laboratory survey on analytical methodology is being prepared for submission with the third quarterly exchange.

Two manuals describing the analytical methods used are available. *Plant, Soil and Water Reference Methods for the Western Region* is available from Ray Gavlak, Plamer Research Center, 533 E. Fireweed Ave., Palmer, AK 99645, (907) 746-9467. *Western States Agricultural Laboratory Exchange Program: Suggested Soil, and Plant Analytical Methods* is available from Janice Kotuby-Amacher, USUAL, Utah State University, Logan, UT (801) 797-0008.

Crop Responses to a New Organo-Inorganic Fertilizer Compared with Inorganic Fertilizer and Compost

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Fortified pelleted manure, a new organic base fertilizer was studied in pot experiments during 1994 for its effect on biomass production and N,P,K uptake by spring wheat, bush beans and Swiss chard grown on Palouse (pH 5.3), Shano (pH 6.5) and Warden (pH 8.1) soils. It was compared with compost and urea at four rates of N. Nutrients N,P,K and S in pelleted manure were supplied on equal basis through compost and urea and adjusted for P,K, and S with inorganic sources. The harvested biomass of all the three crops at 55-60 DAE increased with urea-N on all the three soils and with pelleted manure on Palouse and Shano soils. On Warden soil, only chard responded to pelleted manure. There were no responses to compost, with a lone exception. Urea was superior to pelleted manure in five of the nine crop-soils and it was on par in 3 cases. N uptake by wheat was similar with both of these sources. N uptake by beans and chard was higher with urea except for beans on Shano soil. P and K uptake were generally highest with inorganic fertilizer. Overall, pelleted manure has potential as a plant nutrient supplier and to aid in safe use of organic wastes improving the productivity of marginal soils.

Lettuce Response and Nitrate-N Leaching to Water and Nitrogen on Sand

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The low desert region of Arizona is the major area of lettuce (*Lactuca sativa* L.) production during the winter. Most lettuce is grown on alluvial valley loam and clay loam soils. There is interest in moving some vegetable production onto sandy soils on the upper terraces (mesa) to partially relieve the intensive production pressure currently being placed on land in the valleys. Water and N management is a major concern in coarse textured soils. Studies were conducted to evaluate the response of crisphead lettuce to sprinkler applied water and N fertilizer on a coarse textured soil (>95% sand). The experiments were irrigated using a modified lateral irrigation system that applied five levels of water and five levels of N in specified combinations. Nitrate-N concentrations were determined in samples collected in ceramic suction cups placed below the crop rooting zone. Leaching fraction was estimated by frequent neutron probe soil moisture measurements. Lettuce yield increased with water and N where rates required for maximum economic yield exceeded rates typically required on finer textured valley soils. These data show the potential for large N leaching losses on this coarse textured soil.

Development and Promotion of Nitrogen Quick Tests for Determining Nitrogen Fertilizer Needs of Vegetables

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Cooperator:
Louise Jackson
UC Davis--Vegetable Crops

Because of the high values involved and the need for high quality products, vegetable growers cannot take the risk of under-fertilizing their crops. In order to reduce the amount of fertilizer applied with a minimum of risk of under-fertilization, a simple, quick, and inexpensive method of monitoring crop nitrogen status is needed. The Cardy nitrate meter is a compact, inexpensive (about $300) specific ion meter that can be used by growers for quick analysis of fresh sap from a variety of vegetable crops.

A recent economic study by Louise Jackson (unpublished) places the cost of weekly sampling of lettuce at about $15 per acre. In this case study, enough money was saved by reduced fertilizer and application costs to cover the cost of sampling. This shows that the use of sampling can reduce the potential for nitrogen leaching with little cost to the grower and that, in many cases, the testing will likely result in an economic benefit to the grower. We have been promoting the use of quick tests on the central coast for the last two years and growers are beginning to adopt the technology. As more growers begin to use quick testing, we need to make sure they have a good understanding of the accuracy and use of the nitrate quick tests.

OBJECTIVES

1. Continue to refine correlations between fresh sap and dry tissue nitrate levels for vegetable crops by analyzing split samples by both the Cardy specific ion meter and the UC Davis DANR Lab.

2. Evaluate integrated monitoring, using quick tests of the soil nitrate status and petiole nitrate-nitrogen as a technique to reduce nitrogen fertilization in drip irrigated vegetables.

3. Evaluate the uniformity of nitrate levels throughout typical growers' fields, in order to make better recommendations to growers on site selection and number of samples needed to adequately monitor nitrate levels.

