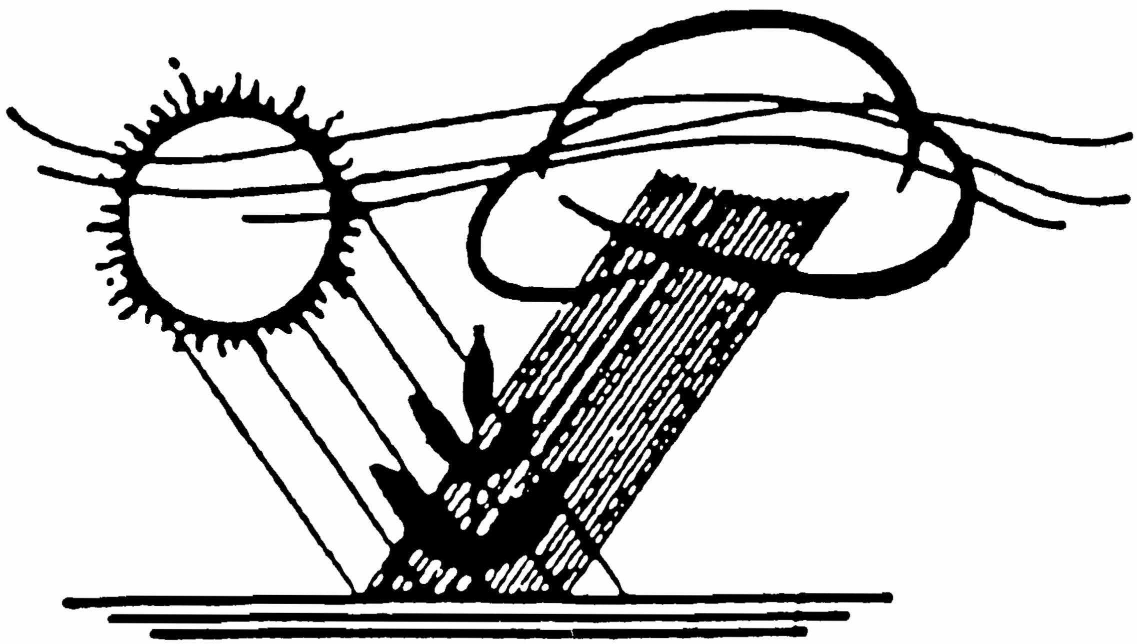
PROCEEDINGS
1999
CALIFORNIA PLANT AND SOIL CONFERENCE

AGRICULTURAL TECHNOLOGY - MOVING CALIFORNIA INTO THE 21ST CENTURY



CALIFORNIA CHAPTER OF AMERICAN SOCIETY OF AGRONOMY

AND

CALIFORNIA FERTILIZER ASSOCIATION

JANUARY 20 & 21, 1999

Visalia Holiday Inn
9000 West Airport Drive
Visalia, CA 93277

WEDNESDAY, JANUARY 20, 1999

GENERAL SESSION

Session Chair: **Shannon Mueller,** UC Cooperative Extension, Fresno County

10:00 **Introduction** - Session chair

10:10 **California Agriculture and the Global Marketplace -** Daniel Sumner, Professor of Agricultural Economics and Director of Agricultural Issues Center, UC Davis

10:40 **New Technologies for Precision Agriculture** Richard Plant, Professor of Agronomy, Department of Agronomy and Range Science, UC Davis

11:10 **Environment for Agriculture (Regulatory Issues and Resource Availability) -** Roger Isom, Director of Technical Services, CA Cotton Ginners and Growers Assn., Fresno

11:40 **Discussion**

12:00 **UNIVERSITY-INDUSTRY LUNCHEON**

CONCURRENT SESSIONS

I. AGRICULTURAL METEROLOGY-MEASUREMENT, PREDICTION AND APPLICATION

Session Chair: **Ron Brase**, California Agquest Consulting, Fresno

1:30 **Introduction -** Session chair

1:40 **Regional Scale Climate Predictions in California** - Sutzai Snoog, Professor, LAWR, UC Davis

2:00 **Advances in Meterology Applied to Agriculture** - Dan Grudgel, National Weather Service, Hanford, CA

2:20 **Commercial Weather Services -** Don Schukraft, General Manager, Weathernews, Chico, CA

2:40 **Discussion**
3:00 **Break**

3:20 **Weather and the Web -** Richard Mead, Research Specialist, United Agri Products.

3:40 **Short and Medium Term Forecasting for the San Joaquin Valley** - Sean Boyd, Weathercaster, KJEO, Fresno, CA

4:00 **Applications of Meterology in Agriculture - An Overview** - Joyce Fox Strand, Ag Meterologist, IPM, UC Davis

4:20 **Discussion**
4:30 **Adjourn**

II. SOIL SALINITY, MANAGEMENT, DRAINAGE AND ANIMAL WASTES

STATUS OF MANURE USE FOR CROP PRODUCTION
Session Chair: **Marsha Campbell Matthews,** UC Cooperative Extension, Stanislaus County

1:30 **Introduction** - Session chair

1:40 **Impact of Central Valley Dairies on Groundwater Quality -** Thomas Harter, Extension Hydrologist, University of California, Kearney Agricultural Center

2:00 **Composition of Manure and Dairy Lagoon Water -** Deanne Meyer, Extension Livestock Waste Management Specialist, UC Davis

2:20 **Using Dairy Lagoon Water to Replace Commercial Fertilizers -** Marsha Campbell Mathews, UCCE, Stanislaus Co. and Roland D. Meyer, Extension Soils Specialist, UC Davis

2:40 **Discussion**
3:00 **Break**

UPDATE ON SALINITY AND DRAINAGE IN THE SAN JOAQUIN VALLEY
Session Chair: **Doug Davis,** General Manager, Tulare Lake Drainage District

3:20 **San Joaquin Valley Implementation Program Update -** Maucher Alemi, Coordinator, San Joaquin Valley Drainage Program

3:40 **On-site Mitigation and Mitigation Habitat for Evaporation Basins -** Doug Davis, General Manager, Tulare Lake Drainage District

4:00 **Reuse of Saline Drainage Water for Forage Production -** Steve Kaffka, CE Agronomist, UC Davis and Jim Oster, CE Soils Specialist, UC Riverside

4:20 **Discussion**
4:30 **Adjourn**

THURSDAY, JANUARY 21, 1999

III. PEST MANAGEMENT STRATEGIES FOR THE 21ST CENTURY

Session Chair: **Shannon Mueller**, UC Cooperative Extension, Fresno County

8:30 **Introduction** - Session Chair

8:40 **Biologically Integrated Vineyard Systems (BIVS): Implementing Grape IPM** Michael J. Costello, UC Cooperative Extension, Fresno County

9:00 **Dried on the Vine Raisin Production - Moving into the 21st Century** - Joseph O. Kretsch, Sun-Maid Growers of California, Kingsburg

9:20 **Returning to More Biological Reliance in Cotton IPM** - Peter B. Goodell, UCCE IPM Entomologist, Kearney Agricultural Center

9:40 **Discussion**
10:00 **Break**

10:20 **Reduced Tillage Technology in California Vegetable Crop Production** - Jeff Mitchell, UC Cooperative Extension Specialist, Kearney Agricultural Center, Parlier

10:40 **Insecticides of the 21st Century - Who, What, When, Where and How?** - Larry Godfrey, Extension Entomologist, Dept. Entomology, UC Davis

11:00 **Pest Control Technology: Where We Are and Where Are We Going?** - William Steinke, CE Agricultural Engineer, Dept. Biological and Agricultural Engineering, UC Davis

11:20 **Discussion**

12:00 CONFERENCE LUNCHEON

IV. ADVANCES IN NUTRIENT MANAGEMENT

Session Chairs: **Warren Bendixen**, UC Cooperative Extension, Santa Maria and **Casey Walsh Cady,** CDFA, Fertilizer Research and Education Program, Sacramento

8:30 **Introduction** - Session Chairs

8:40 **Drip Irrigation Management of Celery - Theory vs. Reality** - Timothy Hartz, CE Specialist, Vegetable Crops, UC Davis

9:00 **Evaluation of Controlled Release Fertilizers and Fertigation in Strawberries** - Warren Bendixen, Cooperative Extension, Santa Barbara County

9:20 **Nitrogen Management in Citrus Under Low-volume Irrigation** - Mary Lu Arpaia, CE Specialist and Lanny Lund, Professor, UC Riverside

9:40 **Discussion**
10:00 **Break**

10:20 **Accuracy and Precision of Soil Analyses and Their Impact on Nutrient Recommendations** Robert O. Miller, Colorado State University and Janice Kotuby-Amacher, Utah State University

10:40 **Fertilizer Use Efficiency and Influence of Rootstocks on Uptake and Nutrient Accumulation in Wine Grapes** - Larry Williams, Viticulture and Enology, UC Davis

11:00 **Management of Nitrogen Fertilization in Sudangrass** - Dan Putnam, CE Specialist, Agronomy and Range Science, UC Davis

11:20 **Discussion**

12:00 CONFERENCE LUNCHEON

V. SITE SPECIFIC FARM MANAGEMENT

Session Chair: **Steve Kaffka,** CE Specialist, UC Davis and **Walt Bunter,** USDA Natural Resource Conservation Service, Davis

1:30 **Introduction** - Session Chairs

1:40 **Remote Sensing in Cotton Production** - Richard Plant, Professor, Agronomy and Range Science, UC Davis

2:00 **Salinity, Soil Mapping, Data Analysis and Interpretation** - Scott Lesh, US Salinity Lab, Riverside

2:20 **Using Site Specific Agriculture Technology for Farm Management** - Panel: William Reinert, Precision Farming Enterprises, Davis and Brock Taylor, Brock Taylor Consulting, Merced

3:00 **Discussion**
3:20 **Adjourn**

VI. BIOENGINEERING - PROGRESS WITH CROPS

Session Chairs: **John Palmer,** Phytogen, Corcoran, CA and **Bill Rains,** Professor, Agronomy and Range Science, UC Davis

1:30 **Introduction** - Session Chairs

1:40 **Biotechnology in Crop Agriculture** - George Bruening, Professor Plant Pathology, Director CERAP, UC Davis

2:00 **The Making of Transgenetic Cotton: Strategies and Targets** - Thea Wilkins, Professor, Agronomy and Range Science, UC Davis

2:20 **Expression of "Designer" Anti-microbial Peptides in Crops to Improve In-season Management and Post-harvest Quality** Paul Zorner, Vice President, Product Development, Mycogen, San Diego

2:40 **Applying the Technology to Improve Economics of Cotton Production in the San Joaquin Valley** - Dave Anderson, Team Leader, Acala, Pima and International Cotton, Phytogen, Corcoran, CA

3:00 **Discussion**
3:20 **Adjourn**

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	Bob Ball
	Owen Rice

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Bill Fisher

Bob Ball

Owen Rice

Bill B. Fischer

Bill hails from the foothills of the Carpathian Mountains where he received both his early schooling and farming (weeding) skills. After moving to the U.S., he served in Patten's Third Army during World War II. Then, taking advantage of the GI Bill, he graduated Cum Laude from Ohio State University in Agronomy and Dairy Science in 1950. Bill continued his studies at the University of California, Davis, where he earned his Master's Degree in Agricultural Education in 1952.

Bill started working for the University of California Cooperative Extension in Stockton as a field assistant and was transferred to Fresno County in 1957 as a Farm Advisor. Before he retired, Bill completed 50 volumes of his Fresno County Extension publication, "Runcina," each one containing detailed summaries of applied research studies written in a "farmer friendly" manner. Bill also developed numerous weed susceptibility charts to enhance the effective and economical use of herbicides in many crops. These are used throughout California and are included in many publications.

Bill is a contributing author of several texts, including *Sugar Beet Production, The Tomato Crop -- A Scientific Basis For Improvement, Principles of Weed Control in California*, and *Cotton Production in California*. He published many articles in refereed journals, popular publications, and newspapers. He is the senior author of the *Growers Weed Identification Handbook*, one of the best-selling publications of the University of California. He also contributed to many of the Integrated Pest Management Manuals published by the University of California.

Bill maintains that without proper weed identification and keeping records of their distribution on the farm, effective and economical vegetation management systems cannot be developed. To encourage keeping records, he designed a weed infestation card and distributed tens of thousands in the San Joaquin Valley.

Bill's applied research studies were supported by: District 6, California Sugar Beet Growers; The Alfalfa Seed Research Board; California Tomato Research Institute; California Melon Research Board; California Pepper Improvement Foundation; California Planting Cotton Seed Distributors; American Dehydrator Onion and Garlic Association; California Almond Board, California Fig Institute; California Citrus Research Board; California Pistachio Commission; California Kiwi Growers Association; and numerous manufacturers and formulators of herbicides.

He values time spent during his sabbatical studies in Australia, England, Israel, New Zealand and Central Europe and his work with weed scientists in Argentina, Mexico, China, Japan, Chile and several African countries.

Although Bill retired at age 70, six months later he was rehired on a part-time basis and spent two more years developing effective vegetation management systems. Since full retirement in 1994, he has been consulting and conducting a large number of IR-4 Projects. In fact, recently he was recognized for his work and contribution toward the registration of pesticides for use in minor crops. In 1998, Bill was recognized with a "Meritorious Service Award" by IR-4.

Robert (Bob) B. Ball

Born in Sacramento, Bob attended local schools and Sacramento Junior College (AA). In 1951, he started at UC Davis in Agronomy, only to be called into the Air Force for 21 months where he served in North Morocco. He returned to the University in 1953 and graduated in 1955 (BS). His first job was with Caladino Farm Seeds, Inc. (now Cal/West Seeds) in Artois, CA. He returned to the Agronomy Department, UCD in 1956, where he remained until his retirement.

Bob retired from the University of California, Davis in 1991. He started at the University as a staff research associate working in seed production research with Luther Jones. In 1957, he joined the California Crop Improvement Association (CCIA) as office manager. With the retirement of Frank Parsons and Burt Ray, he became manager and then executive secretary (1988) until his retirement in 1994.

Bob was very active in seed certification in California and the U.S. He administered the research funding for fees collected by CCIA for alfalfa, clover, small grains, beans and cotton. California has been one of the outstanding seed certification agencies in the U.S., certifying large acreages of crops in the state and providing large poundages of high quality seed for California, the U.S., and many other countries.

Bob served on many committees of the Association of Official Seed Certification Agencies (AOSCA), including the Executive Committee and Chair of the National Alfalfa Variety Review Board. AOSCA recognized Bob's contributions in 1995 with their Honorary Life Membership.

He also served as Director of the Certified Alfalfa Seed Council and for many years on the committee for the Seed Industry Conference. During his career Bob worked closely with Farm Advisors, Agricultural Commissioners, seedsmen and certified seed growers throughout the state to improve the seed certification program.

Bob also served the UCD campus in many ways. He served on the Academic Staff Personnel Committee (twice as chair) and on advisory committees. For many years, he was on the Ag Science Field Day Committee (Judging Day) and was chair for three years (College of Agri. & ES). Bob also served on many Agronomy Department committees and was involved with the planning and construction of three campus buildings. In addition, Bob served on the Board of Directors of the Faculty Club and as president.

In 1985, his peers awarded him the Outstanding Achievement Award in recognition of his remarkable service. This is the highest campus award for academic staff personnel.

Bob is a member of the American Society of Agronomy, Crop Science Society of ASA, and the California Chapter of ASA. Over the years, he has been involved in his community in PTA, Boy Scouts, Willowbank Club Director and President, Willowbank Club water committee. He is presently a Commissioner, East Davis County Fire Protection District.

Bob and his wife, Joan Pesavento Ball, have six children and seven grandchildren. Joan is an accomplished pianist and continues to perform concerts in Davis, Sacramento and the San Francisco Bay area.

Owen Rice

At a very young age, Owen learned how to profit from cooperation with the University Extension system by watching his father's many trials and tests with the service. Born and raised in the Santa Maria area, Owen graduated from Santa Maria high school in 1930 and was known as "a pretty good football player." Supporters of the new San Diego State College offered him employment if he would attend and play football for their team. He played four years, was chosen captain his senior year, and made All Conference tackle three times. Owen chose economics as his major and graduated with a degree in Business Administration.

During the middle of the Great Depression, there were very few jobs available. So when an opportunity arose to promote the sale of Shell Oil Company's new Anhydrous Ammonia to farmers, Owen took the job. Some of his most vivid memories are of those experiences as a young college graduate telling farmers they could fertilize crops with a product that would escape into the atmosphere when released.

To supplement his income, Owen drove a delivery truck for a small oil company. World War II was brewing and prices improved, so he and his father formed a partnership known as Owen T. Rice & Son that continued until 1992, when the company name changed to OSR Enterprises. Owen and his father felt very fortunate to be able to work together and build a strong operation.

In the early 1940s, Owen was chosen chairman of the local Farm Bureau Center that met once a month and was supported by most local farmers. He worked very closely with the Extension Service and offered interesting programs at the meetings. This served as an introduction to his cooperation with specialists from the University in field trials for beans, peppers and sugar beets. Trials are still being carried on to this date. Owen was then asked to serve as Regional Director of the California Farm Bureau, representing Los Angeles, Ventura and Santa Barbara counties on the state board for two terms.

Sugar beets were a very important crop, with a local refinery in the area. Owen came on the Advisory Board of the California Beet Growers Association (CBGA) District Number 8 in 1945. In 1948, he was elected president of the district and became a member of the State Board of Directors. In 1952, he was elected vice president of the state board, and in 1957, he was elected state president, serving in that capacity until 1969. In 1963, he stepped down as president of the local district and was elected statewide director-at-large, serving until 1973. Owen has taken a lead in many projects from 1971 to 1998.

Owen was a member of the local high school and junior college boards, helping develop the Allan Hancock Community College system. His service covered 30 years, retiring as the chairman. In addition, he took an active interest in the Farm Credit System, retiring as chairman of the Ventura system after serving for many years. He also helped organize the California Agriculture Leadership Foundation and served on the board.

He now resides at the old homestead, where the shops and office are located, with his wife of 40 years, Betty. Anything but retired, Owen works daily with his son and offers whatever assistance his experiences can provide. He also devotes considerable time as a director of the local water conservation district.

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III. Pest Management Strategies for the 21st Century

IV. Advances in Nutrient Management

V. Site Specific Farm Management

LATE ADDITIONS

SCHOLARSHIP ESSAYS

Agricultural Impacts of the Asian Economic Climate: A California Focus

by
Daniel A. Sumner and JooHo Song*

Introduction

Starting in the fall of 1997, agricultural production and markets have been buffeted by El Niño and its aftermath. Meanwhile, the climate for agricultural exports from California and the U.S. also changed dramatically. Beginning with the devaluation of the Thailand baht, a financial and economic slump spread across Asia. A combination of exchange rate drops and income declines now affect all the developing countries of East Asia outside of China. Even before the financial crisis hit other Asian countries, the value of the Japanese yen had declined and the rate of growth of the Japanese economy had fallen. The economic situation in East Asia remains truly serious and in a number of countries, residents are facing real hardship. In addition, these events are having significant impacts on the US economy and agriculture.

This paper has limited objectives. We examine the still unfolding Asian economic situation and consider its present and forthcoming impacts on California agriculture. To make this assessment, first we outline the mechanisms by which the economic situation in Asia affects agriculture in California and the rest of the US. Second, we consider the role of Asia in the market for California and US agricultural products. Third, we review briefly the evidence about and prospects for the Asian economies. Fourth, we analyze recent evidence. Finally, by way of conclusion, we summarize potential impacts looking towards the future.

1. How the Asian Economy Affects California and US Agriculture

Before reviewing some data and empirical analysis it is important to outline how the economic situation in another part of the world affects agriculture back here in the U.S. There are six major ways that the economic situation in Asia may affect the agricultural economy here. First, changes in the exchange rates of Asian currencies relative to the US dollar have made U.S. agricultural products more expensive relative to those produced at home (or in many, but not all, other nations). Second, drops in incomes or dramatically slowed income growth lowers the purchasing power of Asian consumers and reduces their demand for imported food and other consumer goods. Third, precipitous nature of

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*Sumner is the Frank H. Buck, Jr., Professor in the Department of Agricultural and Resource Economics at the University of California, Davis and the Director of the University of California Agricultural Issues Center. Song is an economist with the Ministry of Agriculture, Food and Fisheries in Seoul, Korea, currently on leave as a visiting fellow at the California Department of Food and Agriculture.

the economic reversals in Asia created a short run credit crunch that reduced financing available for imports and a longer term lack of investor confidence for Asian investments. Fourth, the international financial bailouts of some of the Asian countries included some imposed changes in trade policies. Some of these may require more trade liberalization and further opening of restricted markets. Fifth, in some countries the gradual movements towards less traditional and more capital-intensive agriculture may be delayed due to the increased cost of capital available to investors and government. For example, in Korea the gradual conversion of rice paddy land to horticultural crops is likely to be delayed because government aids are less forthcoming and because farmers find financing difficult. A related adjustment suggests return to more labor intensive farming methods, as off-farm employment is less available. Finally, internal economic stress in Asia and the urge to increase the net trade balance may increase political pressures to limit imports to reduce dislocation of inefficient domestic producers and to reduce foreign exchange needed to finance agricultural imports.

These six factors may all be important over some length of run, for some commodities and for some countries. Here we will focus especially on the first two factors because they are clearly important across Asia and have lasting impacts.

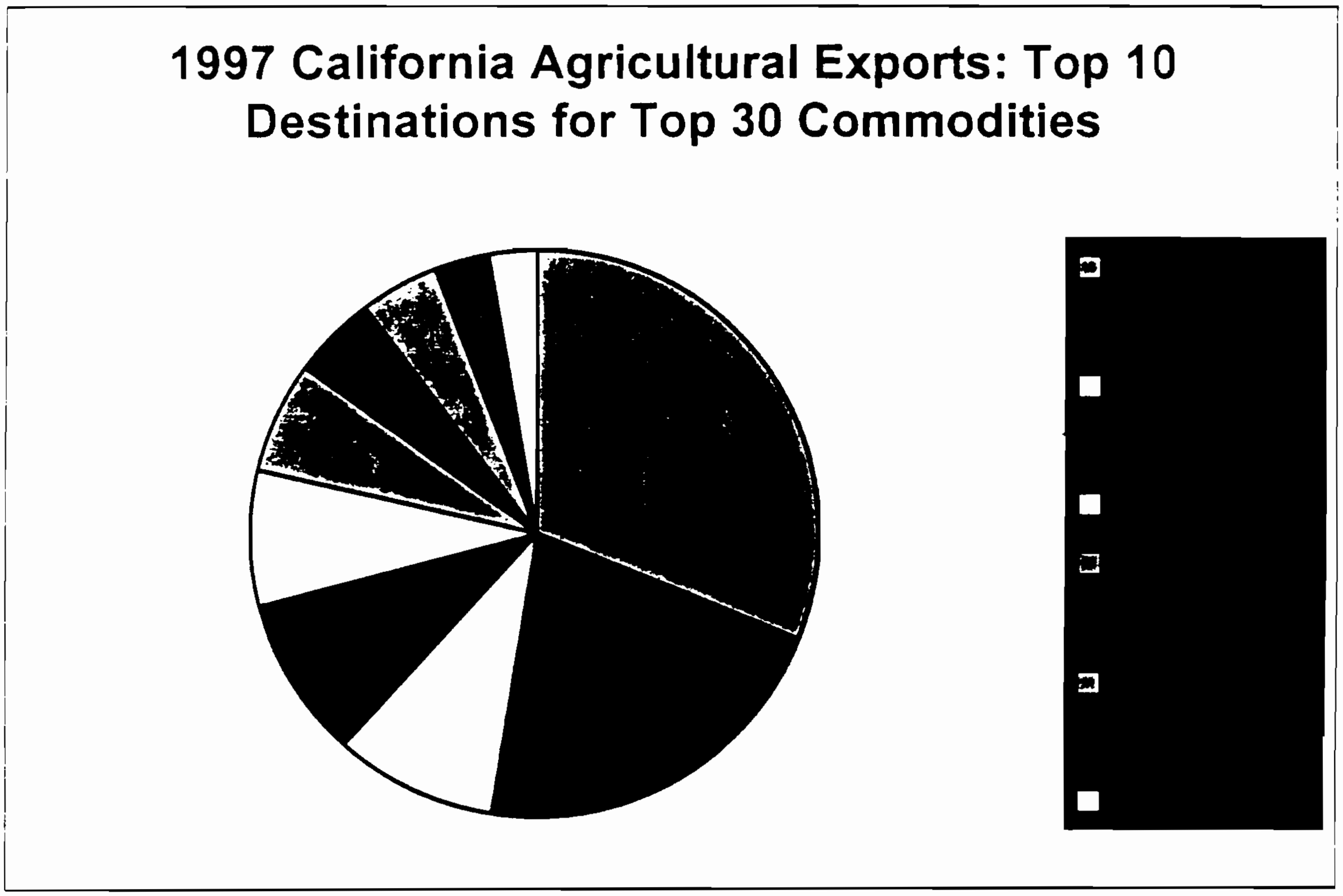
The effects in California agriculture are of two types. First, quantities shipped to Asia are likely to decline. Second, the dollar prices of agricultural commodities will consequently be lower than they would have been in all markets not just in Asia. For some agricultural industries reduced commodity (and other product) demand from Asia could be a benefit as the price of their inputs are likely to be lower. For example, the dairy industry could benefit from lower feed prices. Clearly, the impacts depend on how important Asian markets are, and this varies by commodity.