4. Promote the use of nitrate quick tests for managing fertilizer applications through meetings and mass media.

Bromide Tracer Experiments to Illustrate Salt Movement in a Cracking Clay Soil

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Water and solute transport during overland flow from basin or furrow irrigation is a complex process; made even more complex when soils exhibit high shrink-swell behavior that creates large cracks. The purpose of our experiments was to characterize water and solute movement through soils that develop large shrinkage cracks upon drying. A series of bromide tracer experiments was conducted on two contrasting field soils, one sand (on cracks) and one silty clay (large cracks). Results give a clear message. On non-cracking soils, solute movement was mostly vertical. On cracking soils solute in the irrigation water increased as it flowed down the furrow indicating substantial horizontal solute transport.

The Effects Of Various Phosphorus Placements On No-Till Barley Production

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Cooperators:

G. Stuart Pettygrove **UC Davis LAWR**	**Keith Saxton** **USDA Ag. Res. Service**	**Kenneth, Jerold and** **Ronald White--White** **Ranch Company,** **Shandon, CA**

SUMMARY

This two year project is studying various sub-surface phosphorous placements and their effects on the growth and yield of cereal grains grown using a no-till farming system in San Luis Obispo County. Planting and fertilizing equipment designed specifically to apply seed and fertilizer at the same time is being used.

A randomized complete block design with six replications is being used to study the effects of various possible combinations of phosphorous placement on nitrogen and phosphorous uptake. This is determined by measurement of actual uptake of N and P using a "difference" method--analyzing biomass production at various growth stages, yield components, *(number of headed* *tillers, number of kernels per spike, kernel weight, and grain: residue ratio)*, and grain yield measurements.

Determining optimum phosphorous placement, along with potential yield and economic advantages in no-till farming systems, will help bring grower adoption of this technology a step closer to fulfillment. This will help stop the unnecessary loss of thousands of tons of productive soil each year from often "HEL" (Highly Erodible Lands) sites, and significantly reduce soil pollution of surface water streams.

On-Farm Demonstration of Polyacrylamide (PAM) to Reduce Sediment Erosion in Surface Irrigation Systems.

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Washington State University

Extension education programs and On-Farm demonstrations were used to introduce the use of polyacrylamide (PAM) applications in irrigation water to reduce soil ersoison and to increase infiltration in surface irrigation systems. Polyacrylamides were utilized by crop producers in the Granger Drain HUA and the lower Yakima Valley during the 1994 and 1995 irrigation seasons. Polyacrylamides formulations, methods of application and their effectiveness will be discussed. Soil erosion was reduce by 90% and better.

Denitrification Following Fertigation of Subsurface Drip Irrigated Broccoli.

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Gaseous losses of N from soils are of concern because they represent a loss of fertilizer N. Reliable estimates of N gas losses from agricultural fields are rare, due to difficulty in measurement and soil variability. The use of subsurface drip irrigation (SDI) is increasing in Arizona and California, because it is a highly efficient delivery system for water and nutrients. The magnitude of denitrification losses with SDI is unknown. Moreover, SDI may sometimes result in soil conditions of low O_2 and high NO_3^- following irrigation and fertilization. When these conditions occur in the crop rhizosphere, denitrification may result. A study was conducted with subsurface drip irrigated broccoli (*Brassica oleracea* L. cv. 'Claudia')during winter 1994-95 in southern Arizona to i) develop a system for using the acetylene inhibition method to measure denitrification with SDI, and ii) determine the magnitude of denitrification fluxes as affected by irrigation and fertilization. Plots received optimum or excessive irrigation, and no N or 300 kg N ha^{-1} as $Ca(NO_3)_2$. Denitrification fluxes were measured periodically for 48 hours following fertigation. Rates of denitrification increased as the season progressed. Denitrification was higher in fertilized than in unfertilized plots, and was higher in plots receiving excessive irrigation. The maximum rate of denitrification observed was 27 g N/ha/hr following fertigation of 10-12 leaf

broccoli plants under excessive irrigation. Overall, denitrification was more responsive to fertilization with N than to excessive irrigation. These results suggest that N losses via denitrification are inevitable following fertigation in SDI systems.