2. The Importance of the Asian Market for California Agriculture

California data, developed recently by the Agricultural Issues Center, provide a good sense of the importance of direct exports from California to Asia. (For a summary see the AIC Quarterly XII-3 and for detail see the Web site www.AIC.ucdavis.edu. As figure 1 shows, out of a California export total of about $5.7 billion for the top 50 commodities, almost half goes to Asia. The comparable figure for the United States as a whole is about 40 percent. For these 50 major California commodities, an average of about 20 percent of production is exported. Therefore, the Asian share of total sales for these commodities averages about 10 percent.

These aggregate percentages conceal considerable variation across the commodities for which Asia is most important and across the countries within Asia that are most important as destinations. Space constraints limit how much detail we can provide here, but a few facts must be stressed. First, Japan is key. For California and for the United States as a whole, shipments to Japan comprise almost half of all exports to Asia and Japan is important for a large variety of commodity exports. Other Asian markets with imports of more than $100 million from California are (in order of the export value of shipments): Korea, Hong Kong, Taiwan, China, and Indonesia. Thailand, the Philippines and Malaysia are also significant destinations for some commodities both for California and for the United States as a whole.

Figure 1: The Distribution of California's Agricultural Exports



Cotton has the highest value of California agricultural exports. More than 80 percent of California cotton is exported (worth more than $900 million) and almost all of the cotton exports are to Asia, with Japan, Korea, China and Indonesia heading the list. For almonds, wine, and table grapes, Japan is the only Asian market in the top export destination. For oranges, Hong Kong, Japan and Korea all are important.

3. Asian Economic Situation is Serious Indeed

We will highlight two dimensions of the Asian economic decline of 1997 and 1998. First, as shown in table 1, there have been large drops in the value of domestic currencies relative to the dollar in all of East Asia, except China and Hong Kong. The gradual decline in the value of the yen began earlier but continued in the later half of 1997. The yen and the Taiwanese dollar each have lost some 20 percent of their value over this period. The other major currencies have lost around forty percent, except the Indonesian rupia which, in September 1998, was worth only 20% of what it was worth 15 months earlier.

This currency depreciation means that goods from the United States are all much more expensive in the region relative to what they were in early 1997. Further, since the Australian dollar, among others, has also fallen, U.S. goods are also expensive relative to goods from other exporters. (That does not apply to exports from Europe, where currencies have maintained or even gained relative to the U.S. dollar.) The one positive piece of information on this score is that the exchange rates in the region seem generally to have stabilized. Indeed a couple of currencies, the Korean won and the Thai baht, have firmed significantly from lows reached at the end of last year.

Table 1: Quarterly Exchange Rate Depreciation Ratio
(June 1997 = 1.0)

Year/ Month	Japan	Korea	Taiwan	Philip.	Indonesia	Thailand	Malaysia
97.6	1.00	1.00	1.00	1.00	1.00	1.00	1.00
97.9	0.95	0.97	0.97	0.77	0.75	0.69	0.78
97.12	0.88	0.52	0.85	0.66	0.45	0.53	0.65
98.3	0.86	0.64	0.85	0.70	0.28	0.63	0.69
98.6	0.81	0.65	0.81	0.64	0.17	0.59	0.61
98.9	0.84	0.64	0.81	0.60	0.22	0.63	0.66

The second primary dimension of the economic crisis in Asia is the loss of income relative to the growth that the region had been experiencing in recent decades. Notice in table 2 the robust growth rates that occurred in all these East Asian countries in 1996. This had been the pattern for decade. On an annual basis, even 1997 was a pretty good year for many countries. That is not true for 1998. All countries except China and Taiwan will experience growth rates near zero or significantly negative. The case of Korea is typical. After decades of very rapid GDP growth on between 6 and 10 percent per year, Korean growth slipped to 5.5 percent in 1997 and will be a negative 4 percent (or worse) in 1998. Table 2 shows a small positive growth rate for Korea in 1999, but many observers now think that this is optimistic. Thus relative to a pre-crisis growth rate of about 7 percent per year, the growth was 1.5 percent below trend in 1997, about 11 percent below trend in 1998 and another five percent below trend in 1999. Thus, by 1999, Korea will have lost at least 16.5 percent of GDP from where it might have reasonably expected to be when making plans in the spring of 1997.

Table 2: Real GDP Changes in some Asian Countries

(percent change, year to year)

Year	Japan	Korea	Taiwan	HK	China	Philip.	Indon.	Thai.	Malay.
1995	1.4	8.9	6.0	5.8	10.2	4.8	8.2	8.7	9.5
1996	3.5	7.1	5.7	4.6	9.7	5.7	8.0	6.4	8.6
1997	0.9	5.5	6.8	5.3	8.8	5.1	4.6	-0.4	7.8
1998(p)	-1.3	-4.2	5.9	-3	7.5	2	-9	-6	-4
1999(p)	0.6	1.8	6.2	-1	7.5	2.5	--	--	0.4

4. Initial Impacts in California and U.S. Agriculture

We can learn some about the impact of the Asian economic mess by examining the U.S. agricultural export experience in the first seven months of 1998 compared to the same period in 1997. Exports to Europe and North America actually increased over this period so total exports have not preformed too badly. However, when we look at specific Asian markets, we see the impacts of income losses and exchange rate declines. Exports to Japan are down 11 percent, exports to Korea are down 29 percent, exports to Taiwan are down 36 percent (in part because of a unique disaster in the Taiwan hog industry), and exports to Hong Kong are down 7 percent. Total U.S. agricultural exports to Southeast Asia are off about 30 percent.

Much of the losses of U.S. exports are in feed grains and oilseeds. But, there are also losses for commodities particularly important in California. Cotton exports in the first seven months of 1998 are down 7 percent from the same period in 1997, while fresh fruit exports are down 15 percent. Tellingly, tree nut exports, which go primarily to Europe, are up 16 percent.

5. Prospects for the Future of Exports to Asia and Impacts in California

Let us now discuss some issues of particular importance for California agriculture. When the value of the dollar rises, it costs the customer more in their own currency, even though the U.S. seller sees no more dollars in return. In general, the products most sensitive to price increases are those for which the consumer has relatively close substitutes that did not experience the price increase. For some U.S. export products, there are clear domestic or regional substitutes available at a reasonable price. For example, beef sales to Korea or Southeast Asia will suffer relative to domestic beef, Australian beef and cheaper domestic pork or poultry. The same reasoning applies to fresh fruit imports. Imported beef and fresh fruits and vegetables are also relatively sensitive to income declines, so these products may expect substantial export declines to Asia. This lack of demand also means downward price pressure in all markets.

Cotton exports to Asia are different from other farm commodities because cotton is an industrial raw material that is largely re-exported after processing. This means that the income and price factors apply differently to cotton. Consider cotton exports to Korea. First, Korea grows no cotton so there is no local substitute available. Second, because the textile processing industry is capital intensive and factory owners lose when their plant is not operating, there is a tendency to be less price-sensitive for raw material inputs. Third, as the price (in won) of imported cotton went up, so did the price of cotton textile products shipped to the U.S. and Europe. (This effect does not apply to textile products that stay in the Korean or Japanese markets). Finally, since much of the cotton textile production is not destined for the local market income, drops in Korea have a diluted effect on the Korean demand for cotton. In general, short-term credit problems were perhaps more important for cotton exports than were price and income effects. Finally, for the rest of 1998 and 1999, the extremely poor cotton crop that California has experienced in1998 may be more important than the Asian situation.

It is also useful to devote a paragraph specifically to Japan. The economic problems in Japan have not resulted in the kind of severe contraction experienced by the Korea or the nations of Southeast Asia. Nonetheless, for California the situation in Japan is perhaps more important. First, Japan is by far the largest export market and the most diverse market for California agriculture. Second, the economic situation in Japan has been poor for several years now. If forecasts prove true, growth from 1995 to 1999 will have averaged only about 1 percent per year, with almost all of that occurring in 1996. This lack of growth in Japan, coupled with the massive declines in asset values, means that Japan is likely to be a depressed market for years to come. Trade barriers cause imported food products to be expensive luxury items in Japan. Therefore, prospects are bleak for export growth in that market. Rice is an exception because an expanding import quota for rice is mandated by the Uruguay round GATT trade agreement. Indeed, a positive outcome of the current economic turmoil in Japan would be if consumer and voter dissatisfaction cause trade policy changes that allowed more imports to compete directly on the basis of price in the Japanese market.

Overall, it looks as though the Asian export picture for U.S. and California agriculture will remain depressed for another year or so. However, given poor harvests in 1998, it is not clear if California agriculture will be in a position to supply the Asian markets, even if demand were to pick up next year.

New Technologies for Precision Agriculture

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Site-specific management, also called precision agriculture, is the management of agricultural crops at a spatial scale smaller than that of the individual field. The introduction of site-specific management practices into crop production was made possible by the confluence of a number of technologies, including yield monitoring, remote sensing, geographic information systems, global position systems, and variable rate application technology. The initial development of precision agriculture methodology took place during the late 1980's in the corn/soybean/wheat production systems of the Midwestern U.S.A. For a variety of reasons research into this technology did not begin in California until the mid 1990's. A number of factors, however, make California production systems well suited for site-specific management. In particular, the generally cloud-free skies during the summer growing make California particularly well suited for remote sensing.

In order for site-specific crop management to be commercially feasible in a particular field three criteria must be met. First, the field must have substantial variability in its properties, including yield. Second, it must be possible to measure that variability. Third, it must be possible to make use of the measured data to modify management practices for improved economic yield. It is widely accepted that technology is ahead of science in precision agriculture. That is, although certain technological improvements would provide measurable benefit, currently existing technology is in all ways sufficient to support adoption of site-specific management practices. What is preventing their adoption is the inability to interpret data we have for use in management decisions in crop production. This will involve determining the causes underlying spatial variability and integrating responses into a site-specific program.

There are six primary technologies that are used in precision agriculture. These are intensive soil sampling, remote sensing, geographic information systems, yield monitoring, global positioning systems, and variable rate application technology. Intensive soil sampling means simply collecting soil samples at many different places in the field. Typically this is done on a square grid of roughly one sample per acre. These are analyzed for N, P, K levels; clay, sand and silt content, etc. Remote sensing can be used in the form of aerial infrared photographs that indicate the vigor of vegetation at each point in the field. A geographic information system, or GIS, is a computer program that stores spatial data and generates maps of the data. The soil sample and remote sensing data can be entered into a GIS and transformed into a map of the field's soil and vegetation properties. A yield monitor is a device that is attached to the harvester and measures the rate of harvested material coming from the field. A global positioning system (GPS) is a device that uses signals sent from satellites overhead to determine, with an accuracy of about a meter, the exact position on the earth's surface. By mounting a GPS on the harvester and linking it to the yield monitor, the yield at each point in the field can be recorded. This can then be entered into the GIS to produce a yield map of the field. Based on the combined information from the maps of the field the grower can, when he applies an input (such as fertilizer), use the GPS to determine exactly where he is in the field adjust the application rate accordingly using a variable-rate applicator.

All this works well in theory; there are of course some major difficulties to overcome in practice. For many California crops, the most important is a lack of commercially available yield monitors. Yield monitors for combine harvested crops are readily available, but monitors for cotton, sugar beets, processing tomatoes, and potatoes are just coming on the market. A more serious issue involves adjusting input application rate based on soil and yield data. In order for the farmer to properly adjust the application rate of an input, he must know by how much and under what circumstances to adjust it. Considerable research has been done in Midwestern cropping systems to address this question, but much more needs to be done. Most of this research has focused on the precise application of fertilizer nitrogen.

The complexity of precision agricultural practice can be illustrated through a variable-rate Pix trial conducted by D. Munier, S. Wright, and B. Weir and reported in Volume 33 of California Cotton Review. The experiment used an ingenious mechanical device to adjust the rate of Pix application so that more Pix was applied where the crop was taller and less where the crop was shorter. When compared with a uniformly applied control, the variable-rate trial had a significantly *lower* yield. It is evident that the plant's yield response to any input is complex and that precision agriculture practices will require a lot of research to develop. Many Midwestern growers, however, find the information gained from yield and soil maps helpful by itself in their farming operations. They can adjust their practices based on these maps and conduct their own in-field experiments with fertilization, irrigation, and even variety selection.

At present, precision agriculture research in California is just beginning. The irrigated cropping systems here have little in common with those in the Midwest. We are still at the stage of identifying how precision agriculture will be carried out here and which practices are appropriate for this technology. Researchers will be listening carefully to growers in trying to develop these practices, and the industry can help to provide researchers with guidance as to how to develop precision agriculture techniques that work for California crops.

THE ENVIRONMENT FOR AGRICULTURE IN THE 21st CENTURY

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INTRODUCTION

Farmers have always been stewards for the environment. However, as we head into a new century, the necessity to address environmental concerns will never be more dramatic or ever more critical. The steadily growing population is increasingly surrounding our farms, and slowly, but surely, infiltrating our legislative strongholds. In fact, it is doubtful that California will have more than one or two farmers in both the state and federal legislatures. As a result, an increasing population, uneducated on the ways and means of agriculture, will be dictating to farmers on how to farm.

Farmers in the United States, particularly those in California, already face the toughest, most demanding environmental rules and regulations in the world. As we begin the 21st century, two environmental issues will be leading the way: air quality and water quality. To remain viable, it will never be more important for farmers to become involved and educated on these crucial environmental issues.

AIR QUALITY

Ozone

Many of you have heard the term smog, and probably have attributed that term to the Los Angeles area. However, the problem of smog is much more far reaching than that. Most of the Air Basins in the state of California, are classified as non-attainment, which means that they exceed the National Ambient Air Quality Standard (NAAQS) for ozone. Furthermore, all of the primary agricultural regions in the state are classified as non-attainment under the California Ambient Air Quality Standard for ozone. Smog, or ozone, as it is properly known, is caused by the chemical reaction of oxides of nitrogen (NO_X) and volatile organic compounds (VOCs), in the atmosphere in the presence of sunlight. Hence, this is why most ozone exceedances occur in the summer when sunlight is so prevalent, and there is little or no air movement.

The question that many growers ask is "How am I affected by ozone?". Well, regulations implemented to bring an air basin into attainment with an ambient air quality standard are growing intense. Agriculture is currently being affected in four primary areas including; VOC emissions from pesticides, on-road and off-road engines, NOx emissions from soils, and the regulation of diesel fuel. We need to discuss each of these in somewhat more detail to understand their full impact.

Pesticides are currently being regulated by the California Department of Pesticide Regulation (DPR). Besides the many regulations for pesticides that we are all well aware of such as worker protection standards, FIFRA, FQPA, and others, pesticides are also being regulated under the current California State Implementation Plan (SIP) to reduce the overall VOC emissions inventory statewide by 20% over a 15 year period extending from 1990 to 2005. Implementation of this program is being carried out in a tiered approach. Failure to meet the requirements will lead first, to voluntary control measures, and second, to mandatory measures, such as reformulation. Reduction milestones are set for every five years to ensure that the reductions are occurring. To date, the state has already met the necessary 20% reduction, and no regulatory measures are being forced upon agriculture at this time to increase that reduction. However, a year of increased pesticide use might trigger the necessity to take action. Also, there is some concern with the new, more stringent ozone standard. It is feared that EPA or CARB may ask DPR to consider further VOC emissions reductions from pesticides, which would almost assuredly trigger a mandated reformulation of certain pesticides.

One particularly interesting area of concern is the issue of oxides of nitrogen emissions (NOx) emissions from the soil and the application of fertilizer. Federal EPA has funded some studies in North Carolina that appear to indicate significant emissions from winter fallow fields. CARB has also funded a "soil NOx" study, which was conducted by U. C. Berkeley in 1995. Conclusions from this study presented a broad range of emissions rates for various crops, but indicated that "NOx fluxes in the San Joaquin Valley ... are <u>not</u> remarkably high in comparison with the range of values published in literature". There seems to be a belief in the environmental and regulatory community, that NO_X emissions from fertilizer applications are significant.

The cost of farming equipment may also be on the increase as a result of tighter ozone regulations. Most on-road and off-road engines have been targeted for some sort of emission reduction for NOx. Heavy duty on-road diesel engines are the current primary target, since they are considered to be one of the largest sources of NOx emissions in the state. There have been a flurry of efforts to develop incentive programs throughout the state to retrofit existing trucks and buses with new low emission engines. There is also a renewed effort to consider off-road engines for emission controls. In fact, the CARB is currently considering regulations on heavy duty off-road equipment. In addition, in 1997 the ARB also considered the adoption of low emissions standards for existing irrigation pump engines. This would be at an estimated cost of $195,000, according to ARB, for only an 80 hp diesel engine. There is no resolution of this issue at the present time.

The attempt to achieve attainment for ozone has created additional implications for the sources of diesel emissions. We have already discussed the engines, but we must also mention the mandated reformulation of diesel fuel in California, and the recent action by the CARB to list diesel particulates as a Toxic Air Contaminant (TAC). In addition to limiting the sulfur content of diesel fuel, the ARB also mandated a 20% reduction in aromatics. A reduction in aromatics reduces the NO_X emissions from diesel engines, which CARB estimates to be approximately 70 tons per day statewide.

It must be mentioned that this past year EPA tightened the ozone standard, replacing the old one hour standard with a new 8-hour standard. The ozone threshold was dropped from 0.12 ppm for a one hour maximum to 0.08 ppm over an 8-hour period. This development translates into more non-attainment areas, and more importantly means that those areas who were close to attainment with the old standard, are probably not going to be in compliance with the new standard and will face new additional rules and regulations to achieve the new standard. For example, there have already been discussions on increasing the level of reductions for VOC emission reductions from pesticides from 20% to 40%. There have also been discussions on increasing control requirements for on-road and off-road engines as a result of this new tougher standard.

PM_{10}

Many of you have heard of the term "PM_{10}" in the past three or four years. PM_{10} is a categorization of particulate matter that is smaller than 10 microns. These are the particles that are believed to be able to get past the human body's normal defense mechanisms and actually penetrate the membranes in the lungs causing serious health problems. Most of the agricultural regions in the state are non-attainment for the Federal PM_{10} air quality standard, and all of the agricultural areas in California are non-attainment for the state PM_{10} ambient air quality standard.

Agriculture is affected in many ways by the regulatory requirements being put into place to achieve attainment of the PM_{10} standard. Currently, most of the requirements are focusing on "fugitive dust" sources such as unpaved roads, harvesting, discing and land preparation activities, and unpaved lots. Ag burning is also a key element that has been, and will be addressed under current and future PM_{10} regulations. But secondary sources are also a concern, such as dairies and feedlots with emissions of dust and ammonia, which can react to form ammonium nitrates. These secondary particles are the leading components of particulate matter exceedances during the winter months.

The most current discussions have centered on fugitive dust emissions from agricultural operations such as harvesting and land preparation. The San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD), South Coast Air Quality Management District (SCAQMD), and Maricopa County Air Pollution Control District in Arizona, have some sort of plan in place to regulate emissions from these type of operations. In California, these plans contain requirements for voluntary "Resource Conservation Plans" (RCPs), which are being developed as scientifically valid information is developed demonstrating actual emission reductions from new equipment or agronomic practices. Maricopa County, Arizona, is similar, except that farming operations under their program fall under a permit, that mandates the requirement to have a fugitive dust plan. This issue has been elevated to such a level that a special USDA-NRCS Air Quality Task Force was created in the 1996 Farm Bill to deal with air quality issues and agriculture. The Task Force recently adopted the initial framework for a voluntary control measure concept. When finalized, the plan will be adopted by air districts nationwide to use in implementing air quality measures on agricultural operations.

It is inevitable that growers will have to address some portion of their operation to satisfy PM_{10}

concerns. It may be an unpaved road, an equipment storage yard, reduced tillage, or a new "low emission" piece of equipment. Almond harvester manufacturers are already testing new pieces of equipment, designed to have lower PM_{10} emissions. With the USDA-NRCS Agricultural Air Quality Task Force in place, the CRPMAQS Study underway, and the efforts of those agricultural organizations involved, it is hoped that the impact will be minimized. However, there is little doubt that each and everyone of us will be affected in one form or another, by attempts to achieve the PM_{10} standard.

$PM_{2.5}$

The "new kid on the block", in terms of air quality, is the new national ambient air quality standard for $PM_{2.5}$. $PM_{2.5}$ is a categorization of particles less than 2.5 microns in size. Recent health studies appear to indicate a more predictable link between health risk and $PM_{2.5}$. It is believed that the smaller particles are truly the ones that are able to reach the critical areas of the lungs. However, EPA has not dropped the air quality standards for PM_{10}, and efforts continue to attain them. $PM_{2.5}$ has a propensity to form in the winter time, especially when foggy conditions prevail. The biggest source of $PM_{2.5}$ appears to be secondary aerosols, such as ammonium nitrates and sulfates. However, some preliminary studies have indicated that soot, especially from wood fireplaces, may play a dramatic role in the formation of $PM_{2.5}$.

Ammonia emissions may also play a key role in the formation of $PM_{2.5}$ through creation of secondary particulates. Similar to "soil NO_X", some scientists have indicated the potential for significant amounts of ammonia emissions, "soil NH_3", to be emitted from soils and fertilizer applications. A study released in 1995 indicated that NH_3 emissions from soils and fertilizer applications amounted to 46% of the total NH_3 emissions in the San Joaquin Valley. To verify this theory, some actual field sampling was conducted in the winter of 1996. NH_3 measurements were taken at an alfalfa field, a dairy, and a wastewater treatment facility. The results are not necessarily conclusive, but indicate that dairies are a much more significant source of ammonia emissions than an alfalfa field. While somewhat inconclusive, the study did appear to substantiate the agricultural community's claim that farms are not a significant source of ammonia emissions during the winter, the critical time of the year for secondary particulate formation.

In order to address many of these concerns, the agricultural community was one of the original sponsors of the California Regional Particulate Matter Air Quality Study (CRPMAQS). This is a $27 million study aimed at determining the primary sources of PM_{10} and $PM_{2.5}$, and how they contribute to exceedances of the ambient air quality standards. The geographic area covered by the study includes the Monterey, Sacramento, San Francisco, San Luis Obispo, San Joaquin Valley, and Desert areas. It is a jointly funded project where sponsors include: USDA, EPA, CARB, DOE, DOD, SJVUAPCD, BAAQMD, Cotton Inc., CCGGA, Nisei Farmers League, and many numerous agricultural organizations. The study will run from 1993 to 2003, with a preliminary field study taking place in 1995, and major field studies being conducted in 1999 and 2000. For agriculture, the key questions to be answered include PM_{10} and $PM_{2.5}$ emissions from agricultural harvesting and land preparation activities, NOx and NH_3 emissions from soils, and emissions of PM_{10}, $PM_{2.5}$, and NH_3 from dairies and feedlots. Actual field measurements from these operations are already underway, and will continue throughout 2003.