Establishing Updated Guidelines for Cotton Nutrition

Project Leaders:

Robert Travis **UC Davis Agronomy & Range Sci.**	**Bill Weir** **UC Coop. Ext., Merced Co.**
Bruce Roberts **UC Coop. Ext., Tulare Co.**	**Mark Keeley** **UC Cotton Research Station**
Robert Miller **UC Davis, LAWR**	**Robert Hutmacher** **USDA Water Management Research, Fresno**
Steve Wright **UC Coop. Ext., Tulare Co.**	

Cooperators:

Ron Vargas, Dan Munk and Doug Munier
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OBJECTIVES

1. Establish the relationship between tissue nitrate level and leaf function in cotton. About 50 percent of the nitrogen in a leaf blade is part of a protein (RUDPase) which through the process of photosynthesis incorporates carbon dioxide into sugars (carboxylation). Early season levels of nitrate typically occurring under present fertilization practices are believed to be much higher than necessary to maintain leaf function. Before adjustments can be made in either the quantity or timing of nitrogen applications, we must establish the critical level for optimum leaf function.

2. Determine if yields can be maintained and potential nitrogen losses impacting groundwater quality minimized when nitrogen is supplied on an "as needed basis" instead of preplant, or split applications between preplant and side dress at the early square stage.

3. Improve the predictive ability of current soil K test procedures. Ammonium extractable K is the soil test currently used to identify potassium sufficiency. Soils with montmorillonitic or vermicullitic clays exhibit K fixation. Current procedures will be compared to two new possible methods under development.

4. Develop nitrogen and potassium recommendations that simultaneously consider the soil supply rate, the quantity of nutrients stored in plant vegetative structures which can be mobilized without affecting leaf function, and the demand (timing and intensity) by developing bolls.

DESCRIPTION

Critical Nitrate Levels

Plots were established at the UC West Side Research and Extension Center under drip irrigation. Nine combinations of nitrogen application included variation in the quantity of nitrogen and the time during the season when it was applied. Field sampling of nitrogen rate and timing plots has been completed for the first year. Leaves at three positions on the plant have been sampled when they were first fully expanded, the subtending boll was at bloom, bloom plus 21 days, and bloom plus 42 days. This detailed enzyme work to establish the effect of nitrogen rate and timing upon leaf function and longevity has been completed. All plots were sampled for nitrate on the appropriate sample dates, and tissue analysis has been completed.

Growth and development data have been collected throughout the season. All in-season samples have been summarized. Growth the last half of June averaged 93 percent of the rate established for non-stress Acala SJ-2 and square retention was high (95 percent). At this early date all treatments had similar leaf size, leaf area, leaf density, plant height, number of nodes, and similar growth rates. No differences in any variables monitored were noted. On July 12, low nitrogen plots began to show a trend for decreased number of nodes and fewer nodes above white flower. Fruit retention remained high. At this stage of growth no differences were noted in leaf size, area, or density. By late July, low nitrogen plots had growth rates well below the highest nitrogen plots. Fruit retention remained high but differences in leaf size, area, or density were not apparent.

Preplant Versus In-Season Nitrogen Application

Nitrogen deficiency symptoms were detected in the water run nitrogen treatments (no preplant N) at the UC West Side Research and Extension Center. Tissue analyses are not yet available. Final plant mapping has been completed. Plots where 200 lbs/A nitrogen was applied with the three in-season irrigation were 4.4 inches shorter than plots where all the nitrogen was applied prior to the first in-season irrigation. Delayed nitrogen also decreased the number of fruiting branches, decreased fruit retention approximately 6 percent at the first position of the first 10 fruiting branches, and caused a 12 percent reduction in total number of harvestable bolls per plant at the end of the season.

Approximately 50 field locations in all six SJV cotton growing counties were screened for soil potassium at two depths. Three locations in each of six counties were selected for study. These 18 field locations represented a difference in soil test level, ranged geographically in the SJV, and represented soils that have fixation characteristics as well as soils without K fixation. Prior to the first irrigation, 0 or 400 lbs/A of potassium was applied to large scale plots. Petiole and plant growth data were collected four times during the season. The first year's data has been summarized.

Evaluation of Nitrogen Utilization and Petiole Nitrate Testing in Cover Cropped Tomato Systems with Differing Carbon to Nitrogen Ratios and Nitrogen Sources

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Petiole nitrate tests have been used as indicators of future yield in processing tomato production. Five treatments with varying sources and amounts of N and varying C:N ratios were established to test their usefulness as a management tool in organically fertilized systems. Established sufficiency and deficiency levels do not seem to correspond with yield in these systems. Available soil N was measured in each treatment as well as total N at harvest. The relationship of the soil and plant parameters analyzed and their importance in managing cover crop driven systems is discussed. Data indicates that tomato systems which have received annual organic inputs do not have reduced yields from low input N and high C:N ratios.

Nutritional Guidelines For Potassium In Cotton

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INTRODUCTION

A three bale cotton crop accumulates approximately 180 pounds of elemental potassium (216 pounds of K_2O). Since the entire plant is not harvested, much of the potassium is returned to the soil, and an estimated 42 pounds of potassium (50 pounds of K_2O) are removed in seeds and lint. During mid-season growth, potassium accumulation may approach 7 pounds per acre per day. To maintain soil potassium at sufficient levels, it is usually necessary to supplement cotton with additional sources of potassium. Nutritional guidelines for potassium on cotton were established in the late 1960's using different varieties with lower lint yield potential, and different cultural practices.

MATERIALS AND METHODS

Field scale potassium trials were conducted on 16 sites throughout the six cotton growing counties in the San Joaquin Valley. Three years of a four year study have been completed. Potassium fertilizer (muriate of potash) was applied at rates of 0 and 400 pounds of K_2O per acre at each site using a replicated experimental design. The material was banded in the shoulders of fallow beds at a depth of 7 inches after emergence. Tests were conducted in exact locations each year in order to evaluate the effects of high rates of potassium fertilizer applied in successive years.

CONCLUSIONS

Critical values for petiole K content, and extractable soil K, relative to cotton yields have been established. Some conclusions which will be explored and expanded during subsequent research are: (1) Petiole K determined on samples collected at peak bloom (two weeks after first bloom) should have at least 2.70% potassium. Petiole levels lower than this indicate that potassium should be applied for subsequent cotton crops. (2) A pre-plant soil sample from a depth of 5-15 inches should have least 105 ppm extractable potassium (extracted by either ammonium acetate or Mehlich 3). Lower levels indicate the need for potassium fertilizer to assure adequate growth. (3) A pre-plant soil sample from a depth of 5-15 inches should have as least 95 ppm extractable potassium (extracted by the AB-DTPA method). (4) A soil sample with less than 105 ppm (ammonium acetate or Mehlich 3), or 95 ppm (AB-DTPA), should be evaluated for K- Fixation. (5) Lint yields on soils with K fixations greater than 62% were highly responsive to K applications. (6) Statistical analyses currently establish a critical soil K level of 105 ppm when extracted by Ammonium Acetate or Mehlich 3, and 95 ppm when extracted by AB-DTPA method. (7) potassium fertility for cotton is most accurately evaluated based upon (I) ammonium acetate, Mehlich 3, AB-DTPA extractable potassium; (II) A sampling depth of 5-15 inches; (III) potassium fixation potential; and (IV) petioles concentration from tissues collected two weeks after first bloom.

Potassium Relationships in Potato Plants

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The relationship between the K concentration in petioles and the K status of the potato plant (Solanum tuberosum L.) must be known to properly manage K applications during tuber growth. We evaluated this relationship in six irrigated field experiments on calcareous soils with the Russet Burbank cultivar where K fertilization was a variable. Whole plants, active leaves, tubers and the fourth petiole were sampled at selected intervals during tuber growth for both K uptake and concentrations. Petiole K concentration was highest at tuber initiation and decreased during tuber growth, and related to the K concentration of active leaves, whole top, and tuber. The whole plant K uptake rate:tuber K uptake rate ratio (K-balance) was linearly related to the petiole K concentration. Across all studies, this ratio was 1.0 when the petiole contained 64 g kg-1 K. At lower petiole K concentrations, K translocated from the vegetative plant parts to the developing tubers. The petiole K concentration at K-balance varied between 55 and 72 g kg-1 and was dependent upon tuber growth rate. These results provide a range of petiole K concentrations to use for scheduling K applications during tuber growth.

Soil Sampling for Subsurface Drip Irrigated Fields

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Fertigation via subsurface drip irrigation is a line source application of N fertilizer, resulting in soil N distributions which are non-random. In order to accurately determine postharvest soil N the soil sampling strategy employed should account for this. Sweet corn (*Zea mays L.*) was grown on raised soil beds at two sites in southern Arizona with subsurface drip irrigation. The objectives were to: (i) compare residual profile N concentrations on each side of the drip tubing, and (ii) determine appropriate soil core sampling strategies to estimate post-harvest soil profile N concentrations. Residual inorganic soil N was determined in bulk soil samples (0.35 m^3) collected in 0.30 m depth increments from each side of the drip tubing. Residual inorganic N was also determined in vertical soil cores (0.05 m diameter) collected to a depth of 0.90 m at various positions relative to the drip tubing. Recovery of N in various combinations of core samples was compared to N recovery in bulk samples. Analysis of bulk soil samples showed that N recovery was approximately equal on each side of the drip tubing. To accurately estimate the mass of residual N in the profile, sampling strategies must reflect the distribution of N. Composited samples consisting of two or more equally spaced cores from one side of the drip tubing were generally adequate for estimating residual soil N. However, core sampling tended to overestimate residual N concentration.