The primary concern here is the extremely low ambient air quality standard that has been set for $PM_{2.5}$. With very little ambient data on $PM_{2.5}$ in existence, no one is sure if it is even possible to achieve the low levels. The CRPMAQS will definitely provide some answers, unfortunately the standards are already set in law. The best that can be accomplished with the CRPMAQS is to find the most feasible, most economical way to attempt to achieve the standard.

Air Toxics

The term "air toxics" has now reached agriculture. In recent months, diesel exhaust has been a highly talked about subject. The CARB has recently classified diesel particulate emissions from diesel engines as a "Toxic Air Contaminant" (TAC). We should expect to hear more as measures are put into place to "lower the risk" from diesel exhaust. Lower emissions standards will be set for both on-road and off-road engines. Emission standards will be set for activities not currently regulated, such as diesel trains, and diesel irrigation pump engines on farms.

Pesticides can also be classified as "Toxic Air Contaminants" (TACs). DPR is already working on several pesticides including: DEF, Temik, Telone, and methyl parathion. Ambient air monitoring is already underway in farming areas where these chemicals are used. This data will be used to determine whether the chemicals pose a health risk to the surrounding communities, and then whether the chemicals should be listed as TACs. If listed as a TAC, restrictions would be put into place to lessen the risk to the exposed populations.

WATER QUALITY

Non-Point Sources

The issue of non-point source runoff is growing. Environmental activists are pushing for compliance with the Clean Water Act, and most point sources have had to address water quality from run-off for years now. The emphasis is beginning to point towards non-point sources, especially agricultural drainage waters. U.S. EPA has adopted the California Toxics Rule (CTR), which established levels for specific pollutants in California waters. The State Water Resources Control Board (SWRCB) is also in the process of addressing the matter of agricultural run-off, through development and implementation of the Enclosed Bay and Estuary Plan (EBEP) and Inland Surface Water Plan (ISWP). These two plans would establish water quality standards for agricultural drainage waters as required by the Federal Clean Water Act, and develop implementation plans for those standards. While specific details have yet to be finalized, the plans are being developed and will play a critical role in farming in the 21st Century.

CONCLUSION

In summary, environmental matter will be of the utmost concern in 2000 and beyond. Naturally so, with urban encroachment, and increasingly environmentally conscious legislature. It is not the end, but it truly is the beginning of a new era. One in which farmers will have to be ultimately more conscious about the methods and practices of growing and raising their crops. With new more stringent regulatory requirements being set in motion, it is more imperative than ever to become involved in the development and implementation of these rules and regulations. It is also necessary to incorporate provisions for these matters in any long term plans, as environmental rules and regulations are not going away, only growing more stringent and more intrusive.

COMMERCIAL WEATHER SERVICES

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INTRODUCTION

"Everyone talks about the weather, but nobody does anything about it." Commonly attributed to Mark Twain, this observation was actually made by Charles Dudley Warner in the *Hartford Courant* in 1897. Indeed, one cannot change or "fix" the weather, but one can evaluate trends and forecasts that may help in business planning. In the farming business, accurate weather predictions can make a positive economic impact on crop and livestock production. They can be used in time and resource management, which, in turn, may lower operating costs.

Unfortunately, no one is 100 percent accurate when it comes to forecasting weather. Short-term forecasts are not always on target and long-range forecasting remains an inexact science. However, there are trained, experienced specialists in the private sector who can help farmers make more informed production or marketing decisions based on weather trends. These specialists can be of value to farmers who do not have the time to study weather conditions affecting their business.

The commercial weather industry was founded in the mid-1940's in the United States. Over the years the industry has grown greatly to provide a wide variety of services offered by companies ranging from one man shops to companies with over 700 employees worldwide. Although the commercial weather industry has been in existence over 50 years, it has seen most of its growth in the past 18 years.

WEATHER FORECASTING BY THE PRIVATE SECTOR

The role of the commercial weather information service provider is varied. While many may think of a private weather company being involved only in weather forecasting, the role of the commercial weather industry goes far beyond this one aspect of meteorology.

Farmers have many short-term "weather resources" available to them for free. They can watch or listen to local broadcasts, watch the Weather Channel, refer to farm publications, or read the *Old Farmer's Almanac*. They can talk with business associates at the local grain elevator, for example, or rely on their own instincts.

So, why would a farmer need (and pay) a weather consultant or weather service? The Weather Channel and local television and radio weather forecasters provide good general information. However, they do not know what end users plan to do with the information. The private weather consultant interprets weather information tailored to customers' needs. Farmers want specifics, such as whether rain is expected in the morning, afternoon or evening, so they know when to apply fertilizer, for example. Consultants put forecasts in perspective.

If the farmer has good advice that it will rain in the morning or evening, he or she can schedule planting or herbicide application accordingly. Without an informed opinion from someone who regularly tracks weather, a farmer might delay doing such a job and lose valuable production time or miss a narrow application window. If it looks threatening, but never rains, you can waste a day. The private weather forecaster provides a shoulder to lean on when weather sensitive decisions need to be made. Having a knowledgeable meteorologist looking out for one's situation is a tremendous stress reducer.

Farmers need forecasts for their immediate areas. General weather forecasts, including those on television and radio broadcasts, are based on information primarily from airport observations. These reports may be accurate for the urban areas where airports are generally located, but not rural areas where most farmers operate.

ROLE OF THE PRIVATE WEATHER CONSULTANT

Because weather data was free for so many years, it has been difficult for the agricultural industry to adjust to paying for services. Therefore, it is important that consultants help farmers understand how weather information may be used to improve their return on investment, particularly in the multi-million dollar citrus crop industry that is affected by frost.

Weather is everywhere. It's on television and radio and, therefore, farmers expect it for free," Consultants need to do explain how farmers can use targeted forecasts to their advantage. A more targeted forecast will cost money but is likely worth it in the long run. Choosing a regional meteorologist as your weather consultant is advantageous because this person is more familiar with how weather patterns behave in a farmer's local area.

Weather forecasting firms generally specialize in short (present to 48 hours) and medium range (3 to 10 days) forecasting or in long range (one month and beyond) forecasting. Long range weather forecasting is an entirely different science than providing short and medium range weather predictions. Long range forecasters may find themselves studying sea surface temperatures or tree rings as compared to the short-term weather forecasters using medium range numerical models output twice daily. Long-range weather forecasting is an inexact science so it is helpful to look at one's track record. The mission of the private weather consultant, both short and long term forecaster, is to help clients understand how future weather will impact their business.

National retailers (i.e., WalMart, Kmart and Sears) use commercial weather information providers to forecast weather-related demand for lawn and garden products, for example. This can help retailers make more efficient use of inventory and distribution centers, or have the right products in the right locations at the right time. The private weather consultant can help their clients apply knowledge of weather to their business. Farmers can also use long-term forecasts in their purchasing and marketing plans.

Accurate long-range forecasting (two to four months out) and a good marketing program could help a farmer improve his or her bottom line by ten to fifty percent. The key is finding an advisor with a track record of accurate predictions. One should also note there are considerably few long-range weather forecasting firms. Most commercial weather services provide short and medium range outlooks.

Another reason a farmer might hire a weather consultant is for guidance on prediction models. Insect and disease models which use local weather information can be of value to crop producers. An example would be a model that predicts the development of mildew in grapes based on temperature. A grower familiar with such a model might apply a fungicide if conditions are right for mildew development, thus preventing or reducing mildew damage and economic loss by treating early.

In addition to disease and insect prediction, a farmer might choose a weather consultant for help in irrigation scheduling, frost warnings, planting and harvest dates, as well as pesticide, herbicide and fertilizer application. The farmer might also use the consultant's advice to schedule labor and burn fields.

WEATHER INSTRUMENTATION SERVICES

A few commercial weather forecasting firms also specialize in weather monitoring services for industrial and agricultural applications. Meteorological instrumentation can range from a manually read field thermometer to a complete automated weather station. Pricing on instrumentation can vary just as much, ranging from a few dollars to several thousand dollars.

Like any product on the market, meteorological instrumentation is similar, you get what you pay for. The farmer or agricultural consultant must evaluate his needs and his budget. Then he should consult with the weather instrumentation consultant for the best hardware and software that will meet his needs and economic constraints.

While a complete industrial quality weather monitoring system can be very expensive, it should be looked at as a long term investment. However, the return on investment can be short if the farmer is able to utilize the information in his field to make better economic decisions. The higher quality meteorological monitoring systems ranging in price from $3500 to $5500 should have a life span in the field of 15 years or longer.

Automated meteorological monitoring systems for agricultural applications generally include the following sensors.

Air Temperature	Canopy Temperature	Relative Humidity
Wind Speed	Wind Direction	Precipitation
Solar Radiation	Leaf Wetness	Soil Temperature
Soil Moisture		

Information from the automated weather stations can be gathered by various methods, including:

Telephone Modem	Voice Synthesizer Modem	Short Haul Modem
Cellular Telephone	Radio Telemetry	RS232 Direct Interface
Storage Module	Direct Readout in Field	

An automated weather station collecting data in the farmer's field or orchard can provide a wide range of benefits to save time and money. Some of these applications are:

Evapotranspiration for Irrigation Scheduling
Wind Direction and Speed for Chemical Applications
Degree Days for Harvest Dates
Degree Days for Phenology Models
Disease Models
Fertilizer Applications
Frost Warning
Local Climatological Database

WHAT TO ASK OF YOUR WEATHER CONSULTANT

Have a clear set of expectations. Communication is essential. The farmer must discuss his or her needs and wants with the consultant. The farmer also may need to educate the weather consultant on some agronomic issues. While many questions are asked up front, the question and answer process should be ongoing.

Farmers who are interested in what a weather consultant might have to offer are advised to ask questions of themselves as well as the consultant. Here are some questions one might ask.

- How does weather impact my business? At what levels? Weather may impact availability and price of feed in the livestock business, for example. A consultant may alert the farmer to weather conditions affecting feed.

- What would I do differently if I was told what the weather would be like?

- If I had good weather information would I be able to make better decisions and save money and time? If the answer is yes, then the farmer should ask about specific information needed to benefit the operation.

- Can my size of operation pay for weather services? Will a consultant make a difference in my profitability? What return on investment will I need to add a weather consultant to my budget?

- What educational and work experience does the consultant have? Has the consultant worked with other farmers or agribusinesses? How do those farmers assess the consultant's abilities?

- Does the weather consultant produce localized forecasts targeted to my needs?

- Does the consultant specialize in short-term or long-term forecasting?

- What is the consultant's track record? How accurate is he or she?

- On what types of information or data does the consultant base predictions? Is this applicable to my needs?

- Does the consultant specialize in weather monitoring systems?

- Does the consultant specialize in the commodity market?

- Does the service last a growing season? month to month? a year? It may make sense to use a monthly service because services change as a crop progresses.

WEATHER AND THE WEB

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INTRODUCTION

Although only five years old, the World Wide Web has become the most ubiquitous and efficient source of information in history. With approximately 27% of American homes and 25% of California growers using the "Net", the amount of information, including weather, will undoubtedly increase in the future in addition to even more homes and growers getting connected.

Not only has the *point and click* feature of the Web made the Internet easier to use, it has also visually opened the door to the dissemination of information. Now one can see very recent satellite photos, radar imagery and 3-D visualization using a PC, an Internet connection and a browser.

Weather information on the Internet has become rather ubiquitous. All the major print and electronic media have weather information links. There are more than 90 web sites dedicated to broadcasting weather information. Most sites are free, but some offer more forecasting or site specific information for a subscription fee.

WHAT'S OUT THERE?

The following web sites are the major weather niches on the Internet.

Accuweather

Located at http://www.accuweather.com, Accuweather offers features that include current conditions, U.S. Weather Maps, U.S. Satellite imagery, local radar and forecasts chosen by a zip code or city search engine.

For a fee, Accuweather also offers Hour-By-Hour(tm) Forecasts. This service displays the forecast for every hour over the next 10 days or 240 hours. The product includes; Temperature, Dew Point, Relative Humidity, Wind Direction, Wind Speed, Wind Gust, RealFeel Temperature(tm), Cloud Cover, Precipitation Type, 1 Hour Rainfall, 1 Hour Snowfall, 1 Hour Icefall, 1 Hour Liquid Equivalent and the UV Index.

Annual personal subscriptions start at $39.95. Accuweather offers a free 30-Day non obligatory trial.

AGRICUTURAL WEATHER

Found at http://www.agriculturalweather.com/, this site offers numerous features including specific California regional weather linked to a gopher directory. It also offers agricultural information that could be related to weather such as agricultural market data, dairy, livestock, grain, fruit and vegetable, poultry, cotton, tobacco, crop progress and international reports. Planting and harvesting dates are also offered in HTML or PDF format.

Agricultural Weather also has computer generated extended forecasts for 10 Day Temps, 10 Day Precipitation, 14 Day Soil Moisture and Non Computer forecasts for temperature and precipitation.

Agricultural Weather Information Service Inc.

Located at http://www.awis.com/ag_samples.html, the site prides itself as the "Ag Weather for Ag Producers". For a subscription fee, AWIS offers soil temperature, drying potential, rain forecasts, pesticides application timing, WISDOM potato late blight, TOM-CAST tomato disease forecast products.

Other models include AU-Pnut and Jensen-Boyle peanut leaf spot advisory, Insect degree-days, pan evaporation and potential evapotranspiration maps.

7-Day temperature forecast tables and maps are made twice each day and are available for 5,200 locations. AWIS also offers daily ag weather forecasts, growing degree days for cotton and corn (observed and forecast), Chill Hours, Livestock Heat Stress, Livestock Safety Index, Poultry Heat Stress, Minimum relative Humidity Forecasts, Dew intensity and dryoff time.

AWIS also forecasts hourly for air temperatures, wet bulb temperatures, dew point temperatures, and winds inversions. AWIS also offers Tropical Weather Outlooks, Hurricane Advisories, Forecast Hurricane Tracks, Doppler Radar Maps and Satellite pictures

National Weather Service - Interactive Weather Information Network (IWIN)

Located at http://iwin.nws.noaa.gov/iwin/iwdspg1.html and averaging one million visits per day, IWIN is linked from over 8,500 other web sites.

The IWIN site offers current weather conditions for major cities, live data-stream 'PUSH' broadcasts and major satellite and radar imagery.

National Oceanic and Atmospheric Administration

Found at http://www.nws.noaa.gov/, this large site offers current warnings, conditions, weather maps, and storm predictions. It also specializes in regional weather information with specific sub-web sites for Alaska, Central and Eastern U.S., Pacific Rim, Southern and Western U.S.

The NOAA home page opens with current western and eastern US satellite imagery, real time radar for the country, individual state information regarding all aspects of weather and color coded sea temperature maps. The web page refreshes itself every five minutes.

The Weather Channel

Although the Weather Channel is found on cable television, it's also located on the Internet at http://www.weather.com/

The Weather Channel web site has a feature for customizing homepages for your location only. One can also find weather information using a city or zip code search engine. Nationally it also provides breaking weather, tropical updates, all the major U.S. city forecasts and quasi weather related issues such as a health and allergies section, gardening, aviation and of course their own *Weather Channel* bookstore.

EarthWatch

EarthWatch Communications offers a newly developed 3-D weather visualization process. Earth Watch provides numerous software and Internet related products at http://www.earthwatch.com/

Reality3D is an EarthWatch product offering the next generation in weather and news graphics. Combined with EarthVision software, Reality3D allows you to render animations in the background while working on other applications. If you had a Silicon Graphics workstation and are a weather announcer, Reality3D lets you playback your favorite fly-by live on air. This product offers the most recent data in weather graphics

Virtual Weather Set is a product that enables weather or news anchors to interact with the graphics. Television broadcasters could walk into the eye of a hurricane or educate their viewers with a description of severe weather cloud formations

EarthVision is another functional weather graphics system. EarthVision combines the ability to generate weathercasting in 2D or 3D with street level mapping. Street level mapping creates a roadmap for any city in the United States. *EarthVision* is enhanced by StormTracker which allowing viewers to see when and where big storms will strike, within the minute and city block.

Forecast2000 takes satellite and radar loops into the future. This software utilizes sophisticated computer model output to show where the weather will be.

But with all the software available from EarthWatch's web site, the home page also provides customized reports and a National Warnings Area for severe storms and related issues.

Wateright and UC Davis IPM web sites

Traditionally, most of California weather conditions stay fairly constant throughout the summer. During an average June, July and August, the Central Valley turns into one big greenhouse.

One of the main weather related parameters used by growers during the summer is evapotranspiration. A series of statewide networked weather stations are deliberately located in agricultural regions. Known as CIMIS stations (California Irrigation Management Information System), they correlate weather information to assess what the evapotranspiration demand has been. The scientific unit used in estimating evapotranspiration is termed ETo and is reported in inches or depth of water lost.

The ETo data from CIMIS weather stations are available on a web site solely created to help schedule irrigations. The web site known as Wateright (http:www.wateright.org) was designed by the Center for Irrigation Technology and the Bureau of Reclamation. Using Wateright, the user can input soil type, various irrigation systems and CIMIS station locations to create a weekly, monthly or annual irrigation schedule. The site is also divided into agricultural, turf and homeowner categories.

The ETo data can also be accessed from UC Davis's IPM site at http://www.ipm.ucdavis.edu. This web site contains very recent and archived weather data going back to the inception for each specific CIMIS weather station. The site is also one of the most useful on the Internet for pest and disease models, degree day calculations and pest management and identification.

APPLICATIONS OF METEOROLOGY IN AGRICULTURE—AN OVERVIEW

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INTRODUCTION

Growers face increasing pressures to manage their farms economically and in an environmentally sensitive manner. Meteorology affects most aspects of agricultural operations, and by utilizing weather and climate information growers can make operational decisions that minimize risks and maximize profits.

Applications of weather information to agriculture are both strategic and tactical. The climate of a region influences the choice of crop or specific variety to grow. Characteristics such as average conditions and extremes in rainfall and temperature help to determine the natural suitability of a crop to an area and the possible need for modification of the environment. Use of drought tolerant, pest tolerant or resistant, or frost tolerant varieties, can result in reduced need for additional water, pest control, or frost protection measures. In-season decisions, such as when to plant or harvest, by are directly influenced by weather.

Climatic analyses, short and long-term weather forecasts, and data from local weather stations can provide distinct advantages to growers and managers who know how to incorporate the information into their decisions. Weather data and systems information are used as inputs to algorithms or formal or informal sets of decision rules that can produce results to guide growers. Many operations utilize rules of thumb or simple measures to assist decision making: measured and forecast dew points for poultry house ventilation, soil temperature for planting, humidity for optimum harvest, wind speed for pesticide spraying. Increasingly, quantitative tools are being used to process the information and produce recommendations for managing crops.

CROP MODELS

Crop models vary widely in complexity. The simplest ones use degree-days calculated from air temperatures to estimate phenological development. Pest, fertility, or water management actions may be necessary at specific phenological stages, and models may help to predict when the stage can be expected to occur so that a grower can plan operations. More complicated models require temperature, a humidity variable, and solar radiation to simulate the plant's physiological processes, and may provide information on crop stage as well as estimates of plant status in terms of nutrients and water, and expected yield. A grower can respond to crop needs as indicated by the model, and in some cases use the model to test the possible effects of a particular action before execution.

In practice, specific pieces of crop models are usually used, rather than an integrated system that portrays all aspects of crop management. The phenology part of the model may be used for timing harvest, or the bloom part of the model may be used for timing a critical spray, or the fertility part for assessing additional nutrients needed.

WATER MANAGEMENT
Good management is required for efficient and profitable use of water for irrigating agricultural crops and turfgrass. Weather plays an important role in determining irrigation dates and how much water should be applied to the field for each irrigation.

Reference evapotranspiration (ETo) is used to estimate the evapotranspiration rate of a reference crop, in California usually short grass. ETo can be accurately estimated through the use of a model. (The model used widely in California is a version of Penman's equation modified by Pruitt/Doorenbos.) The inputs to the equation are values of net radiation, air temperature, wind speed, and vapor pressure, measured over the reference crop.

Crop water use can be calculated with ETo values and a crop-specific coefficient (Kc) as ETc = ETo x Kc. These ETc estimates can be used to determine day-by-day soil water depletions from field capacity and thus can be used to schedule irrigations.

PEST MANAGEMENT
Choice of crop, variety, and the place to grow it will affect the pest situation to be addressed during a growing season, and all are heavily influenced by climate. Many regions rely on selection of climatically-suited pest-resistant varieties as the primary means of managing pests.

Many in-season cultural practices related to pest management are influenced by recent past, current, or near-future weather. Good water and fertility management can help to avoid conditions suitable for development of plant diseases. Late season pest problems, particularly those caused by rains or which attack only ripe fruit, may be avoided by manipulating the time of harvest by growing a shorter season variety, or planting early or late, if weather conditions are suitable.

Burning of crop residue in the field kills pathogens that would otherwise attack the crop in the next season and can eliminate weed seeds in the top layer of soil. Forecasts of the air temperature profile, winds, and humidity are used to identify times when fields may be burned with least effect on humans.

Pesticide applications are directly influenced by current weather. Inversions, high air or soil temperatures, windy conditions, and fog or rain are unsuitable conditions for pesticide spraying, and rain immediately following a pesticide application will wash the chemical from the plant surfaces, rendering it useless for control.

For some pests, the possibility of aerial transport from one location to another is an issue. Surface winds may transport over short distances, and insects, weed seeds, and disease propagules may travel long distances on upper level winds. Forecasts and analysis can provide warning of pending arrival of these pests.

Quantitative pest management decision tools
Control measures taken at an organism's most susceptible life stage can improve control and thereby crop quality, and reduce costs. In addition, where pesticides are used, observations and

forecasts can be combined into models to provide accurate timing of the spray that improves control, reduces environmental concerns surrounding pesticide use and residues on food, and reduce the likelihood that the pest population will grow resistant to the pesticide.

Development of insects and mites is governed primarily by temperature. Degree-days are commonly used to estimate life stage development. A biofix, or observed biological event, is used as the date to begin accumulating degree-days above or between developmental thresholds. When the degree-day model indicates that an organism is in a susceptible life stage, a farmer monitors the field to determine the presence of damaging populations above an economic threshold for control, or instigates a specific control measure.

Temperature and moisture are the primary weather factors influencing crop disease development, including spore survival. Disease models may relate air temperature, moisture conditions, wind, and rain experienced by the pathogen to spore dispersal, survival, and infection. Models, based on recent past conditions and sometimes forecasts of the important variables, indicate when conditions are favorable for infection and in practice can significantly reduce the number of sprays applied during periods of unfavorable weather. In California, Campbell Soup has been working with growers for five years to encourage their use of a blackmold model on processing tomatoes, and a UC model for powdery mildew on grapes is in wide use. Models of at least 15 diseases on 11 crops are currently being developed or validated by California researchers.

The application of weather data to weed control has focused on current conditions for cultivation or spraying herbicides, including observations and forecasts of winds and temperature for issues relating to coverage and drift; rainfall and wash-off of the herbicide from the target; and air or soil temperature effects on herbicide activity. Currently, operational uses of models describing weed development and population dynamics are rare.

OUTSTANDING ISSUES

Although many have been available for several years, quantitative tools are not in wide use. Direct uses of weather, often one variable related to one farm practice, are more common. Shortcomings in reliability, affordability, timely availability, convenience and wide applicability of models and other meteorological applications contribute to the lack of success. Although the required technology, including weather monitoring equipment, forecasting services, and computer models, is generally available, the information has not been packaged to take into account how the water, fertility, pest, and crop systems overlap. Unfortunately, the farmer rarely has the luxury of managing only one aspect at a time, and the inputs and models will need to be better integrated in order for him/her to make the best decisions.

Other outstanding issues relate to model reliability, applicable scale, adequate model validation, and in some cases sensor design or deployment. Improvements are also needed in making available forecasts of important agricultural variables, at time and spatial resolutions needed by growers to support their operational decisions.