Influence of Rootstock on Bloomtime Petiole Analyses of Selected Grape Cultivars

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OBJECTIVE

To determine the influence of rootstock on nutrient status of Chardonnay, Cabernet Sauvignon and Zinfandel grapevines.

DESCRIPTION

In coastal areas, phylloxera-infested vineyards are being removed and replanted with alternative, resistant rootstocks. However, little is known about how these rootstocks will influence vine nutrient status as determined through the routine analyses of petioles. Over two years, 1993 and 1994, petioles were gathered at bloomtime in three trials, one each of cultivars: Chardonnay, Cabernet Sauvignon and Zinfandel. In each trial, scions were grafted onto 14 rootstocks: Harmony, Freedom, 3309C, 101-14 Mgt, 5C, 5BB, 420A Mgt, 110R, 1103P, St George, 1616C, 44-53 Malègue, Ramsey, and O39-16.

RESULTS AND CONCLUSIONS

Petioles were analyzed for NO_3-N, NH_4-N, K, P, and Mg. NO_3-N and K levels were highest in Chardonnay, followed by Cabernet Sauvignon and Zinfandel. Among rootstocks, NO_3-N levels in a given year differed by as much as 16-fold (126 to 2064 μg/g), NH_4-N by as much as 4-fold (253 to 1028μg/g), K, P and Mg by about 3-fold (9.7 to 30.6 mg/g, 1.8 to 6.3 mg/g, and 2.9 to 7.5 mg/g, respectively). Freedom had the highest levels of NO_3-N. Ramsey had moderate levels of NO_3-N but had the highest levels of NH_4-N. The rootstock 420A Mgt was consistently low in NO_3-N, NH_4-N and K. Freedom was among the highest in K content. The rootstock 44-53 Malègue had high levels of K and low Mg. Although bloomtime sampling is the currently recommended practice, it is not clear whether these early season differences among rootstocks will hold throughout the year, especially in the critical period between the onset of ripening and harvest.

More research is needed to confirm these preliminary observations. UC farm advisors and vineyard managers often report that petiolar nitrate nitrogen is a particularly unreliable measure of vine nitrogen status, irrespective of rootstock. The values change with variety and are strongly influenced by meso-climate, vineyard floor management, or other cultural practices.

The next stages of this project are: i) to confirm the influence of rootstocks on vine nutrition, especially N and K, at other times of the growing season; ii) to investigate the influence of differing nutrient status by correlation with vegetative and reproductive growth; and iii) to test for negative trade-offs in fruit quality (excessive K or N). The overall objective is to investigate the relationship of rootstocks to vine nutrient status in the hope of reducing fertilizer inputs.

In addition to vine nutrient status, we will need to gather important vine attributes including: yield components (crop weights, cluster number, berry number, and berry wt), dormant season growth (pruning weights and shoot numbers) and standard fruit maturity indices (juice soluble solids, titratable acidity, pH, color and phenolics).

The timing of this project is critical because replanting is in progress. Growers who have replanted vineyards need rootstock-specific fertilizer recommendations. Those who are planning vineyard replacement have an opportunity to choose a rootstock more suited to their site. Local deficiencies in N, K or P may be ameliorated by proper rootstock choice. By knowing more about a rootstock's nutrient uptake dynamics we may find long-term, genetic solutions to fertility limitations. Future vineyard fertilizations will be more efficient and cost effective, with a low environmental impact.

Early Season Irrigation Timing Effects on Cotton Growth and Yield in an Irrigated Desert Environment

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A plant mapping survey of 30 commercial fields in California's Imperial Valley indicated that cotton in the low desert was not as tall for its age as cotton grown in the San Joaquin Valley, nor did it retain as many first position squares. In replicated field research plots we varied the timing of the first irrigation following planting to test the effect of early season water stress on height to node ratios (HNR's), yields, and first position square retention of five varieties of cotton. Water was applied when leaf water potentials reached -15 bars (Early), -18 bars (Mid), or -21 bars (Late). Subsequent irrigations for all treeatments were applied when leaf water potentials reached -15 bars until bloom, and -18 bars after bloom. Highest yields were measured in the Mid irrigation treatment (3.0 bales/acre). More first position squares were retained in plants from the Early and Mid irrigation treatments. Although HNRs from the Early treatment were highest, they were not as high as those measured in the San Joaquin Valley.