Evaluation and Update of "A Management Plan For Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley, September 1990"

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Summary

In September 1990, *A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley* (Management Plan), also known as Rainbow Report was published by an interagency program comprised of federal and State agencies. In the more than seven years since plan was published, districts and farmers have made progress on implementation of certain components of the 1990 Plan. Field demonstration projects are being conducted to test the feasibility of implementation of some other components of the Plan, thus full implementation has not been achieved. The Management Plan states that "uncertainties in the scientific information base, plus difficulties in forecasting human events, necessitates that the plan be updated from time to time as monitoring, additional studies, and local actions reveal new facts." In 1996, an association of local districts, the University of California, and the California Department of Food and Agriculture proposed an initiative to the San Joaquin Valley Drainage Implementation Program (SJVDIP). The initiative is intended to review the present drainage status in the San Joaquin Valley and review any new information since adoption of the 1990 Management Plan, and update the Plan in three stages. The initiative was adopted in December of 1996. SJVDIP has published a report in February of 1998 on the status of drainage conditions in the Valley and progress made to implement the Management Plan recommendations.

The first stage in updating the Management Plan consists of two tasks. One task is the preparation of reports on San Joaquin Valley drainage problem areas by Subarea Committees. The subarea reports will assess the progress toward, and constraints of implementing recommendations in the Management Plan. The second task will be technical and economic evaluation of the drainage management options recommended in the Management Plan and salt utilization by a set of technical committees.

The second stage will be synthesis of the information developed under activities of the first stage into a report which identifies interactions between drainage management options, trade-offs between management options, and a set of recommendations based on technical and economic considerations.

The third stage will use the recommendations formulated during the second stage along with input from the public sector to formulate an updated management plan and identify

acceptable mechanisms conducive to voluntary implementation.

The Activity Plan implementation, a cooperative effort among SJVDIP agencies, University of California, and stakeholders began by forming eight technical committees: Drainage Reuse, Drainage Water Treatment, Land retirement, Evaporation Pond, Source Reduction, Groundwater Management, River Discharge, and Salt Utilization. The technical committees held a joint meeting in September 1997 at UC Davis. Individual technical committees have met several times and began review of individual tasks. Some technical committees have already developed their draft final reports. Technical committees consist of university scientists, government agencies, and stakeholders representative.

The technical committee reports are due in November of 1998 and the Stage Two report is due in March of 1999.

Three representatives from the San Joaquin Valley Subareas (Grasslands, Westlands, and Tulare/Kern) have assumed responsibility to form subarea committees and develop their respective subarea reports. The Grasslands subarea representative is emphasizing on the accomplishments of the Grasslands Bypass Channel as an example of the subarea efforts. Westlands Water District assumed responsibility to develop a report for the subarea (which coincides with the boundaries of the district) and have it reviewed by the subarea stakeholders. Tulare and Kern Subarea will utilize the Central Valley Agricultural Pond Operators (CVAPO) as their subarea committee. The Tulare Subarea report was submitted in July 1998 and a draft report was submitted for Grasslands subarea.

In addition to evaluating and updating the 1990 Plan, this process is intended to remove the constraints to implementation of the 1990 Management Plan. The process is also intended to foster cooperation among the University scientists, government agencies, environmental interests, growers, and other stakeholders in resolving the long-term drainage, salinity, and trace element problems with the goal of achieving agricultural and environmental sustainability in the Valley.

References

A Management Plan For Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley, September 1990. USBR.

Drainage Management in the San Joaquin Valley. A Status Report. February 1998. San Joaquin Valley Drainage Implementation Program. DWR

SOUTHERN SAN JOAQUIN VALLEY EVAPORATION POND ON-SITE MITIGATION, MITIGATION HABITAT AND RESEARCH

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INTRODUCTION

The evaporation pond operators initiated a program of management actions in 1993 designed to reduce and avoid adverse environmental impacts to wildlife. Modifications to the design and operations of the evaporation basins were based on findings and recommendations contained in 1993 environmental impact reports (EIR) submitted to the Central Valley Regional Water Quality Control Board (CVRWQCB). In compliance with the California Environmental Quality Act (CEQA) and the CVRWQCB Waste Discharge Requirements (WDR), the evaporation ponds that were identified to have impacts would: (1) avoid adverse effects associated with evaporation basin operations, (2) reduce and minimize site-specific evaporation basin impacts, and (3) mitigate for unavoidable site-specific impacts through development of an off-site mitigation habitat. Waterbirds, specifically American avocets and black-necked stilt, have been selected as the target species for this program. The on-site actions designed to avoid and minimize adverse effects, in combination with off-site compensation for unavoidable losses, are designed to reduce adverse impacts to less-than-significant levels.

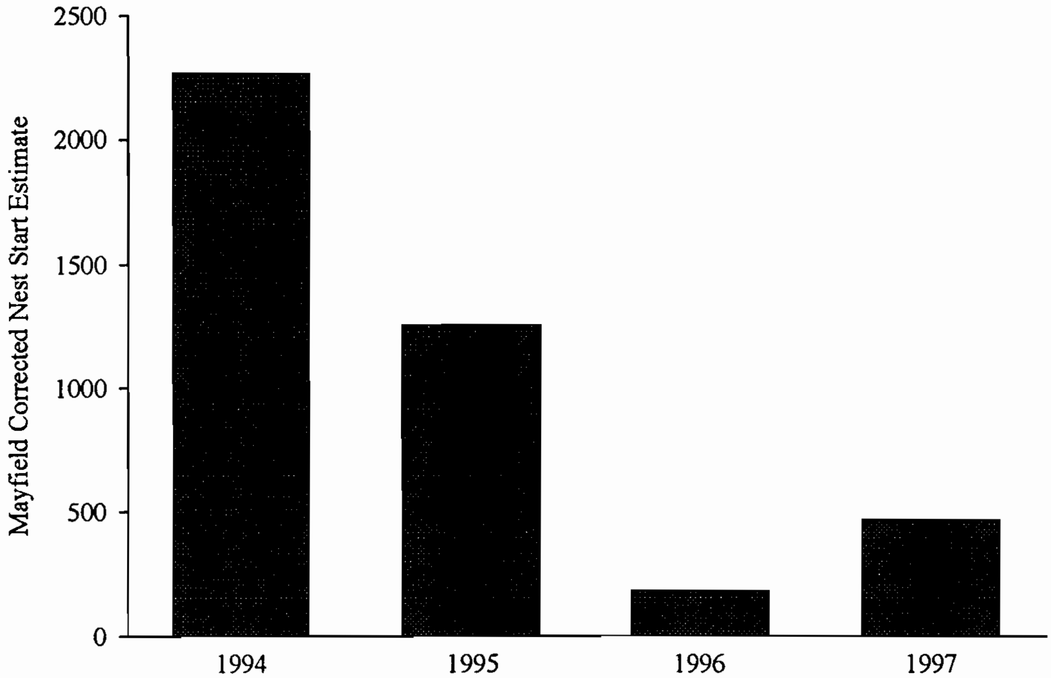
The pond operators perform biological monitoring at the evaporation basins and the mitigation habitat. Primary objectives of the monitoring are (1) to evaluate the success of the program in reducing foraging and nesting by avocets and stilts, and (2) to determine the reproductive success of American avocet and black-necked stilt nesting at the mitigation habitat. Results of these monitoring programs are provided to State and federal resource agencies, and will be used to determine whether the program has reduced adverse impacts to less-than-significant levels.

REQUIREMENTS

A number or requirements were included in the WDR's to reduce the impacts to waterbirds on the evaporation basins. These included: 1) removing all tires used for levee stabilization due to potential bird entrapment in the tires; 2) removing all interior wind breaks that could provide nesting habitat; 3) steepen the levee slopes to 3:1 to inhibit foraging and nesting; 4) maintain a water level of two feet or deeper to inhibit feeding and the growth of forage grasses; 5) sample the water from various cells for chemical analysis; 6) complete semi-monthly year around bird surveys; 7) conduct semi-monthly nest surveys; 8) collect and analyze eggs samples from the nests; and, 9) implement a hazing program to reduce bird usage. For those impacts that could not be reduced to less than significant levels with the above listed on-site mitigation measures, off-site mitigation in the form of mitigation habitat was required.

RESULTS

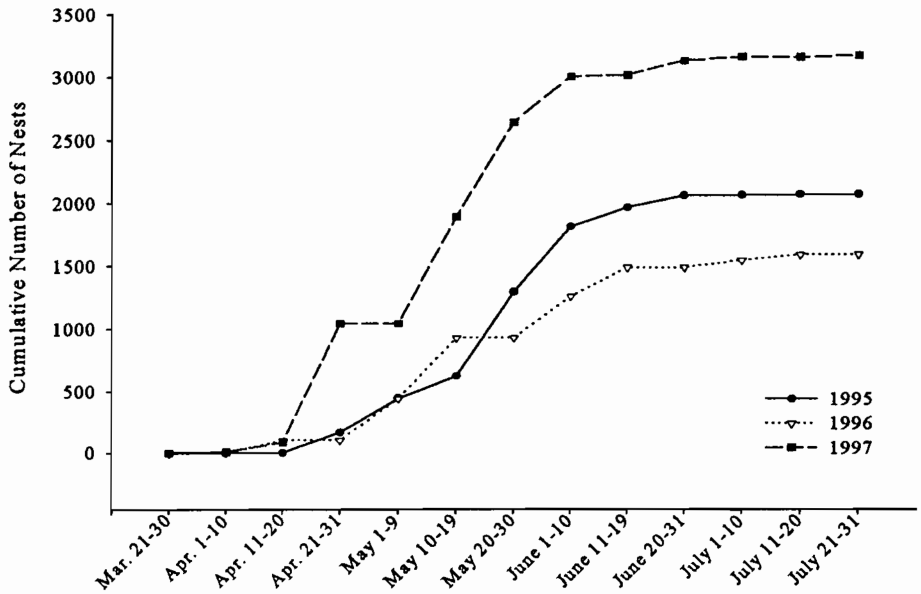
The effectiveness of the on-site mitigation measures have been effective in reducing the number of birds using the evaporation ponds and the number of birds nesting at the ponds. For example, biological monitoring during 1994-1997 has shown a dramatic decrease in nesting by American avocets and black-necked stilts at South and Hacienda Evaporation Basins at Tulare Lake Drainage District (TLDD). 2,266 American avocet and black-necked stilt nests were observed at South and Hacienda Evaporation Basins in 1994, which declined to 179 nests during the 1996 nesting season - over a 90% decline in nesting at the two evaporation basins. Similarly, 462 American avocet and black-necked stilt nests were observed at the two evaporation basins during the 1997 nesting season - nearly an 80% decline compared to the 1994 season.



Mayfield corrected estimate of American avocet and black-necked stilt nest starts at TLDD South and Hacienda Evaporation Basins.

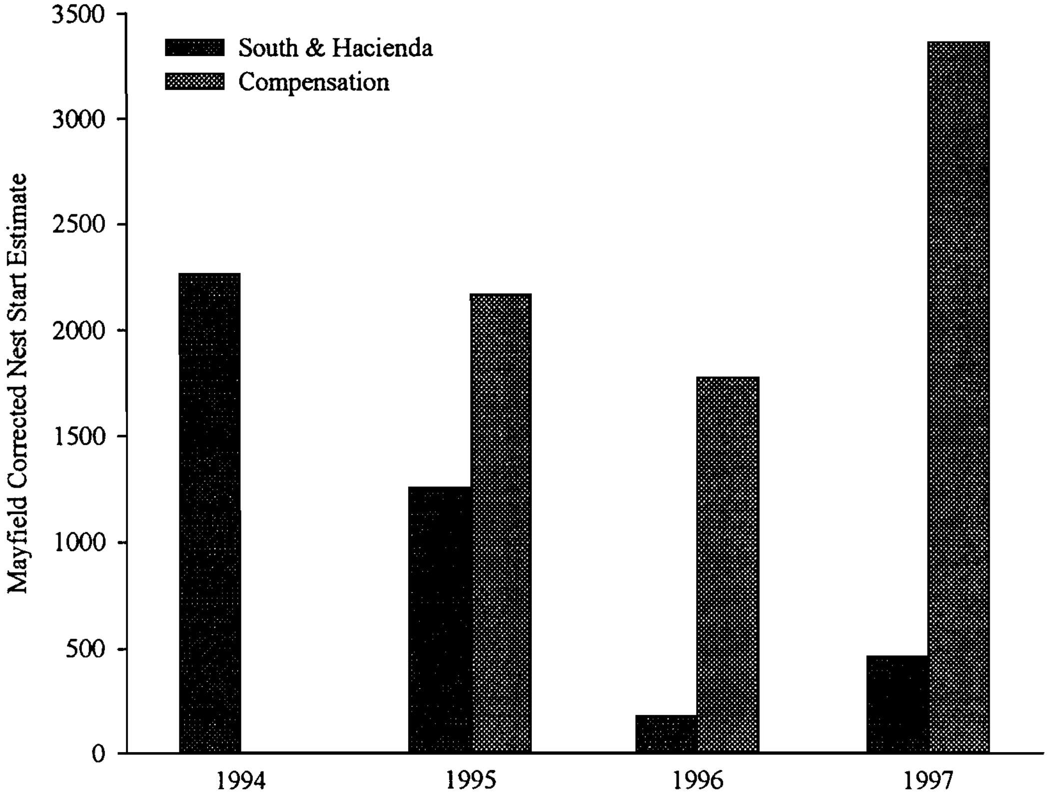
Off-site mitigation habitat has also been effective in compensating for unavoidable losses at the evaporation basins. For example, TLDD has designed and constructed a Compensation Habitat, approximately 307 acres in size, to mitigate for unavoidable losses to waterbirds. The Compensation Habitat was designed specifically to provide foraging and nesting habitat for American avocets and black-necked stilts. The Compensation Habitat includes low-profile islands immediately adjacent to extensive shallow-water areas which support macroinvertebrate production and provide extensive foraging habitat. Island habitat has a gentle sloping shoreline, with 12:1 slope, to encourage waterbird foraging and nesting. The habitat is operated to maintain a water depth of four to six inches - the preferred foraging water depth for shorebirds. The habitat is operated as a flow-through system, thereby reducing the potential impact of evaporation on water quality. The Compensation Habitat is completely surrounded by an electrified predator-exclusion fence. The primary predator of concern in the area is the coyote, although raccoon, opossum, skunk, and badger are also known predators in the area.

A total of 2,165 avocet and stilt nests were observed at the Compensation Habitat in 1995 (the first year of operation) - a trend which has continued with 1,771 nests observed in 1996, and 3,372 avocet and stilt nests observed in 1997. No embryonic deformities were detected in American avocet or black-necked stilt eggs collected in 1995, 1996, or 1997 at the Compensation habitat.



Cumulative number of observed American avocet and black-necked stilt nest starts at the Compensation Habitat.

A comparison of the trend in American avocet and black-necked stilt nesting at South and Hacienda Evaporation Basins and nesting at the Compensation Habitat is shown below. Nesting data have been adjusted (Mayfield corrected) to account for the potential bias in nest survey results.



Mayfield corrected estimate of American avocet and black-necked stilt nest starts at South and Hacienda Evaporation Basins combined and the Compensation Habitat.

RESEARCH

Selenium Reduction by Emergent Wetland Vegetation - Flow Through Wetlands

TLDD, working as part of a cooperative program, developed a flow-through wetland bio-remediation treatment pilot project. The research program includes testing selenium reduction in agricultural drainage water by various species of emergent aquatic plants. TLDD assisted in the development of the field pilot test facility which included the commitment of land and development of testing facilities. The testing facilities completed in 1996 include a managed supply of agricultural drainage water and a system for the distribution of drainage water among individual flow-through wetland cells. A drainwater collection facility was also developed as part of these testing facilities. The matrix of wetland cells was completed and vegetation planted during 1996 in accordance with the overall study plan and experimental design for the interdisciplinary investigation. Intensive water quality monitoring and evaluation of the effectiveness of the emergent wetland vegetation in reducing selenium concentrations will be performed.

Selenium Uptake and Volatilization by Algae

TLDD is cooperating in a research program conducted by Dr. Teresa Fan, University of California at Davis, to evaluate *In situ* selenium bio-remediation using biochemical transformation by assemblages of aquatic algae. TLDD has provided samples of agricultural drainage water from the inlet and Hacienda Evaporation pond cells for use in this research. Water samples are subject to chemical analyses to determine total selenium, salinity, and pH as part of the baseline information to be used in the algal volatilization study.

Experiments have been performed under laboratory conditions to evaluate selenium volatilization by macrophytic algal species collected from the TLDD evaporation basins. Two of the macrophyte algae species tested were found to volatilize selenium from saline waters. Selenium volatilized by the macrophyte biomass accounted for a major fraction of the selenium depletion that was observed in these experimental laboratory studies. The laboratory results are promising in showing substantial declines in waterborne selenium, and subsequent field testing has begun.

Westlake Farms Agroforestry

Dr. Jim Oster and Dr. Steve Kaffka are investigating the viability of utilizing saline-sodic drainage water likely is a resource for forage production. Some forages are among the most salt tolerant crops, and some that are less tolerant can be grown when the climate is cool and humid, conditions that enhance crop salt tolerance. Along the west side of the San Joaquin Valley in California, forages for dairy, beef and sheep production are currently in short supply. If forage production using saline-sodic drainage water proves feasible from physical and economic perspectives, it would provide a needed resource for animal production while reducing the volume of drainage water requiring disposal. The objective of the forage production system would be to provide a year round supply of high quality feeds suitable for grazing and economic weight gains in cattle or sheep, or alternatively for sale to dairy farms as ensilage or hay.

Tulare Lake Drainage District Agroforestry

TLDD has an agroforestry project that was developed in cooperation with the Department of Water Resources to determine the effectiveness of using saline water to grow salt tolerant crops as a means of disposing agricultural drain water. Water from salt sensitive agricultural cropland is transported to the agroforestry site to be used as irrigation water on salt tolerant crops. The project has a subsurface tile drain system. Drainwater is collected after use on the salt tolerant crops and transported to adjacent storage ponds for reuse on highly salt tolerant crops. There are 23 field plots in the project, five acres each. The first four field plots are irrigated with the drainwater collected and concentrated from the remaining checks that is stored in the adjacent storage ponds. To date, TLDD has tested salt tolerant eucalyptus, casurina, atriplex, corn, sugar beets, forage grass, wheat, and a number of other salt tolerant crops with varied success. Since 1991, an average of approximately 250 acre feet of drainwater has been applied per year to the TLDD agroforestry site.

Lost Hills Water District Agroforestry

In 1997, LHWD landowners initiated an agroforestry test plot within the LHWD drainage area by planting 84 pistachio trees. During 1997, the test plot was irrigated with fresh water. Landowners plan to begin applying blended drainage water at different rates over the next two years. A revised proposal has been submitted by LHWD for a Cooperative Agreement with DWR to expand the pistachio planting with other salt tolerant trees and halophytes during 1998. The proposal has been accepted and a contract has been drafted. LHWD plans to evaluate the potential of using agricultural drainage water to grow salt tolerant trees and halophytes within the District's drainage area.

Lost Hill Water District Aquaculture

Alexander Research is currently evaluating the use of drainwater in aquaculture at LHWD. They are currently experimenting with the production of fish in two small raceways. Preliminary results have been favorable. Alexander Research plans to expand the operation and ultimately grow both algae and fish utilizing drainwater.

Commercial Harvesting of Artemia Brine Shrimp in Evaporation Ponds

Since October 1997, Novalek, Inc., of Hayward, California, has been developing procedures for the commercial harvest of Artemia Brine Shrimp (anostracan branchiopod crustaceans) from the evaporation ponds in Kern and Kings Counties, California. Novalek is a research and development company with a history since 1950 through its predecessor companies of commercially harvesting brine shrimp in Asia, Oceania and North America. Its market for premium brine shrimp and other high quality aquatic products is world wide in aquaculture and the aquarium trades. In recent years Novalek has been active in commercially harvesting brine shrimp in San Francisco Bay, California, and Great Salt Lake, Utah. The original company, established before Novalek, was formed by aquatic biologists on the staff of the Steinhart Aquarium, under the administration of the governing California Academy of Sciences, San Francisco. Novalek has continued with a scientific basis in its operations to the present day under the direction of Dr. Robert Rofen (Ph.D. biological-aquatic sciences). Novalek has been asked by concerned scientists to use its expertise to investigate the effect of selenium on brine shrimp naturally occurring in San Joaquin Valley evaporation pond systems.

Forage Production using Saline-sodic Drainage Water?

J.D. Oster and S.R. Kaffka

INTRODUCTION

Saline-sodic drainage water {EC > 4 dS/m; SAR > 4 $(mmol/L)^{0.5}$} likely is a resource for forage production in the San Joaquin Valley in California. Some warm and cool season grass species are among the most salt-tolerant crops, and some that are less tolerant can be grown when the climate is cool and humid, conditions that enhance crop salt tolerance. Safflower, wheat, barley, used for forage rather than grain, sugarbeets and forage brassicas fit this climatic niche in the San Joaquin Valley. Along the Westside of the San Joaquin Valley, forages for dairy, beef and sheep production are currently in short supply. Dairy production has risen 50 % in the last decade, grazing locations for sheep producers are limited, and access to public lands during the summer for cattle producers is decreasing in the traditional mountain grazing areas. Using saline-sodic drainage water for forage production could provide a supplemental resource for animal production while reducing the volume of drainage water requiring disposal.

FORAGE PRODUCTION SYSTEM

The objective of the forage production system would be to provide a year round supply of high quality feeds suitable for grazing and economic weight gains in cattle or sheep, or alternatively for sale to dairy farms as ensilage or hay. The choice of forages include salt-tolerant, perennial crop species such as wheatgrass, Bermudagrass, salt grass, silt grass and other annual crops such as wheat, forage brassicas, sugarbeets, and safflower. The growing seasons for these crops differ considerably, and allow for year-round feed production with cropping options that impact the quality and quantity of forage produced (Table 1.). Including grass crops in the crop rotation provide management opportunities to minimize the effects of water quality on soil tilth, infiltration rates and hydraulic conductivities.

The management operations need to be low cost, particularly in terms of the needs for herbicides, insecticides, and soil amendments, and simple to manage. The crop rotation system should not cause problems related to pest and crop disease control in neighboring fields, for example by harboring inoculum of aphid transmitted virus diseases for sugar and fodder beets. Forage crops should not lead to toxicity in livestock or wildlife due to high concentrations of minor elements such as molybdenum and selenium.

At this time there is little farmer or research experience with developing and sustaining a forage production system using saline/sodic drainage water. There are several basic issues that need to be considered:

1. The selected crops must tolerate high levels of salinity.
2. Leaching needs to occur to maintain tolerable levels of soil salinity.
3. Infiltration and hydraulic conductivities of the soils need to be sufficient to allow adequate irrigation for the crop and for leaching.
4. Physical properties of the soil aggregates must facilitate the preparation of seedbed with

good tilth.
5. Effects of climate on irrigation water requirements and crop salt tolerance need to be optimized.

What crops can be grown? The primary sources of information to answer this question are published salt tolerance tables (Maas, 1990), although some of the crops in Table 2 – for example *Puccinellia distans* -- are not included in these tables. For these, the source of information is referenced in the footnotes of Table 2. The salt tolerance classification for most of the crops in Table 2 is tolerant; the criterion for including moderately tolerant forages in the table was that the leaching requirement (Col.6) would not exceed 30 %. Table 2 does not include all the possibilities as is evident when one reads the footnote to the table, or the books entitled Saline Agriculture: Salt-tolerant Plants for Developing Countries (National Research Council, 1990) and Chapter 9 in Soil Salinity and Water Quality (Chhabra, 1996).

Perhaps the most tolerant species in Table 2 are atriplex and salicornia; both have forage potential (Glenn et al., 1994), particularly when grazed. Animal intake may be limited, however, because of poor palatability and the drinking water requirements would be increased because of the high salt content of the plant tissue, which can exceed 25 % on a dry weight basis. Another negative aspect of atriplex is that it is a host plant for leafhopper an important insect pest in the San Joaquin Valley. Asparagus is included to emphasize that many salt tolerant crops may have a potential use as a forage crop, and if necessary, it may be possible to increase the potential through plant breeding (Shannon and Noble, 1990).

Table 1. Relative forage value for cool season and warm season crops.

Season	High Energy	Intermediate	High Protein
Cool season	Brassicas	Cool season grasses (wheat and wheatgrass)	Forage brasicas, immature wheat and wheatgrass
Warm season	Stockpiled sugarbeets	Warm season grasses, safflower hay	Vegetative safflower a sugarbeet leaves

Table 2. Growth habit and salt tolerance characteristics, and average rootzone salinity (ECe70) at 70 % yield and leaching requirement (LR) for forages and Eucalypus camaldulensis (clone 4544) when irrigated with a water having a salinity of 10 dS/m. Unless noted, the salt tolerance data were obtained from Maas, 1994.

Forage crop	Growth Season, Habit	Salt Tol. rating	Salt Tolerance Coefficients		ECe(70) DS/m	LR
			Thres-hold	Slope		
Puccinellia distans		T			32 [b]	< 10
Distichlis spicata	Summer	T			>15 [c]	< 10

Salt grass	Perennial					
Paspalum vaginatum Silt grass	Summer perennial	T			10 – 22 [d] 23 [c]	< 10
Asparagus	Perennial	T	4.1	2.0	19	15
Triticum aestivum Wheat, cv. Probred	Winter Annual	MT	4.5	2.6	16	15
Triticum durum Wheat, durum	Winter Annual	MT	2.1	2.5	14	20
Tall wheatgrass	Winter perennial	T	7.5	4.2	15	20
Sugarbeet	Annual	T	7	5.9	12	20
Fescue, cv. Alta [b]	Winter				12 [e]	25
Cyndon dactylon Bermudagrass	Summer	T	6.9	6.4	12	25
Leptochloa fusca Karnal or Kallar grass	Summer Perennial	T	3.0	3.4	12	25
Safflower		MT			11 [e]	25
Crested wheatgrass, cv Fairway	Winter	T	7.5	6.9	12	25
Crested wheatgrass, cv Standard	Winter	MT	3.5	4.0	11	25
Barley	Winter	MT	6	7.1	10	30
Sundan grass	Summer	MT	2.8	4.3	10	30
Fescue	Winter	MT	3.9	5.3	10	30
Salsola iberica Russian thistle	Annual	MT				
Spartina spp. Cordgrasses	Perennial	T [g]				
Atriplex spp. Saltbush	Perennial Shrubs	T [g]				
Kochia prostrata and other spp.	Perennial Shrub	T	17 [g]			
Halosarcia spp. Samphires	Perennial Shrub	T [g]				
Prosopis spp. mesquites	Perennial Shrub	MT [g]				
Acacia spp.	Perennial shrub	T [g]				
Chloris gayana Rhodes grass	Perennial	MT [g]				

Eucalyptus camaldulensis, clone 4544.	Summer Perennial	MT	3.5	5.6	9 [f]	40

Crops with a salt tolerance ranking of tolerant (Maas, 1990) for which there are no M-H for forage yields, include the following: rye, Nuttall alkali grass, alkali sacaton, Altai wild rye and Russian wild rye. Similarly, moderately tolerant crops include the following: kenaf, oats, mountain brome, reed canary grass, Huban clover, sweet clover, meadow fescue, blue panic grass, rape, rescue grass, Rhodes grass, Italian ryegrass, bird's foot broadleaf trefoil, intermediate wheatgrass, slender wheatgrass, western wheatgrass, and Russian wild rye.

[b] Lund et al., 1961.
[c] Shannon and Oster, preliminary estimates
[d] Peacock and Duceck, 1985.
[e] Francois and Bernstein, 1964.
[f] Shannon et al., 1997.
[g] National Academy of Sciences, 1990.

The leaching requirements in Table 2 were calculated using the production function model of Letey et al (1985) using a target yield of 70 % of the maximum. The median composition of shallow ground waters within the Tulare Lake Basin and along its West Side (Fuji and Swain, 1995) was used to correct the calculated leaching requirement for the effects of gypsum and calcite precipitation (Oster and Rhoades, 1990). At a leaching fraction of 30 %, precipitation reduced the salinity of the drainage water by 25 %; at a leaching fraction of 10 % the corresponding reduction was 33 %.

Several comments are pertinent about the leaching requirements in Table 2:

1. Rainfall is not accounted for; rainfall that exceeds ET would reduce the leaching requirement.
2. Soil texture will impose limitations on being able to achieve leaching requirements under conditions that also provide adequate aeration for crop growth. Leaching requirements of 10 to 15 percent should be achievable in most soils, including clay and silty clay loams. Leaching requirements greater than 20 % may only be achievable in loamy and sandy soils.

3. Crops that have a leaching requirement of 15 % or less with a 10-dS/m water could be irrigated with more saline water. These crops could be used in a second stage, sequential cropping scheme.

CONCLUDING COMMENTS.

Guidelines used in selecting crop species include salt tolerance, potential forage value, seasonal distribution, adaptability to the soils, saline-sodic drainage water, climate, complementarity of seasonal growth, production and nutritional characteristics and familiarity with the crops by the growers. Livestock based systems cannot be based entirely on forage analysis and theory. Some experience in feeding trials and in the use of livestock to consume promising forage species will be required. There may be some conflicts in practice between the need to dispose of drainage water and the need to operate a profitable livestock enterprise. These issues require research.

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Biologically Integrated Vineyard Systems (BIVS): Integrating grape pest, soil and plant fertility management

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Introduction

In California, there has been increased interest among farmers, researchers, extension advisors, pest control advisors (PCAs), regulatory agencies and consumers to implement production practices which incorporate the principles of integrated pest management (IPM), plant fertility and soil management. These programs are often described as *biologically integrated*, which was first used in the Biologically Integrated Orchard Systems (BIOS) program developed jointly by the Community Alliance with Family Farmers (CAFF), Merced County almond growers, the UC Sustainable Agriculture Research and Education Program (UC SAREP), UC Cooperative Extension, the USDA's Farm Service Agency, and the federal Natural Resources Conservation Service.

Currently, BIOS has programs for almonds and walnuts in seven counties. The BIOS model as an extension approach is currently being expanded within a number of agricultural cropping contexts in California, in part with support from the California Legislature through AB 3383, the US EPA and the CA DPR. UC SAREP has awarded several grants for Biologically Integrated Farming Systems, which include BIFS for row crops on the west side of the San Joaquin Valley and BIFS for winegrapes in the Lodi-Woodbridge district. BIFS projects have also been established for rice, walnuts, prunes and citrus. Similar programs throughout the state include Best Management Practices (BMP) of Sun-Maid Raisins, Biologically Integrated Strawberry Systems (BISS) in Fresno County, and Biologically Integrated Vineyard Systems (BIVS) for grapes in Fresno County.

Biological integration in crop production recognizes that agricultural systems are made up of many biological components, including the crop, but also the soil dwelling organisms (microbes, nematodes and arthropods), the organisms that exist on the crop, and even the weeds. Some of these organisms may be harmful to the crop, but many are beneficial. Biological integration promotes farming practices that encourage the beneficial organisms in the system, and encourages the use of practices and inputs that have minimal negative impact on beneficials, human health and the environment. Relatively "high risk" materials such as organophosphate and carbamate insecticides, and B2 carcinogens, are strongly discouraged. As with IPM, biological integration employs a multitude of tools, but differs in that it attempts to link pest/beneficials, soil, fertility and water management components into a systems approach.

Because soil and plant health are often important in limiting the impact of pests, practices such as long term soil building, optimizing plant nutrition levels and improving irrigation efficiency can increase plant tolerance to pest attack and may also prevent pests from reaching the economic injury level. Biological integration recognizes that successful and sustainable production systems must maintain high yields, quality and farm profitability. The original BIOS project was very successful, and many growers in the program were able to reduce their reliance on high risk chemical inputs, while maintaining yields and quality and remaining economically competitive (Hendricks 1995, Dlott et al. 1996).

Implementing effective IPM systems is one of the core objectives of biological integration. IPM, first outlined as integrated control by Stern et al. (1959), promotes regular and frequent monitoring for pests and the use of action thresholds to determine treatment timing. A major objective of this model was to minimize the use of broad spectrum insecticides to conserve natural enemies (Wearing 1988), although the definition of IPM has come to include economics and societal impacts (Rabb 1972) along with impacts on human health, the environment (Leslie and Cuperus 1993). Here we are nearly 40 years after the emergence of the concept of integrated control, and heading into a new milleneum. Although much progress has been made over pest control programs based on calendar applications of broad spectrum pesticides, the implementation of a full IPM program is something that has only been attained by a minority of growers. Whereas most growers do have their fields checked at some point in the season, it is usually not frequent enough. Part of the goal of a biologically integrated program is to demonstrate how to implement an IPM program.

In addition to integrating production methods, biologically integrated programs also integrate the exchange of information. At the crux of this model is the active participation of growers, who are directly involved in defining problems, developing creative approaches to their solutions, participating in research efforts, and helping deliver educational information to fellow program participants and wider audiences. Grower input is integrated with that of cooperative extension advisors, researchers, PCAs and community members. This differs from the traditional extension model, in which advisors or specialists impart knowledge to farmers or PCAs in a top-down manner. Instead, the biologically integrated model employs a co-learning environment, within which all participants offer insights and opinions that will help each grower develop a production plan within the comprehensive objectives of biological integration.

Biologically integrated systems are designed to be equivalent economically with conventional practices. Occasionally, growers may achieve cost savings of inputs; for example when insecticide treatments are eliminated in a given year because of careful pest monitoring. However, monitoring is itself an expense. A biologically integrated system may involve some additional investment into an alternative practice or technology; for example, growers who plant cover crops invest time in land preparation and money in seed and inoculant, and may not see direct benefits to specific pests. However, in the long run, cover crops and non-tillage promote vine health, which may aid in the prevention of spider mites and reduced damage from nematodes. An investment in a more efficient sprayer may be comparatively expensive, but the savings in pesticides should pay off over the long run. Biologically integrated programs contribute to enhanced environmental quality in several ways: first, by implementing the IPM principle of monitoring and the use of treatment thresholds. In this way, many preventative or insurance sprays are eliminated. Secondly, by using the safest and least disruptive materials, non-target organisms are spared and the risk of offsite pollution is minimized. Lastly, when treatment is necessary with any material, the minimum amount needed for efficacy is used.

Biologically integrated systems achieve their goals using the following elements:

- A team approach to problem solving. Teams may consist of growers, UC farm advisors and specialists, researchers, private consultants, and representatives from the USDA, resource conservation districts and the non-agricultural community. Teams meet at least once a year, and work together with individual growers to solve problems in a biologically integrated way. Solutions are crafted to meet the needs of each grower.

- Creation of a forum for information exchange. This is accomplished through monthly meetings and field days. At these meetings, current issues are discussed, educational presentations are given and demonstrations are made of practices or technological advantages which contribute to the goal of biological integration. Regular contact among group members establishes a group identity, keeps growers abreast of current production conditions and pest/meteorological phenomena and provides mutual support for modifying past practices. This type of contact is also designed to reassure the grower-participants that the management and advisory teams are committed to them and to the principles of biological integration.

- Regular and frequent monitoring for pests during the season, providing the information to grower participants. Monitoring provides estimates of pest and natural enemy population levels, which are used for treatment decision making. The monitoring program demonstrates to the grower that having access to frequent information is far superior to information received at a single point in time. The data collected are used in discussions aimed at increasing participants' understanding of pest population dynamics and pest management.

- Biological, cultural and selective chemical control of pests, using action thresholds when chemical treatment is warranted. A strong emphasis is placed on cultural and biological controls, so as to minimize the need for chemical treatment. Soil-building practices are encouraged, including cover crops to fix nitrogen and increase organic matter and thereby improve soil structure, water penetration and beneficial soil microbe populations. Laboratory analysis is used to determine optimum plant nutrient levels, and soil/water chemistries. Such practices can help boost plant tolerance to outbreaks of pests that thrive on weak and low vigor plants. Biological controls include the conservation of natural enemies, and the release of beneficials such as predatory mites, lacewings and Trichogramma (parasitic wasps). If chemical treatment is indicated, growers are encouraged to use materials which affect primarily the target pest and have a minimal negative impact on beneficials, human health and the environment.

- Innovative technologies to improve efficiencies of application. New technologies are available to increase efficiencies of herbicide, fungicide and insecticide use. Plant disease and insect development models can be incorporated into weather station software to enable more precise timing of pesticide applications.

Biologically Integrated Vineyard Systems (BIVS): A Case Study

California's San Joaquin Valley is an area of phenomenal agricultural production. Crop value in Fresno County alone was $3.4 billion in 1997 (Fresno County Department of Agriculture, 1997), making it the highest agricultural producing county in the United States for the 45th consecutive year. Fresno County has some 220,000 acres of grapes, which accounts for almost a third of California's vineyard land.

Grape growers in the valley have a number of challenges in meeting the goals of biological integration. Fungicides for powdery mildew, especially sulfur, are the most heavily used inputs in grape production systems. Sulfur dust may be a contributor to air pollution. The herbicides simazine and diuron, which are the most commonly used herbicides on grape acreage, have been detected in surface and well water in Tulare and Fresno Counties (Braun & Hawkins 1991, Roux *et al.* 1991). Spider mites are a major arthropod pest, and are most often treated for with propargite, which has been classified as a B2 carcinogen (Gianessi and Anderson 1995). Mealybugs are a major pest of table grapes, and control strategies usually involve the use of organophosphate insecticides. Fortunately, other major insect pests, such as omnivorous leafroller and leafhoppers, can be treated with relatively low risk materials.

A great deal of grape acreage, especially raisin acreage, is planted on marginal soils, either sandy or alkali, where vines are often water stressed and therefore more susceptible to soil borne pests such as nematodes and outbreaks of spider mites. Compared to crops such as almonds and vegetables, grapes require relatively little nitrogen (25-40 lb/ac). However, on highly leachable sandy soil, nitrogen fertilizer is applied at rates as 2-3 times the amount needed by the plant, which increases the risk of nitrate contamination of groundwater (CDFA, 1989).

Structure of the program

The BIVS program started in Fresno County in the fall of 1995 with 11 growers who committed all or part of their acreage (a total of 240 acres) to the program. By 1998 the program had more than tripled, with 38 growers and 920 acres. BIVS began with a gathering of interested persons for breakfast at a local restaurant, and continues to do so on a monthly basis, providing a support network for grape growers, PCAs and grape industry members. This gathering allows participants to exchange information, discuss current events and participate in education sessions by advisory team members or invited guests. Regular contact among group members establishes a group identity, keeps growers abreast of current production conditions and pest or meteorological phenomena and provides mutual support for adherence to biologically integrated principles. This type of contact is also designed to reassure the grower-participants that the team is committed to them and to the principles of biological integration. The network we have created has a multiplier effect, in that the groups activities and benefits are communicated to non-member growers, who then begin to participate. BIVS is highly visible, and has received favorable press coverage in a number of prominent grower trade journals.

The BIVS advisory team meets with grower participants at least once a year to troubleshoot problems, and decide together how to modify production practices to meet the goals of biological integration. The core advisory team consists of a grape grower (John Tufenkjian), a

UC farm advisor (Michael Costello), a CSU Fresno professor (Mark Mayse) an independent pest control advisor (Larry Whitted) and program coordinator Juliet Schwartz. In addition to the core advisory team, BIVS is supported by a technical advisory team, consisting of a UC IPM weeds advisor (Tim Prather) and a UC viticulturist (Pete Christensen). The team approach allows for an assemblage of opinions, including the grower's, to be expressed in troubleshooting problems. Such teamwork leads to a more thorough understanding of the problem, and a more integrated approach to solving it within the framework of economic and environmental soundness.

Problem solving strategies

There are many examples of problem solving strategies which have been undertaken by BIVS growers. Weeds are one of the pests which every grower has to contend with, and doing so with preemergent herbicides such as simazine and diuron are one of the easiest and least costly methods of weed control. However, several weed control strategies fit the biologically integrated goal of reducing risk and may be equivalent economically. The simplest is to apply the minimal amount of preemergent herbicide which will give adequate control. In meetings between the advisory team, it has been determined that many grape growers apply as much as three times the necessary amount of these materials because of confusion as to proper application rates. As a result, many growers have cut their rate of simazine or diuron by a half to a third and still achieved adequate weed control (T. Prather, UC Area-wide IPM advisor, unpublished data). Another strategy might be to rely more on the use of contact herbicides, especially glyphosate, because of its low risk status. This can be combined with more efficient herbicide application equipment to minimize the amount of material needed. These include light activated units, which spray only when a computer controlled sensor detects green light wavelengths (i.e., weeds) and can result in herbicide reductions of 60% (Elmore *et al.*, 1997). Shielded misters can deliver contact herbicides in a fine droplet size. Finally, cultivation can be effectively used as an alternative to herbicides. In-row cultivators include knives, rotary tines and berm sweeps. Rotary tillers manufactured by Kimco and J&H provided weed control equivalent to that of a standard glyphosate program (T. Prather, unpublished data).

The role of vine condition

Many practices can be used to combat pests which take advantage of weak vines, e.g., spider mites and nematodes. Pacific mite (*Tetranychus pacificus*) populations build most rapidly on plants which are dusty or water- or nutrient stressed (Flaherty et al., 1992). Root knot nematode (*Meloidogyne* spp.) and ring nematode (*Cricanomella xenoplex*) cause greater damage on vines stressed for water (McKenry, 1992). Raisin grape growers in particular tend to create these conditions by infrequent irrigation and frequent cultivation. As an alternative to the use of high risk chemicals for spider mites or nematodes, several BIVS have undertaken efforts to relieve plant stress and improve tolerance to these pests. These include more frequent irrigation (e.g. bi-weekly instead of monthly), and mowing, rather than cultivating, between the rows to improve soil structure, increase the rate of water infiltration and reduce dust. In addition, soil building practices are encouraged; the majority of BIVS growers plant cool season cover crops, and several treat their acreage with dairy manure compost. Nitrogen fertilizer applications are timed to take advantage of the most active nutrient uptake periods of the vine (late spring and early fall). Soil testing is encouraged to determine critical soil chemistry properties such as pH and salts, which can be corrected with amendments such as soil sulfur, lime or gypsum.

Not all pest problems can be solved by improving plant condition. For example, there is no known relationship between vine condition and key lepidopteran pests in grapes (e.g., omnivorous leafroller *Platynota stultana*) or mealybugs (*Pseudococcus* spp.). Leafhoppers (*Erythroneura* spp.) have better survivorship on well watered and fertilized vines. For pests which are little affected by vine condition, cultural controls such as sanitation can be employed, biological controls can be encouraged, or chemical controls can be used which have low human health and environmental risk and a minimal impact on beneficial organisms. Appropriate chemicals have a relatively specific mode of action against the pest (e.g., synthetic insect growth regulators) or are contact materials such as soaps and oils. For example, if leafhopper populations reach treatment thresholds, they can be treated with imidacloprid, a synthetic insecticide used as very low rates (1/2-1.0 oz/ac), and is not known to disrupt biological controls. Spider mite and mealybug populations can be treated with horticultural oil (highly refined petroleum oil), which suffocates small arthropods. More precise timing of these treatments can be made using developmental models and weather stations technology (Kretsch, 1999). Biological controls can be encouraged by conserving naturally occurring beneficial arthropods or by mass releasing natural enemies. Mass releases of predatory mites (*Galendromus occidentalis)* are being employed for control of spider mites, although the rate and frequency of release required for control are not known.

Disease management

Disease management on grapes requires a greater amount of pesticide than for any other pest group. In Fresno County, sulfur applications for control of powdery mildew (*Uncinula necator*) total some nine million pounds annually (UC Statewide IPM Project, 1998). Diseases are difficult to manage with IPM principles, and better control is achieved with preventive fungicide applications. However, most disease development is closely tied to abiotic environmental conditions such as temperature, humidity and leaf wetness. We can take advantage of this by timing fungicide treatments based on knowledge of climatic conditions within the cropping systems.

The BIVS project, in conjunction with Sun-Maid Growers, received an equipment grant from the UC IPM PestCast program, and established a weather monitoring network for the collection and recording of temperature and rainfall data. These data are fed into a computer driven developmental model (either Sall *et al.* 1983 or D. Gubler, UC Davis, unpublished data), and estimate proper timing of treatments for powdery mildew, whose development is temperature dependent. Most grape growers apply sulfur on a calendar basis from spring through mid-summer, usually 7-10 days; using the weather monitoring system should increase accuracy of treatment timing and decrease the number of fungicide applications.

Demonstrating biologically integrated practices

The BIVS project demonstrates the principles of biological integration through several avenues: by regular and frequent monitoring of enrolled acreage for key pest densities, through participatory research and field days, and by evaluating the impact of the program. The information collected is made available to the growers on a weekly basis, and is meant to demonstrate the use of action thresholds, and to show that regular and frequent monitoring is essential to determining the necessity and timing of treatments. Monitoring is the simplest method of eliminating unnecessary insecticide use, as growers will base treatments on action thresholds determined by pest population levels, rather than by an assumption that treatment is needed. Participatory research involves the establishment of small scale on-farm studies to determine the impact of a particular management strategy. Many strategies are based on theory with little or no relevant empirical data. A good example of this is the use of compost for improved vine health and increased tolerance to mite outbreaks and nematode infestations. The BIVS project has established replicated on-farm studies to determine the impact of compost on vine health/pest incidence for three BIVS growers who have chosen to work with compost. BIVS practices are also demonstrated through field days. Biologically integrated practices are more readily adopted and easily implemented if they are physically demonstrated to growers. Examples of field days include a spring weed technology day, which brought together several manufacturers of cultivation implements and contact herbicide sprayers, and field days which have compared different cover crops and cover crop blends.

Accomplishments of the program

The success of BIVS can be gauged by the following criteria: the level of grower participation, the substitution of biorational pesticides for broad spectrum materials, the maintenance of adequate yields and quality, improved soil quality and the maintenance of farm profitability. The overall impact of the program is evaluated by recording in-season pesticide and fertilizer use, compiling pest incidence, and estimating plant nutritional status, yields and quality. These are then compared to field historical averages prior to implementation of biologically integrated practices, and compared to county averages. An economic analysis of the program is forthcoming.

BIVS membership has virtually doubled during each of the three years since its inception. Also, many more individuals who are not officially enrolled in the program participate in monthly meetings and field days.

Some of the efforts that the 23 BIVS growers undertook in the 1996 and 1997 growing season to meet BIVS objectives were:

- 17 used soil amendments such as compost and cover crops to improve soil health, and combat nematode infestations and spider mite outbreaks.
- 3 used horticultural oil as an alternative to propargite for mites or leafhoppers.
- 11 used cultivation as an alternative to pre emergent herbicides for weed control.
- 3 used only contact herbicides as an alternative to pre emergent herbicides for weed control.
- 5 used lower rates of simazine or changed from simazine to another pre emergent that does not have the potential for groundwater contamination.

Use of insecticides, nematicides and herbicides on BIVS acreage in 1997 was recorded as the pounds of active ingredient (ai) applied, and was compared to historical use (the previous 3-5 years) on a per acre basis. Fungicide use was not catalogued.

Of the 13 BIVS growers who treated for leafhoppers, two used oil, and the remainder used imidacloprid; both of these are considered low risk materials. The use of endosulfan and methomyl, although not widespread in the past, was eliminated in 1997. One grower used carbaryl and dibrom just prior to harvest.

Four growers treated for mites, and half of these used oil. The use of propargite (a B-2 carcinogen) for mites decreased by 87%. Two other growers released predator mites in lieu of chemical treatment for spider mite control.

The use of oil for leafhoppers or mites increased from zero to 125 gallons, and the use of imidacloprid (for leafhoppers) increased 51%. Two growers were able to eliminate insecticides for leafhoppers and mites altogether based on the BIVS monitoring program.

For omnivorous leafroller, 58% of BIVS growers did not treat for OLR at all, and those that did timed their treatments to the degree day model. Only one grower treated for a late season OLR infestation (using phosmet). Cryolite use for OLR decreased by 13% and Bt use remained the same.

Pre-emergent herbicide use decreased across the board: simazine by 65%, norflurazon by 11%, oxyfluorfen by 95%, oryzalin by 94% and diuron by 56%. Paraquat dichloride use was eliminated, whereas glyphosate use remained about the same.

Mean raisin yield for eight BIVS growers (cv Thompson Seedless) ranged from 1.68 to 3.44 tons/acre, averaging 2.63 tons/acre. Average raisin yield throughout the San Joaquin Valley in 1997 was roughly 2.50 tons/acre. Raisin quality (graded as % B or better) for the group (8 growers) ranged from 56.2 to 96.7, averaging 71.3, and percentage of substandard raisins ranged from 1.1 to 8.4, averaging 4.1. Raisin deliveries need to meet 50% B or better and less than 5% substandard to pass inspection. Mean green tonnage for seven BIVS growers (cv Thompson Seedless) ranged from 8.5 to 18.5 tons/acre, averaging 11.3 tons/acre. Green tonnage for San Joaquin Valley Thompson Seedless averaged roughly 11.1 tons/acre in 1997.

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Adapting Technology to Meet The Needs of Raisin Production in the 21st Century

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Introduction

United States raisin production is concentrated within a 50 mile radius of Kingsburg, California because of the unique climate and soils. Production techniques have remained relatively unchanged with Thompson Seedless being the main variety for raisin production. Growing techniques for tray dried raisins have changed little in the last 25 years and the harvest is very labor intensive. Raisin harvest occurs when the grapes have attained sufficient sugar to produce a quality raisin. Grapes are picked when ripe and placed on paper trays on sloped terraces in the vineyards for sun drying. This generally allows a harvest period of about 5 to 6 weeks to pick the grapes and lay them on paper trays. Drying raisins are very susceptible to rain damage during this period. The 1998 season was problematic in terms of untimely rainfall and high disease incidence due to the effect of El Nino. The 1998 season was very unusual. Labor availability was a problem during 1998 season due to the lateness of harvest and the competition with other agricultural commodities.

Recent developments in technology are changing the nature of raisin production. Advancements have occurred in the area of weather recording, remote sensing and computer modeling for irrigation requirements, insect and disease forecasting. New materials which utilize entirely new modes of action have been developed for disease, insect and mite control. New raisin varieties suited for dried on the vine raisin production have been developed by the USDA at Peach Avenue in Fresno. Trellis systems which allow dried on the vine raisin production and mechanization of various cultural and harvesting operations are commercially viable and acreage utilizing those systems is increasing.

Use of weather monitoring for pest and disease forecasting

Computer technology and advanced microtechnology have allowed the use of weather stations directly within the vineyards with data collection in a centralized computer. Sun-Maid Growers and the San Joaquin Valley Biologically Integrated Vineyard Systems (BIVS) program cooperated to install six weather stations in vineyards located in Reedley, Del Rey, Easton, Raisin City, Ripperdan, and Kerman. Additional stations have since been added. Funds for installation were provided by a grant from the Statewide Integrated Pest Management Project. The weather stations are located directly under the trellis in the vineyard rows and measure ambient temperature, canopy temperature, relative humidity and rainfall accumulation. The project is referred to as PestCast. Data is recorded every hour and is available via modem from a centralized computer located in the office of Michael Costello, UCCE viticulture farm advisor, Fresno county. The WINDS computer program is utilized to process the collected data. Growers with a computer modem can access the information from the vineyard location nearest to them at no charge. The system monitors weather data and is not used to forecast weather. The software utilizes prior 30 year weather averages in a data bank to predict dates for insect development and phenology. In addition to 30 years of weather data, the WINDS database incorporates degree day phenology models and codes for over 75 insects pests and diseases as well as degree day phenology models for several different crops. Predicted dates can be used to schedule sprays or other types of cultural operations.

Research is underway to develop and verify models which document the degree day development of insects on various commodities including wine, table and raisin grapes. The theory is that timing the application of a material to the appropriate life stage can reduce the amount of material needed while resulting in more effective control of the target organism. Additional research has been performed and data is available on disease development and the climatic factors required for disease initiation. Of particular concern for grape production is the disease powdery mildew. In the San Joaquin Valley, powdery mildew development is temperature driven. Treatment for powdery mildew is essentially preventative rather than curative. Two models have been developed at U.C. Davis, the model developed by Mary Ann Sall, Jeanette Wrysinski and Frank J. Schick and a second model developed by Dr. Doug Gubler. Both models utilize temperature, but the Sall, Wrysinski, Schick model is more complicated and utilizes other parameters as well. The Gubler model is better adapted to the San Joaquin Valley because of our absence of free moisture during the critical infection period between budbreak and veraison. Because the Gubler model is easier to utilize it is more adaptable and more readily accepted by the farming community. Convenient and affordable devices are available to monitor vineyard temperatures and relative humidity while utilizing the Gubler powdery mildew model. These same devices can be programmed to incorporate upper and lower temperature thresholds to calculate degree days for helping in the scheduling of material applications for optimum insect control.

Weather monitoring devices can be either self contained with proprietary software or they can be tied into a computer network with remote access. The weather stations in the PestCast network are connected via modem to the computer in the UCCE viticulture farm advisor office in Fresno. The weather stations are also equipped with a synthesized voice module which gives real-time data which is recorded every minute. Growers without a home computer can access weather information from individual vineyards and calculate the powdery mildew index and degree days using the information. The information from all the weather stations is also used to update a phone recording at the Sun-Maid headquarters in Kingsburg on a daily basis during the growing season through harvest. The weather information, when combined with vineyard monitoring data and other information such as evapotranspiration potential is used to provide an up to date source of information to raisin and grape producers to help with their vineyard management decisions.

Development of new materials for pest and disease control

Traditional materials for insect and disease control are being replaced due to regulatory changes, loss of effectiveness or concerns with the environment. Increasingly sophisticated technology can determine amounts of materials previously undetectable. Consumer awareness is causing many growers to rethink their approaches to pest control in an attempt to satisfy consumer demands by insuring a more wholesome food supply using less toxic materials which are more environmentally friendly. Research indicates that broad spectrum pesticides can result in loss of beneficial control organisms which help to keep pest populations in check naturally. Continued use of broad spectrum pesticides can speed the onset of pesticide resistance, resulting in the use of higher rates of material or total loss of control of those materials.

Manufacturers recently introduced new materials which meet the demands imposed by consumers. Several fungicides which utilize entirely new modes of action have been introduced and registered over the last several years. Azoxystrobin (Abound™) was registered for control of powdery mildew, phomopsis cane and leaf spot, black rot, and downy mildew. This material is based upon compounds derived from strobilurin mushrooms and is classified as a reduced risk fungicide. It has a low risk to workers and the environment and is applied at very low rates. Another compound named Elexa™ is based on a complex carbohydrate and is described as a plant defense booster. It has shown good control of powdery mildew in replicated vineyard trials in California vineyards. The manufacturer submitted for full California registration on October 19, 1998. A third fungicide which has full registration is *ampelomyces quisqualis* (AQ10™). This material is a naturally occurring hyperparasite of powdery mildew. AQ10™ is a completely different mode of action than any other fungicide and has potential for resistance management. A potassium bicarbonate compound (Kaligreen™) was registered for powdery mildew control in 1998 as well. This material has a different mode of action from other fungicides and represents an alternative approach to powdery mildew control. The development of new materials which incorporate differing modes of action is an important means of preventing the development of resistance by target organisms and also frequently reduces risk to the environment and the applicator.

Insect and mite management has also seen the introduction of new materials with different modes of action than carbamates, organophosphates and chlorinated hydrocarbons. *Bacillus thuringiensis* formulations represent a non-chemical approach to control of lepidoptera insects. Different strains of B.t. are being identified and incorporated into new formulations which are reported to have greater efficacy and a longer residual effectiveness. Preharvest intervals with these materials are very short. Some of the B.t. compounds include Javelin™, Dipel™, and Crymax™. The naturalyte compound spinosad is being used for worm control in cotton and other commodities and is expected to be registered for omnivorous leafroller control in grapes in the next several years. Spinosad is being commercially marketed as Tracer™ and Success™. These materials also represent a totally different mode of action for control of lepidoptera and present alternatives to the standard petroleum based insecticides. Pheromones are being used in traps to monitor insect populations and flight patterns. Pheromone mating disruption is a viable method of insect control and is being used commercially. Pheromone impregnated strips or coils are working to reduce selected pest populations, but their use is not 100% effective and further improvements are being sought. Products utilizing pheromones include Checkmate and No-Mate OLR.

Mite management is a major problem in raisin vineyards because of terracing requirements and the nature of the sandy soils where raisins are produced. A new miticide pyridiben is expected to be registered next year as Pyramite™ This material has a broad spectrum of pest control and offers a very good alternative to Omite™ based upon information supplied by the manufacturer. A second miticide actually had a Section 18 registration in 1996 and has been submitted for full registration in 1999. The material avermectin will be registered as Agrimek™ if the manufacturer receives the approval for grapes. The compound is already registered in other commodities as Zephyr™ and as Agrimek™. Rates of pyridiben and avermectin are drastically lower than the standard miticides which have been used the last 25 years.

In summary, recent advances in technology allow the introduction of new materials with totally different modes of action and a much better environmental profile than the materials we have been using for the last 25 years. These materials are an effective component of an integrated pest management program and they help insure a continued safe and wholesome food supply.

Dried on the vine raisin production advances

Raisin production is labor intensive and techniques of production in the field are relatively unchanged for the last 25 years. The uncertainty of weather and labor is making raisin production difficult. The 1998 season was beset with both bad weather during the growing season and a shortage of labor during the harvest season. Some growers were not able to get raisins laid down in time to meet the September 20th Federal Crop Insurance deadline. The USDA in Fresno developed several early ripening varieties with the potential for dried on the vine (DOV) raisin production and will be releasing several new cultivars in the next several years. Two released cultivars include Fiesta and DOVine. Earlier ripening cultivars are desirable for raisin production because grapes can be harvested earlier in the season to reduce the possiblity of rain damage whether the grapes are used to produce tray dried or DOV raisins. The University of California, California State University at Fresno and Sun-Maid Growers of California have been experimenting with trellises and the other aspects of DOV raisin production.

Sun-Maid Growers of California patented a DOV production system which utilizes a trellis system which separates the current fruiting wood from next year's renewal canes. The fruiting wood is borne on the south side of the row and renewal canopy is maintained on a separate portion of the trellis. Canopy separation is an important component of the Sun-Maid DOV production system. Trellising requirements are different for a DOV system because the fruit is carried on the south side of the trellis. Endposts must be reinforced to compensate for the increased stress. Bent stakes are placed every other vine to support the extra weight of the south side fruit and to allow for mechanical harvesting. Training of the vine is different than conventional single or double wire vineyard trellises. Canes are left longer and tied differently than conventional vines to allow fruit to hang within a specified zone to allow mechanical harvesting. Equipment has been developed to allow mechanical cane cutting, leaf removal and harvesting. Canes are cut in mid to late August and allowed to hang on the trellis while the grapes dry into raisins. Leaves are mechanically removed within a few days of cane cutting to allow better light penetration and air movement to facilitate drying. Raisins are machine harvested when sufficiently dry. The drying process takes longer for DOV than for conventional tray dried raisins and the finished fruit is slightly different in flavor and appearance. Existing vineyards can be converted to the Sun-Maid DOV system and the conversion can be done over a two year period. Capital investment for DOV depends upon selection of stakes, wires, and whether the grower provides the labor or contracts for the service. Growers utilizing DOV report cost savings because they do not purchase rain insurance and do not have to buy paper trays. Raisins can be allowed to hang on the trellis following a rain and can be harvested later when dry. Labor requirements are not as critical for DOV because of the potential to utilize mechanization for harvest operations. Growers have expressed increased interest in DOV production following the recent growing season. Acreage is expected to increase as more growers convert to the system. The adoption of new technology is critical to successful raisin production as we proceed into the next millenium.

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Sun-Maid's Best Management Practices program is an innovative partnership with The Pew Charitable Trusts and Fresno Pacific University and is available for all California raisin growers.

RETURNING TO MORE BIOLOGICAL RELIANCE IN COTTON IPM

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One of the key issues facing the cotton industry in the San Joaquin Valley is profitability. Since 1990, production costs have risen and yield improvements have stalled. An important component in the increased cost of production has been insecticides. Several factors may be responsible for the increased insecticide costs. First, the number of applications has increased. Next the number of applications that contain more than one material has increased. Finally, the cost of materials has increased.

Over all, the San Joaquin Valley has a high level of IPM awareness and utilizes many IPM practices. In a 1997 National Agricultural Statistical surveys (Anon., 1998), the West led the country in the utilization of IPM practices in cotton (Figure 1). For example, scouting for pests is done at least weekly and for some pest, more frequently. Sample numbers are interpreted for management decisions. Host plant resistance is utilized to combat nematodes and diseases. In addition, there is an excellent appreciation of the role of natural enemies and the need to conserve them. PCAs have a good understanding of the role of neighboring crops as sources of pests.

Yet in spite of this, the last five years have proven difficult for pest management of insect pests and have required the extensive use of insecticides (Goodell et al., 1997). Why is it so difficult to rely on biological components and build stability? The following general observations provide a framework for discussion:

- The row crop ecosystem must be rebuilt each year;
- Migratory pests are key in the system and determine the amount of broad-spectrum insecticides which need to be applied;
- A field could be in biological balance one day and overwhelmed the next day due to pest migration from neighboring fields;
- There is a heavy requirement on high risk insecticides because of the lack of reduced risk and environmentally benign products
- Profitability shortfalls drive the need for maximum yield

Unlike permanent crops such as orchards or vineyards where a developed and generally stable arthropod complex exists, the cotton plant and the arthropod complex must be developed each year. Thus migration of pests, natural enemies, and even by-standers play a key role. For the most part, pest problems develop external to the cotton field and arrive almost by chance. A fundamental IPM tenet during this colonization period is to limit broad-spectrum insecticides except when indicated through population sampling and evaluation of potential damage. The conservation of natural enemies is a deeply appreciated practice in San Joaquin Valley cotton production. Indigenous natural enemies play a crucial role in keeping worm, spider mites, and aphid populations in check. However, rapid and sustained migrations of *Lygus*, aphid or worms can quickly tip the balance and require chemical intervention to prevent economic loss.

Biological Integrated Farming Systems (BIFS)
The BIFS program is sponsored program California Assembly Bill 3383 through joint support by the California Department of Pesticide Regulation and US-EPA through UC Sustainable Agriculture Research and Extension Program. The aim is to increase biological integration in farming systems with expectation that reliance on synthetic inputs will be reduced. It is modeled after the BIOS almond program that places a high value on participatory research and extension methods. The West Side On-Farm Demonstration community placed the improvement of soil quality as the highest priority followed by improvements in cotton insect pest management.

The main thrust of the BIFS pest management effort was to try as many alternative approaches to insect pest management as possible. The approach followed the general BIFS philosophy:

- In a group setting, identify the problem and potential solutions.
- Establish a group of farmer leaders who agree to follow a set of mutually agreed practices and provide land for side by side demonstration (Attachment 1).
- The farmer would agree to test a variety of biologically intensive pest management practices, their choice depending on their interest and the fit in their practices.
- Closely monitor the fields and provide summary information to farmers and their PCAs.
- Consult with the farmers and PCAs prior to any insecticide treatments

Results and Outcomes:
During the winter of 1998, a series of meetings were held at West Side Research and Extension Center near Five Points California. The key pest problems were identified and a practice list was developed. Between February and April 1998, monthly seminars were held at which invited experts were brought in to discuss a wide range of biointensive pest management topics. These included use of food supplements to attract lacewing, lacewing identification and use, survey of aphid parasites, and the development of green bridges to help overwinter beneficial insects. These meetings provided a forum for discussion around the topic and for the development of ideas.

By the end of April 1998, five farms and eight fields had been identified. All were quarter section in size with a sub-area 20 to 40 acres where the farmer would experiment with novel tactics. Each area was sampled twice weekly during early to mid-season and weekly during the latter part of the growing season. A bug vac and sweep net were used to cover 50 paces. Insects were identified and counted. Plant based monitoring include height, number of nodes, and fruit retention.

Of particular interest to this group was the use of cowpea strips that acted as migration buffers (Goodell and Eckert, 1998). These strips were to intercept *Lygus* bugs as they came in from neighboring fields. The cotton bordering the strips were compared to cotton further into the field or in neighboring fields or compared to cotton along the same edge. Another tactic of interest the bean strips and bordering cotton at a rate of 5,000/acre. Four releases took place over eight weeks beginning in mid-July.

These approaches were designed to increase the biological integration in cotton pest management. Preliminary analysis does not indicate a difference in insecticide application between comparison fields. Pest pressure remained consistent between the fields and required the same amount of insecticide intervention. Bean buffers were more attractive to *Lygus* during August (Figure 2), a less critical time period since cotton is less vulnerable to this pest. More research is required to understand the period of time when beans are most receptive to attract and hold *Lygus*. The amount of area required to draw and slow a migration must be balanced between the size of the migration and the area which is feasible to take out of cotton production.

Interest by farmers in alternative control methods is strong. The community is interested in finding ways to stabilize the arthropod ecosystem in order to maintain productivity while reducing production costs. The BIFS model allows for an evaluation loop (Dlott, 1998) through group discussion and individual experimentation that can be brought back for group consideration. This has opened new opportunities for applied research and delivery of IPM programs in the West Side.

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Attachment 1. Suggested practice list for 1998 cotton BIFS insect management project.

BIFS Cotton Insect Pest Management Approach – Field Demonstration

The following are suggested practices for bio-integrated management of cotton insects in the West Side environment. These plus the agreement to allow UCCE samplers into the field acknowledge your site as a field demonstration site for the West Side On-Farm Demonstration Project. Not all practices are required but using but 80% will qualify as a *bio-integrated* cotton field.

General agreements:

- Allow UCCE access to field for twice weekly sampling of insects and cotton growth and development
- Notify the BIFS Coordinator of any pest control actions would limit access to the field
- A portion of the field not less than 20 acres will be used to demonstrate these practices and consultation will occur before pest control is initiated.
- UCCE agrees to provide a copy of the data on a weekly schedule

Pest management practice check list:

- ❑ Planting of cotton as early after March 10th as soil temperature and five day forecast allows
- ❑ Planting at densities no more than 45,000 – 55,000 plants/ac
- ❑ Use of resistant varieties where appropriate and available
- ❑ Twice weekly inspections for *Lygus*, spider mites, aphids, and beet armyworms
- ❑ Pest density to reach action thresholds before pest control
- ❑ When appropriate, monitoring resistance with bioassays
- ❑ Follow 1998 Insecticide Resistance Management Guidelines
- ❑ Use of cowpea buffer strip on upwind edge of field
- ❑ Release of natural enemies into buffer strip
- ❑ Conservation of natural enemies through judicious use of insecticides, choice of selective materials, and initiating pest control actions only when pest densities reach action threshold
- ❑ Consider the condition of neighboring crops for managing *Lygus*, beet armyworms, and spider mites
- ❑ Crop termination as early as dictated by plant monitoring indices
- ❑ Attend UCCE summer production meetings and BIFS field days

Figure 1. Comparison of the use of pest management practices between southern and western cotton producing regions in the United States. Bars report the percent of acres receiving a practice.

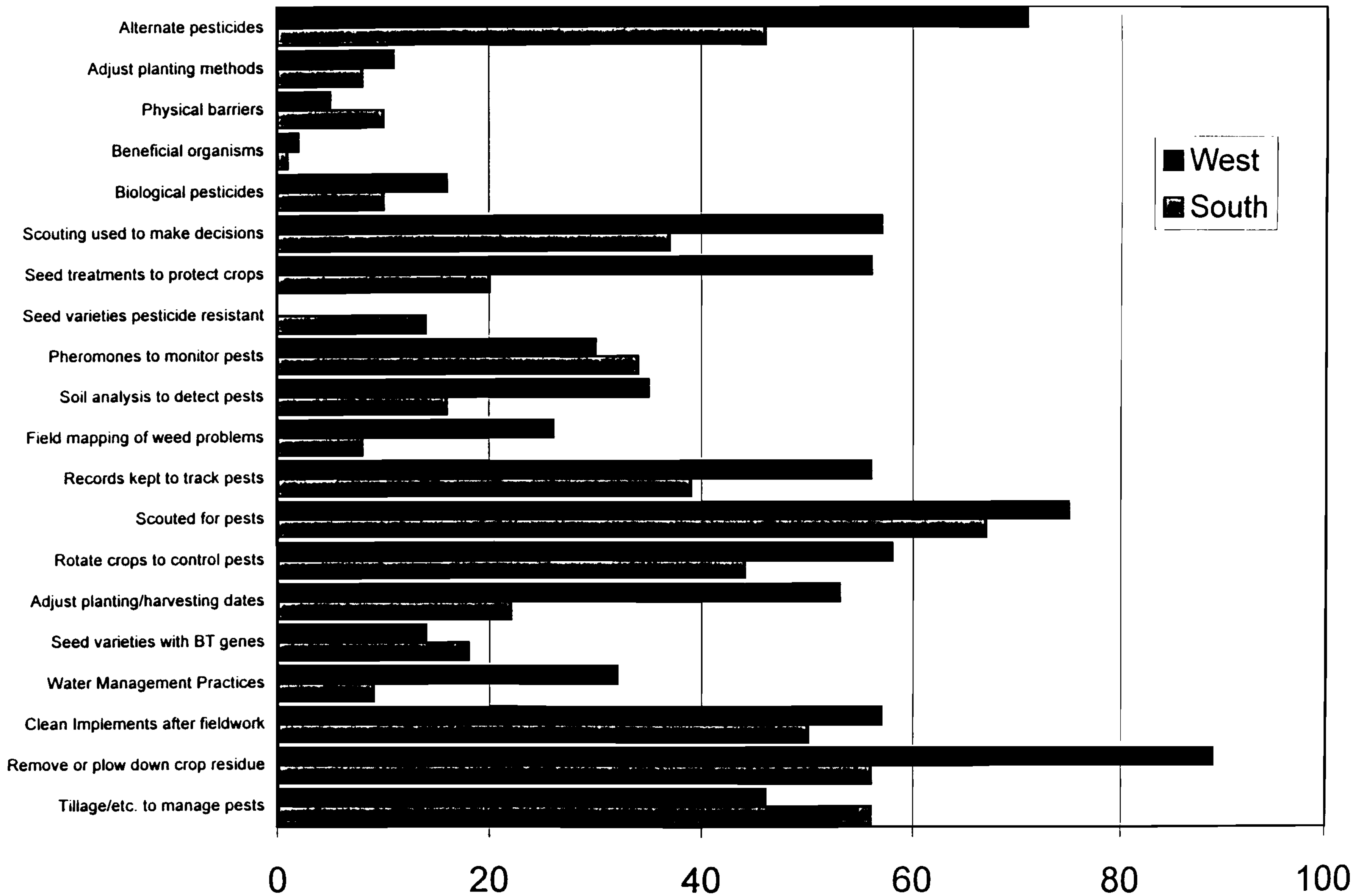
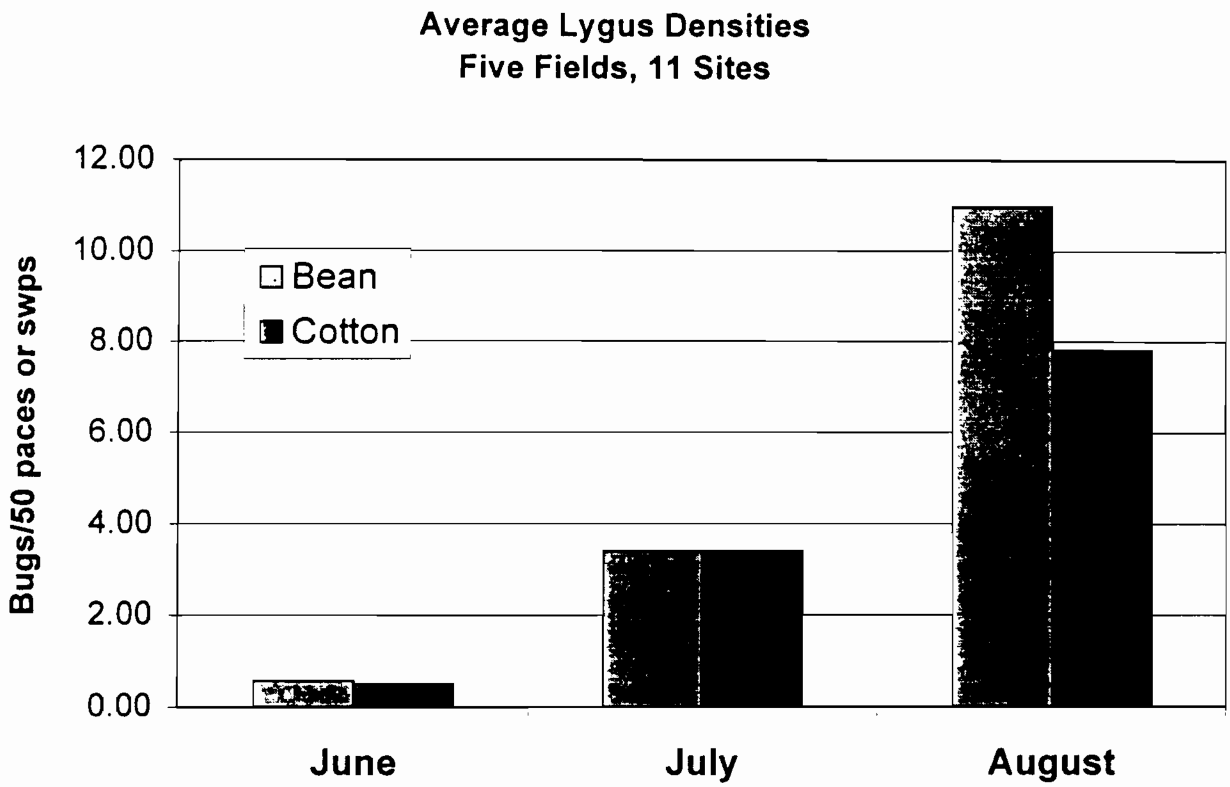


Figure 2. Average *Lygus* population estimates from beans bordering cotton in the West Side of Fresno County.



Conservation tillage technologies in California vegetable production systems

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Introduction

Currently, preplant tillage operations account for about 18 - 24% of overall production costs for annual crops grown in the West Side region of the San Joaquin Valley (SJV) (Biologically Integrated Farming Systems (*BIFS*) Project Farmer Survey, 1998). An average of about 9 to 11 tillage-related passes are routinely done during the fall-spring period to *prepare* the soil for summer cropping. These tillage operations represent not only considerable energy, equipment and labor costs, but recent research indicates that tillage reduces soil organic matter (SOM) as well. Because SOM is widely regarded as an important attribute of good soil quality and long-term productivity, interest has been growing over the last several years, in developing alternative production systems that reduce costs while at the same time improve the soil resource through greater carbon sequestration. Conservation tillage (CT) systems may serve to maintain and increase SOM levels. A variety of CT systems have been established for a number of crops including cotton, corn and wheat in the Midwest and throughout the world over the last several decades.

Recently, growing interest in growing vegetables using conservation tillage approaches has also surfaced in a number of places (American Vegetable Grower Magazine, February 1997). The winter annual legume hairy vetch for example, has been used successfully as both a cover crop and as a mulch in fresh market tomato production systems on the east coast (Abdul-Baki and Teasdale, 1993; Abdul-Baki, Stommel and Teasdale, 1995). As a cover crop, the vetch fixes N, recycles nutrients, reduces soil erosion and recycles nutrients and adds organic matter to the soil. When mowed and converted to a mulch, the vetch reduces weed emergence, lowers soil temperature during the hot summer months, reduces water loss from the soil and acts as a slow-release fertilizer (Abdul-Baki and Teasdale, 1994). This system that Abdul-Baki and Teasdale have developed eliminates tillage, reduces the need for applying synthetic fertilizers and herbicides, and is, according to these workers, adaptable to both large and small-scale production in a low-input, reduced tillage system (Abdul-Baki and Teasdale, 1993). Personal communications with Drs. A. Abdul-Baki and R. Morse, who have worked with organic mulches in no-tillage vegetable systems for over ten years, indicate that such approaches could definitely be adapted to Central Valley conditions provided innovative modifications are made. Recent work in Australiz by Stirzaker (1992), with subterranean clover has shown similar benefits in lettuce and tomato production systems (Stirzaker, Sutton and Collis-George, 1992; Stirzaker, Passioura, Sutton and Collis-George, 1993). There may be however, problems associated with using cover crops in this way: land is put out of production, soil moisture may be depleted during the cover crop growing season relative to a winter fallow, and early summer season soil temperatures may be cooler under a surface mulch than bare soil. There may also be problems related to the management of cover crop residues that can be phytotoxic to certain crops that follow a green manure mulch (Lovett and Jessop, 1982).

Over the last three years, we have evaluated and refined conservation tillage approaches for processing and fresh market tomato production in the Central Valley. Conservation tillage work has also been initiated in other regions throughout the State including the Coachella Valley within a mixed vegetable rotation study at the University of California Desert Research and Extension Center in Indio and the Central Coast regions of San Luis Obispo and Santa Barbara counties. Though these production practices are new for the State, steady progress is being made in evaluating their potential and in refining practices that have been successful in other areas. Progress on our recent work with tomatoes is reported here.

Objective:

The objective of this research has been:

- to evaluate the effectiveness of surface organic mulches in reduced-tillage processing tomato production systems for:
    - suppressing weeds
    - improving production efficiencies in terms of nutrient inputs
    - providing optimal soil temperature regimes for crop growth and
    - conserving soil moisture

Procedures:

Field studies were conducted in 1997 and 1998 at the UC West Side Research and Extension Center (*WSREC*) and the Sustainable Agriculture Farming Systems (*SAFS*) Project's "playground" area on the UC Davis campus. In the WSREC experiment, six winter cover crop mixtures were planted in October 1997 on preshaped 60" tomato beds and killed in late February to provide a surface mulch into which processing tomatoes were machine transplanted. Cover crops were only planted on the bed tops, not in the furrows. These cover crop treatments were compared with a winter fallow to which preplant herbicide is applied and a fallow control to which no herbicide is applied. Each treatment plot was 2250 ft^2 which permitted normal tractor operations. The cover crop mixtures were 1) *Medicago scutellata* "Sava", 2) *Medicago truncatula* "Sephi", 3) *Triticale* / Lana vetch and 4) Ryegrain / Lana vetch / Magnus pea. These treatments permitted a testing of mulches with different growth and cover attributes and cover crop mixtures of different seed costs. Each mulch/fallow plot was split into 3 subplots. One subplot was fertilized at 100 lbs N / acre, one at 200 lbs N / acre and one was not fertilized to evaluate the potential for reducing fertilizer inputs in this system. The mulch/fertilizer treatments were replicated four times in a split plot design with fertilizer applications as main plots and mulch treatments as subplots. A common processing tomato variety, 3155, was transplanted using a single-row machine transplanter that has been modified by B & B No-Till of Laurel Fork, VA. The modifications are based on a successfully-used no-till transplanter that has been developed by R. Morse at Virgina Polytechnic Institute (Morse, 1995). Tomato crop growth was determined during the growing season using a Decagon Accupar Ceptometer, Pullman, WA. Fifty tomato petioles of the first fully expanded leaf were sampled four times during the tomato growing season and analyzed for tissue N at the UC DANR Lab in Davis using a LECO FP428 Nitrogen Gas Analyzer (St. Joseph, MI). Soil temperature at 10 cm depth was monitored continuously during the tomato growth season using a microprocessor controlled temperature data logger (Campbell Scientific). Changes in soil water content during the tomato season were monitored by neutron hydroprobe (Campbell Pacific Nuclear) readings in access tubes installed in the planted row of beds before and after irrigations. Fruit yield determinations were accomplished by machine harvest using field weighing gondolas. Tomato quality was assessed by measurement of soluble solids and color at a State grading station and pH by Mitchell at the WSREC lab.

At four weeks after tomato transplanting, and twice again thereafter, weed cover and species composition were assessed from 3 randomly placed 50 X 50 cm quadrats per subplot.

The trial conducted at the *SAFS* plots in Davis was primarily for demonstration and observation purposes. Tomatoes were transplanted into a variety of cover crop mulched plots and compared with + herbicide and - herbicide fallow plots. Tomato growth was monitored using a Ceptometer and yields were determined by hand harvesting 20 ft sections of each plot.

Results

In general, the following preliminary findings surface from this work.

1. Water content (0 – 9 feet depth) was similar in fallowed and cover crop soils throughout much of the 1997 – 98 winter and at tomato transplanting in April

2. Earthworm populations tended to be higher under cove crop mulch surfaces than under fallow surfaces in February and March 1998 (Table 1)

3. Weed pressure was considerably greater in 1998 than in 1997 under both fallow and cover cropped mulches (Data still being analyzed)

4. Soil water content (0 – 9 feet depth) was generally higher under cover crop mulches from May through August relative to conventional tillage bare surfaces (Figures 1a – c)

5. As in 1997, tomato yields under certain cover crop mulches were comparable to those under bare fallows. Statistical analyses are still being made on this data however, there do not appear to be fertility benefits associated with cover crop mulches at either the 0 or 100 lb N reduced fertilizer rates. (Figure 2a – c)

6. Soil penetration resistance was lower under rye/vetch and triticale/vetch mulches at some 0 – 60 cm depth intervals (Figure 3)

7. No differences resulted from 2 year back-to-back mulching in terms of soil water holding capacity or bulk density

Discussion and Conclusions

Considerably more work is needed to evaluate, refine and adapt conservation tillage techniques for California vegetable production systems before these approaches are ready for widespread adoption throughout the State. Steady progress is being made however, to carefully select the particular types of production contexts where they have the greatest potential opportunity of succeeding. To date, a number of preliminary conclusions can be drawn from the work reported here. These findings include the following: 1) transplanting and harvesting processing tomatoes in surface cover crop mulches is feasible, 2) cover crop mulches may actually contribute more favorably to annual water balances than previously thought, 3) economic analyses comparing production costs between conservation tillage and conventional tillage systems are needed and 4) in-season, post-transplant weed control by appropriate chemical materials or bed shoulder cultivation may make conservation tillage production more farm-ready and are the focus of ongoing 1999 studies at a number of sites.

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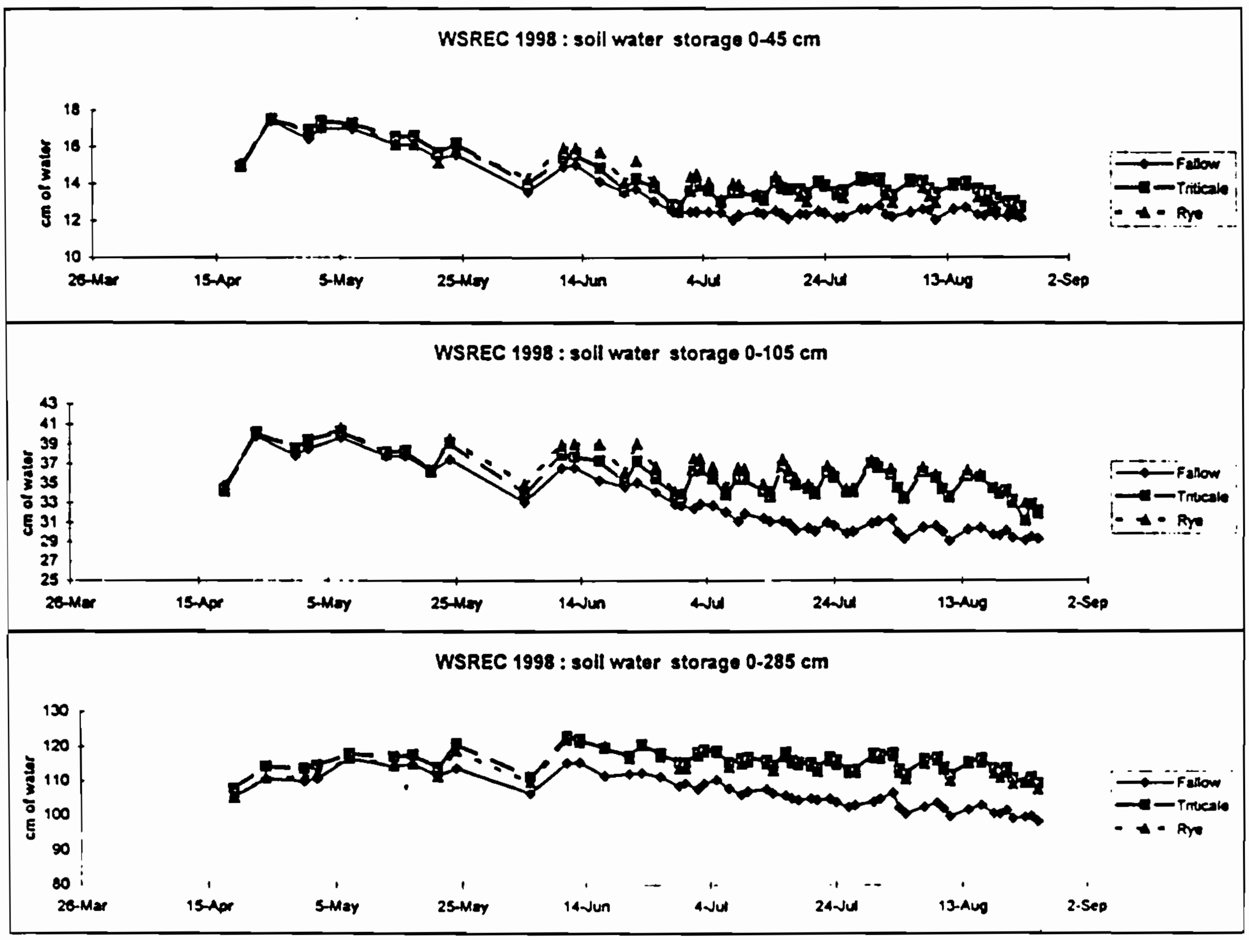
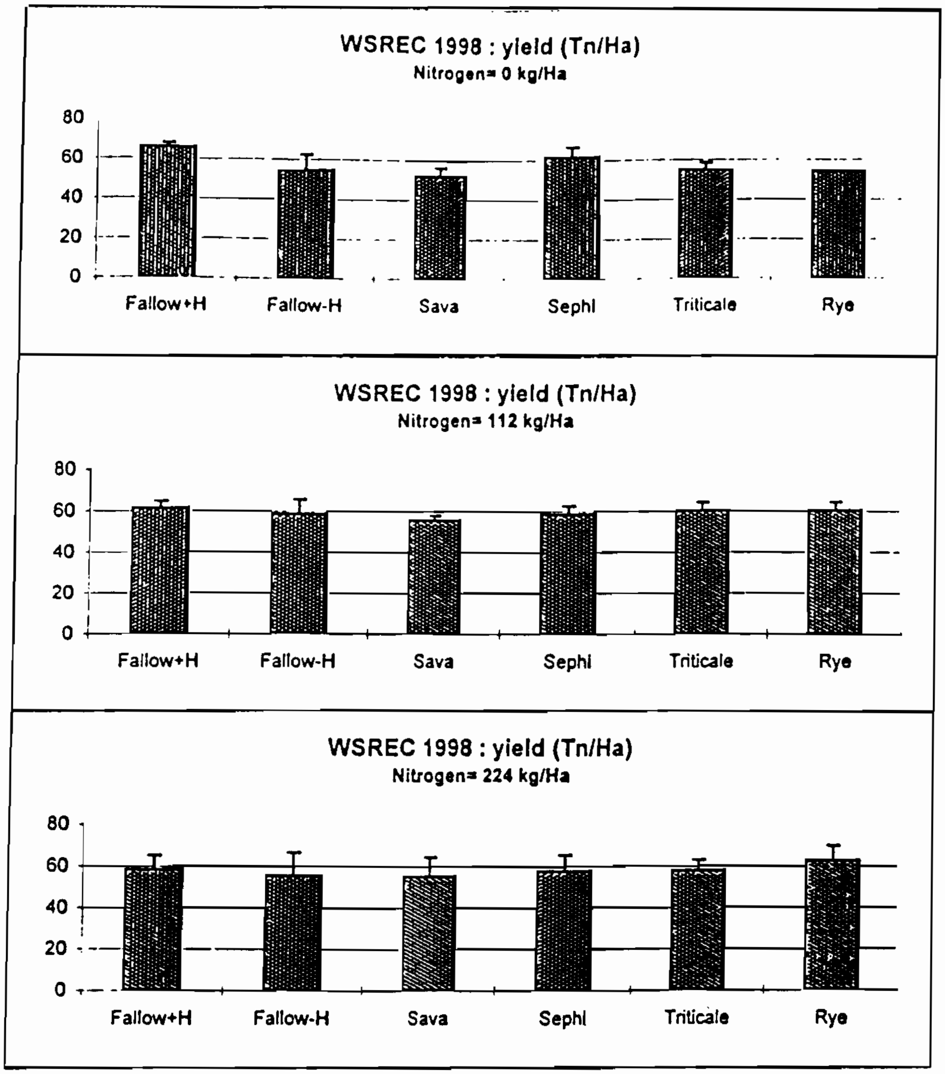
Table 1 Number of earthworms in surface 15 cm February / March 1998

Fallow + herbicide	5.17
Fallow – herbicide	1.42
Sava medic	15.25
Sephi medic	12.08
Triticale / vetch	8.08
Rye / vetch	14.08



Figures 1a, b and c Soil water storage a) 0 – 45 cm, b) 0 – 105 cm and c) 0 – 285 cm under fallow. triticale/vetch and rve/vetch surfaces



Figures 2a, b and ca Tomato (3155) fruit yields under a) 0 kg/ha N, b) 112 kg/ha N and c) 224 kg/ha N

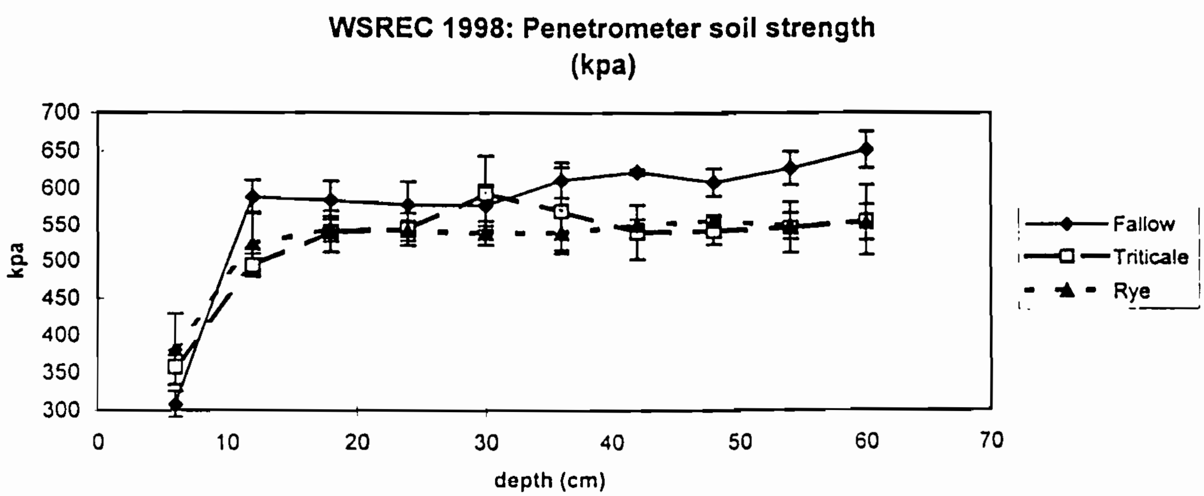
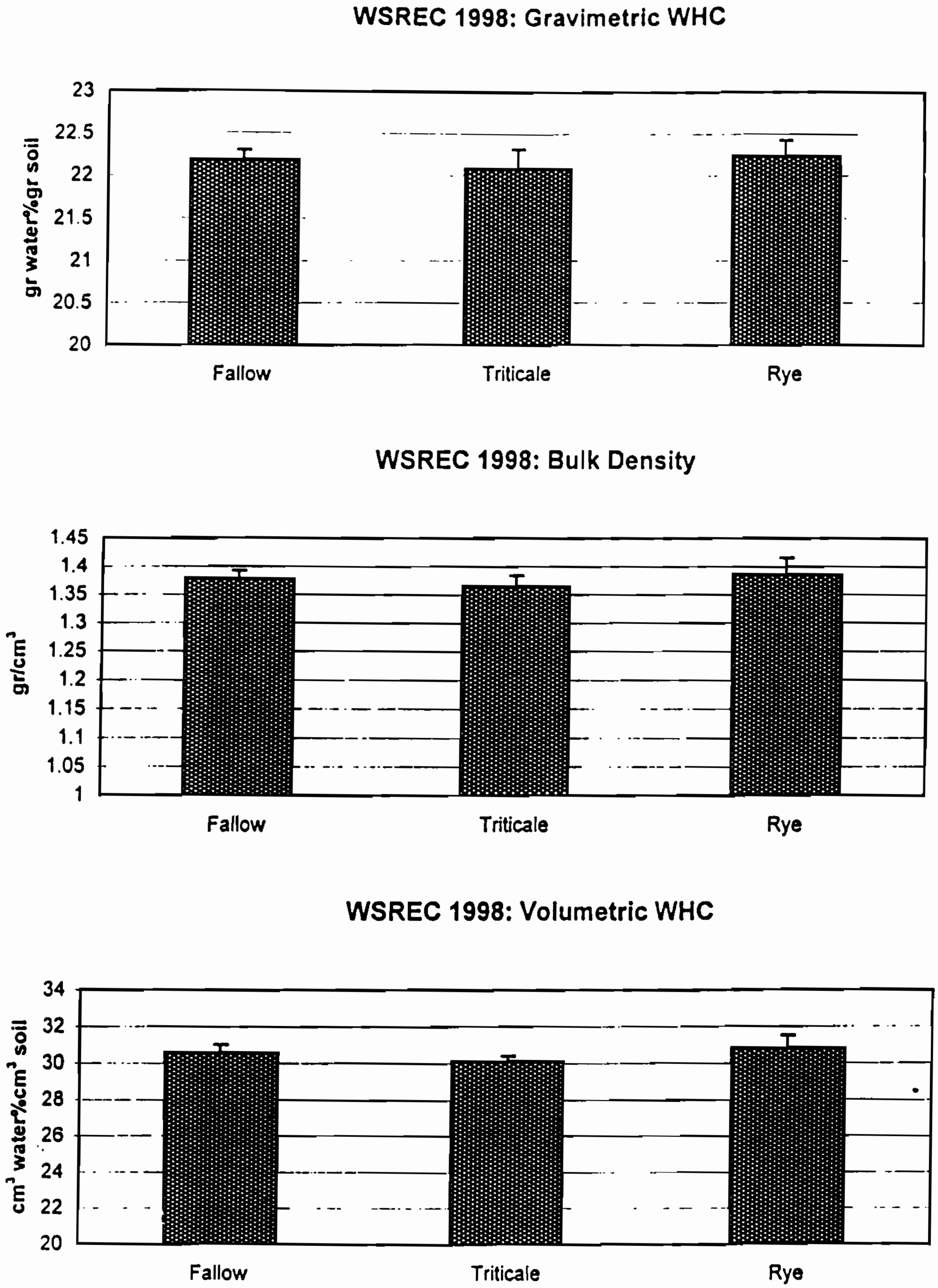


Figure 3 Soil penetration resistance (0 – 60 cm) using cone penetrometer under fallow, triticale/vetch and rye/vetch surfaces



Figures 4a, b and c Soil a) gravimetric water holding capacity, b) bulk density and c) volumetric water holding capacity at 0 – 15 cm

INSECTICIDES OF THE 21TH CENTURY - WHO, WHAT, WHEN, WHERE, AND HOW?

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INTRODUCTION

Insecticides are an important tool in crop production and integrated pest management in California and elsewhere. The same characteristics of the California environment that allow for unparalleled agricultural production and high livability also promote populations of several severe arthropod pests. These conditions include the lack of a long, hard freeze (in the Central Valley), a wide range of host plant material, including crops, weeds, perennial plants, overlapping cropping cycles, etc. and are met as well in California as any other state. In 1995, ~200 million lbs. active ingredient of pesticides were used in crop production. Of this total, ~25% were insecticides and the remaining portion were herbicides, fungicides, etc. These insecticidal materials are critical components of integrated pest management (IPM) programs, and along with biological, cultural, and host plant resistance components, form usable programs. Without these IPM programs, crop losses from insects would be significant; estimates as high as 30-40% have been made. With these management schemes, insects and mites still commonly destroy 5-10% of crop production. Advances are being made, and more will follow, in the various components of IPM (host plant resistance, biological control, etc.) as we move into the 21th century, but insecticides will still be needed to manage outbreak situations and to keep insect levels below the economic threshold. However, the types and characteristics of these insecticides will be greatly different from those on the market today.

Insecticide types and characteristics have changed substantially over the last 60 years. It is likely that countless changes will take place in the next 10 years. Pesticides, and more specifically insecticides, were originally composed of inorganic compounds and natural products. Examples of these compounds, used exclusively until the 1940's, include arsenic, copper, sulfur, petroleum oils, nicotine, and rotenone. The synthetic organic insecticide era began in the 1940's with DDT. In fact, in 1948, the Nobel Prize for Medicine was awarded to the discoverer of the insecticidal properties of DDT. Several other usable insecticides related chemically to DDT were developed in subsequent years. The first organophosphate insecticide used in agriculture was introduced in 1946, but the majority of these compounds came on the market in the 1950's. Diazinon, for instance, was introduced in 1952. The carbamate class of insecticide chemistry followed in 1956 and many of these products reached the market in the 1960's. Synthetic pyrethroid insecticides were introduced into the U.S. in 1978 and into California several years thereafter. These materials provided unparalleled insect control, extremely low use rates, and minimized problems with acute toxicity.

Biorational insecticides, other than the previously-mentioned botanical and oil products, appeared on the scene in the late 1970's to early 1980's. *Bacillus thuringiensis* formulations have been sold under several trade names. The utility as a foliar application has been somewhat limited due to breakdown by UV light, slow speed of kill, and limited pest spectrum. Fermentation products, utilizing a byproduct of a microorganism, are another type of biorational insecticide. Rather than needing the living organism to achieve control, the byproduct can be collected and utilized as a spray. Insect growth regulators, which take advantage of the natural growth and development processes within the insect, have been researched and discussed for the last 30 years. These agents would appear to be the ideal insecticides in that they would be selective for insects (and likely for species within Insecta), have low toxicity to humans, etc. With both of these last two categories, in many cases the fermentation product and insect growth regulator have been identified and synthesized as an organic compound. This may effect the categorization as a biorational product but may improve the stability, availability, etc. of the compound. In the 1990's, these products experienced some important, but specific uses in crop protection.

During the last ~3-5 years, there has been a flourishing of new insecticide chemical groups and modes of action. What has spurred this activity? Some of this activity is the result of fundamental research finally reaching the end user, i.e., biotechnology and genetically engineered plants. The marketplace has demanded new chemistries to maintain effective arthropod control. The agrichemical industry has responded to these needs. Also, regulatory actions, such as the Food Quality Protection Act, which is threatening the registrations of organophosphate and carbamate insecticides, has fueled research activities into alternative chemistries. The desire by EPA, as well as the general public, for "reduced-risk" chemicals and the suggestion by EPA that they will fast-track the registration of these materials has further enhanced research to this end. These products have the general characteristics of low mammalian toxicity, high pest selectivity/minimal effects on natural enemies, and generally short residual. The remainder of this paper will highlight some of the types of products and chemistries that are in the registration pipeline. I will mention some specific examples, not to accentuate these materials but rather as just representatives of the technology. Several of these products have not received any federal registrations, whereas others have been available for 2-3 use-seasons. California registrations are beginning to occur for some of these products; however, considerable work remains on incorporating these products into existing IPM programs in California. The very specific activity of many of these products means that the agricultural system must be better understood to optimize control efficacy. Many of these products are "unforgiving" if used improperly.

Transgenic B.t. Crops: Genetically engineered crops, expressing the insecticidal protein from *Bacillus thuringiensis*, have recently become available. Cotton, corn (field and sweet), soybeans, and potatoes are some of the crops in which this technology is available. This control strategy is the result of many years of research, starting at the very basic scientific level. This technology is an excellent delivery system for the microbial insecticide and helps to overcome the main shortcoming of *Bacillus thuringiensis* insecticides, i.e., breakdown in UV light. With genetically engineered crops, every bite the insect takes contains some level of the toxin. Cotton production has been positively impacted by B.t. cotton. In some states up to 80% of the planted acreage utilizes this technology. Foliar insecticide applications for lepidopterous pests have been dramatically reduced; however, some applications for worms are still needed in some cases. Use of B.t. crops has thus far been limited in California. The strength of this technology is in controlling lepidopteran pests, particularly the bollworm/budworm complex (*Helicoverpa/Heliothis*). European corn borer, salt marsh caterpillar, loopers, cotton leaf perforator, and pink bollworm are also well controlled. These pests, while present at some level in our crops, are generally not the most severe pests facing California producers. For instance in California cotton, lygus bugs, spider mites, silverleaf whitefly, and cotton aphids are the most important arthropod pests. B.t. cotton would have no direct effects on these pests. Beet armyworm (*Spodoptera exigua*) is a lepidopteran pest that can damage California cotton and the B.t. engineered cotton system does not effectively control this pest. Research in other states has shown ~30% control of beet armyworm with B.t. cotton. For field corn in California, spider mites, aphids, and leafhoppers are the most important pests and again B.t. engineered corn provides no control of these pests. In the future, there is the likelihood that this approach and system can be used as a conduit to insert genes and toxins into plants that would have a better fit to our pest spectrum in California. Therefore, advances in biotechnology and engineered plants may play an increased role in insect management in future years.

<u>New Insecticides (reduced-risk):</u> The development of B.t. crops has indirectly spurred research and development of biorational insecticides. In B.t. cotton for example, since minimal broad-spectrum insecticide applications would be needed for bollworm/budworm, natural enemies are conserved. Therefore, a strategy is evolving of attempting to conserve these organisms, so they can aid in pest control, through the use of "softer" products. These applications of softer products are made for pests not controlled by B.t. and as oversprays to control other worm species or B.t. escapes.

Table 1 summarizes some of these new insecticides. Registration of several of these new, biorational products is being pursued in California. Several aspects of these new products are particularly exciting for IPM programs. These new products generally have low toxicity to mammals/humans. For instance, the LD_{50} for pymetrozine is >5820 mg/kg which is in the same range as table salt. The LD_{50} values for several of these other active ingredients are similarly high. The specificity for the target pest is another outstanding attribute and a valuable asset for IPM programs. Finally, the variety and the range of modes of action are apparent and will be useful for delaying the onset of insecticide resistance. Even among the products in the insect growth regulator class or those with neural toxin activity, the exact mode or sight of action varies so the selection pressure for developing resistance is minimized. The variety of approaches used to discover these materials begs the question of how many other usable compounds are waiting to be discovered. For instance, the new insecticide spinosad originated from a soil sample collected in the early 1980's; microbial isolations, purification, and fermentation revealed insecticidal activity.

There will be challenges with using these new products. It is important to use these new insecticides, as well as genetically engineered plants, utilizing the best practices for delaying resistance. Resistance in arthropods can and will develop if it is not managed properly. This is currently one of the concerns and points of discussion regarding the B.t. technology. Secondly, the pest specifically is a "two-edged sword". The pest status of some insects was previously masked by the use of broad-spectrum insecticides. For instance, plant bugs (*Lygus* sp.) are now significant pests of cotton in the Mid-South. These plant bugs used to be killed by the insecticide applications targeted for bollworms/budworms, but now additional plant bug applications are needed. In addition, with the conservation of natural enemies, there is a need to better understand what the predators and parasites are contributing to biological control in the system, including predictive abilities. Questions such as, Which species are most important?, How many do I need to affect pest control?, etc. all need to be answered.

Additional pest control technologies will follow. Biotechnology and other approaches will continue to deliver products for evaluation and possible commercialization. Plant activators/inducers, proteinase inhibitors, and recombinant baculoviruses are a few of the technologies that are presently being researched.

Table 1. Summary of the characteristics of some new insecticides under development.

Common Name	**Class/Type of Product**	**Mode of Action**	**Spectrum (preliminary)**
pymetrozine	pyridine azomethine	inhibits/stops feeding	aphids and certain other sucking insects
buprofezin	insect growth regulator	inhibits insect molting, suppresses oviposition	whiteflies, scales, leafhoppers
pyriproxyfen	insect growth regulator	suppresses egg development	whiteflies, scales, psylla
tebufenozide	insect growth regulator - diacylhydrazine	mimics the molting hormone causing the insect to "molt" when it isn't ready	lepidopteran larvae
emamectin benzoate	avermectin fermentation product	affects insect nervous system	lepidopteran larvae
spinosad	fermentation product; spinosyn - Naturalyte class	affects insect nervous system	lepidopteran larvae, leafminers, others
fipronil	phenyl pyrazole	affects insect nervous system	plant bugs, soil insects, others
chlorfenapyr	pyrrole	affects energy production	lepidopteran larvae, spider mites, thrips
oxadiazine	?	affects insect nervous system	lepidopteran larvae, plant bugs

Drip irrigation management of celery – theory vs. reality

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Celery is a high value crop which has historically been very heavily fertilized and liberally irrigated. The application of 400 lb N and more than 24 inches of water seasonally has not been uncommon. In recent years the use of surface drip irrigation for celery production has increased. Drip irrigation and fertigation management requires a radically different approach than with conventional practices. Celery growers differ widely in their management of drip irrigation, and a number have experienced disappointing results. The California Department of Food and Agriculture Fertilizer Research and Education Program funded a project to develop appropriate drip irrigation and N fertigation guidelines for celery production. In the course of that ongoing project, the diversity of grower practices has become evident, as have some reasons for disappointing results achieved with drip.

Field trials have been conducted in Ventura, Monterey and Santa Barbara Counties. In each field the drip system was installed several weeks after transplant establishment. After system installation, replicated plots of drip tapes of different flow rates were patched into the field system, some higher than and some lower than the flow rates of that system. As the grower managed the field, graduated amounts of water were applied in the various plots, from approximately 40% less than, to 30-60% more than, the field system. Tensiometers were installed to monitor soil moisture. Plant growth and N status were monitored by biweekly sampling. At harvest plants were trimmed and sized by experienced harvest crews. Mean trimmed weight and degree of pithiness of the petioles were also recorded.

At the time this summary was prepared, only three trials had been completed, one in each county. In Ventura County the field was transplanted in March for June harvest, while the Santa Barbara and Monterey County trials were in summer fields harvested in July and August, respectively. The growers employed very different drip management strategies. In Ventura the drip irrigation was begun with a large (2 inch) application; the grower then made modest applications (0.5-0.8 inch) every 4-6 days (Fig. 1). No adjustment was made for increasing plant size, and increasing ET_o, as the season progressed. Not surprisingly, water stress was encountered in the last weeks of the season, even in plots receiving 30% more than the field. A significant level of pithiness developed in all plots (Table 1); the problem was severe enough that sprinklers were brought back into the field to finish the crop. The problem was compounded by the fact that the field was more than 800 ft. long, much too long for adequate distribution uniformity with the 5/8 inch drip tube used; water application at the tail of the field was <75% of that at the head.

In the Santa Barbara trial the grower applied 11.8 inches, including 2 inches by a furrow irrigation three weeks after the installation of drip system (a routine practice for this grower). He irrigated an average only every 5-6 days. Although the total volume of water applied was clearly sufficient (144% of seasonal ET_0), such low frequency resulted in significant transient moisture stress between irrigations. Also, with individual drip irrigations averaging 1.2 inches, some leaching was undoubtedly occurring. The plots receiving less water than the field rate were visually stressed, and smaller at harvest. The absence of pithiness in all plots was surprising.

In the Monterey County trial the grower used higher frequency irrigation, generally keeping pace with ET_0. Plots receiving less than the field rate of water had much smaller plants and very high rates of pithiness. Since the grower was not specifically tying irrigation volume to ET_0, there were two periods (27-35, and 38-45 days after drip installation) when irrigation fell behind. The effect of these transient stresses can be seen in the trend toward larger plants and less pithiness in plots receiving more water than the field rate.

In summary, direct use of ET_0 driven drip irrigation scheduling does not appear to be common among celery growers. Application of this well-documented principle could improve crop yield and quality.

Table 1. Response of celery to varying drip irrigation and fertigation regimes.

Site	Seasonal ET_o (inches)	Irrigation treatment	Seasonal water application (inches)	Mean plant weight (lb)	Pithiness[z] (% of plants)
Ventura	11.5	80% of field rate	8.0	2.17	42
		Field rate	9.9	2.33	30
		130% of field rate	13.0	2.29	42
Santa Barbara	8.2	60% of field rate	7.8[y]	1.69	0
		80% of field rate	9.5	1.94	0
		Field rate	11.8	2.07	0
		120% of field rate	13.5	2.16	0
		160% of field rate	18.2	2.11	0
Monterey	10.6	60% of field rate	7.3	1.41	76
		70% of field rate	8.7	1.60	53
		Field rate	12.9	2.27	12
		115% of field rate	15.0	2.28	5
		130% of field rate	16.8	2.47	2

[z]% of plants with 2 or more petioles showing pithiness

[y]all treatments at Santa Barbara trial include 2 inches by furrow irrigation

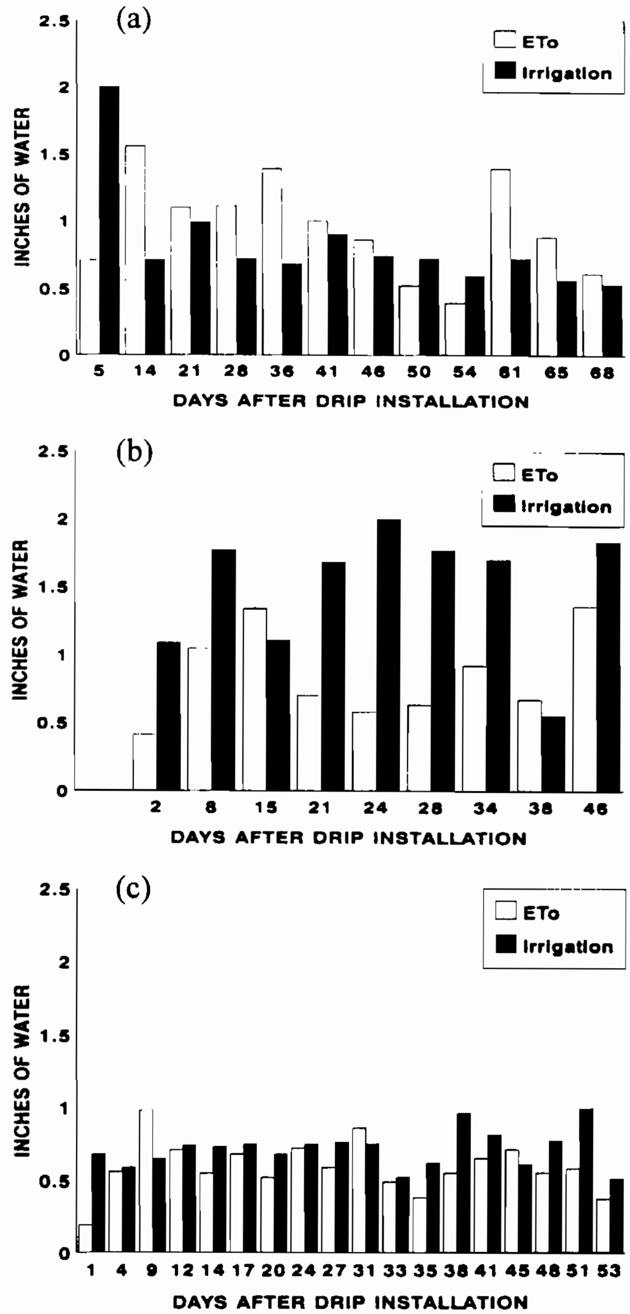

Fig. 1. Seasonal evapotranspiration and drip irrigation in the celery trials in Ventura (a), Santa Barbara (b) and Monterey (c) counties.

Evaluation of Controlled Release Fertilizers and Fertigation in Strawberries 1996-98

Warren E. Benedixen[1] and Blaine Hanson[2]

Strawberries are an important crop in the Central and Southern coastal areas of California. The strawberry plants are dug from nurseries in Northern California and planted in October and early November.

The strawberries require good fertilizer and water management practices to produce economical yields. Drip tape irrigation systems are installed before planting and is the major method of irrigation. Sprinkler irrigation is used along with the drip tape for a short time after planting to establish the crop.

Fertilization practices consist of various preplant applications followed by fertigation through the drip tape during the growing season.

This research was conducted to evaluate various preplant fertilizer treatments in addition to different growers fertigation program.

Procedures

Three fertilizer trials were established in strawberries during 1996-98. All of the trials were located east of Santa Maria. The trials received the same fertigation, irrigation, pest control and picking schedule as the commercial fields.

The strawberries were harvest by the growers commercial strawberry pickers. The fresh and freezer yields were based on the growers high standard for fruit quality.

The preplant fertilizer treatments were applied in October to compare three controlled release fertilizers, a standard fertilizer and no preplant fertilizer. The controlled release fertilizers were compared at 2 rates, 80 and 160 pounds of nitrogen per acre. The fertilizers were placed 5" below the bed surface and 2" to the side of the plants. Each fertilizer treatment was replicated four times in a randomized block design. The plots were 1 bed (64") wide. The 1996 and 1997 plots were 25' long and the 1998 plots were 30' long.

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1996 Procedures

The variety Camarosa was planted on October 25, 1995 with plants dug from a McArthur nursery on October 22, 1995. The grower's fertilization program applied a total of 180 pounds of nitrogen per acre.

The spring rains delayed the first harvest until March 17, 1996. During April, May, and June, the trial was harvested on a 3 or 4 day schedule and irrigated after each picking. The last fresh fruit harvest was on July 4, 1996. The trial was harvested for freezer fruit from July 10 to August 8, 1996.

1996 Results

The strawberry yields are shown in Table 1. The strawberry yields were not significantly different between the 3 controlled release fertilizers. The controlled release fertilizers with 160 lbs. of nitrogen per acre produced significantly higher strawberry yields than the treatments with 80 lbs. of nitrogen. The yields are very high for this area indicting a good production management program.

The standard commercial fertilizer at 160 lbs. of nitrogen produced yields similar to the 80 lbs. per acre rate of the controlled release fertilizers. The treatment with no preplant fertilizer produced significantly lower yields than the other 7 treatments.

Soil samples collected in May and June showed non significant differences between fertilizer treatments in NO_3-N and ECe concentrations. The samples ranged from 1.1-12.0 ppm - NO_3-N and 1.2 -3.9 ECe of the soil solution.

Table 1. 1996 Strawberry Fruit Yields with Three Fertilizer Rates and Three Control Release Fertilizers in Combination with Fertigation.

Fertilizer				Nitrogen[1] lbs/acre	Fruit Yields*					
					Fresh		Freezer		Season Total	
					--------lbs/A--------					
1	Duration	24-8-15	urea	160	71,368	a	9,655	a	81,023	a
2	Agricote	22-7-11	urea	160	70,259	a	9,295	ab	79,553	a
3	Agriform	18-8-13	NH_4NO_3	160	69,744	a	9,172	ab	78,916	a
4	Duration	24-8-15	urea	80	65,804	b	8,672	ab	74,476	b
5	Agricote	22-7-11	urea	80	66,072	b	8,227	b	74,299	b
6	Agriform	18-8-13	NH_4NO_3	80	64,668	b	8,306	b	72,974	b
7	Growers Commercial	15-15-15		160	63,715	b	9,660	a	73,375	b
8	Control				56,747	c	8,618	ab	65,364	c
				CV%:	2.6%		7.4%		2.4%	

*Duncan's multiple range test - Data numbers represented by the same letters are not significantly different at the 5% level.
[1]Nitrogen applied preplant

1997 Procedures

The variety Camarosa was planted on November 7, 1996 with plants dug from a McArthur nursery on October 30, 1996. The grower applied a total of 170 pounds of nitrogen per acre through fertigation.

The first strawberry harvest was on February 24, 1997 and the last fresh fruit harvest on May 18, 1997. The trial was harvested for freezer fruit starting on May 23 and continued until August 1, 1997.

1997 Results

The strawberry yields are shown in Table 2. The fertilizer trial shows the advantage of a preplant fertilizer application. The 3 controlled release fertilizers showed non-significant difference in total strawberry yield. The 3 controlled release fertilizers with 160 pounds of nitrogen per acre produced significantly higher strawberry yields than the treatments with 80 pounds of nitrogen.

The standard commercial fertilizer at 160 pounds of nitrogen produces yields similar to the 80 pounds per acre of controlled release fertilizer. The treatments receiving no preplant fertilizer product the lowest strawberry yields.

Soil samples showed non-significant differences between treatments for $N0_3$-N. The soil $N0_3$-N ranged from 1.0-8.0 ppm. The surface area had relatively low concentrations. The $N0_3$-N at the deeper depths had a wider range with 2-8 ppm.

Table 2. 1997 strawberry fruit yields with two fertilizer rates and three controlled release fertilizers in combination with fertigation.

Fertilizers			Nitrogen[1] lbs/acre	Fruit Yield*		
				Fresh	Freezer	Season Total
1. Duration	24-8-15	urea	160	46,802b	40,275a	87077a
2. Helena	20-7-15	urea	160	46,823b	39,544ab	86,366a
3. Agriform	18-8-13	NH_4N0_3	160	48,166a	38,368bc	86,534a
4. Duration	24-8-15	urea	80	42,563c	36,443de	79,006b
5. Helena	20-7-15	urea	80	42,920c	35,409de	78,329b
6. Agriform	18-8-13	NH_4N0_3	80	44,666bc	35,132e	79,798b
7. Commercial	15-15-15		160	43,843bc	37,168cd	81,011b
8. Control	-	-	-	34,765d	32,561f	67,326c

*Duncan's multiple range test - data numbers represented by the same letters are not significantly different at the 0.05 level.

[1]Nitrogen applied preplant

1998 Procedures

The variety Camarosa was planted on November 1, 1997 with plants from a McArthur nursey dug on October 27, 1997. The grower applied a total of 185 pounds of nitrogen per acre through fertigation.

The first strawberry harvest was on March 20, 1997. The trial was harvested as fresh fruit all season with the last harvest on August 3, 1998.

1998 Results

The strawberries were harvested as fresh fruit all season because the grower sold the fruit in a fruit stand. The spring rains delayed the first harvest until March 20, 1998. The last harvest was August 3, 1998. Heavy rain periods in March, April and early May reduced yield and delayed harvest schedules. During April, May, June and July the trial was harvested on a 3 or 4-day schedule.

The 1997-98 Santa Maria rainfall from July 1-June 30 was 32.6", which as over 2 ½ times the normal rainfall of 12.5". The strawberries were harvested by the grower's commercial strawberry pickers. The fresh yields are based on the grower's high standard for fruit quality. The yield data is the average of the four replications from 64" wide by 30' long plots.

The strawberry yields are shown in Table 3. The trial showed a yield response to preplant fertilizers. All of the preplant fertilizer treatments produced significantly higher strawberry yields than the control treatment that received only fertigation. Similar trials, conducted the two previous years, showed the preplant applications of 160 pounds of nitrogen per acre produced higher yields than the 80 pounds of nitrogen.

Table 3. 1998 strawberry fruit yields with two fertilizer rates and three controlled release fertilizers in combination with fertigation.

Fertilizer			Nitrogen[1] lbs/acre	Season total yield*
1. Duration	24-8-15	urea	160	67890a
2. Helena	20-7-15	urea	160	66279a
3. Agriform	18-8-13	NH_4N0_3	160	67429a
4. Duration	24-8-17	urea	80	69417a
5. Helena	20-7-15	urea	80	65879a
6. Agriform	18-8-13	NH_4N0_3	80	66581a
7. Commercial	15-15-15		160	67376a
8. Control	-	-	-	61914b

*Duncan's multiple range test - data numbers represented by the same letters are not significantly different at the 0.05 level.

[1]Nitrogen applied preplant

Summary

The three fertilizer trials clearly show the response to preplant nitrogen applications in addition to the nitrogen applied by fertigation through the drip system.

Two of the three trials showed a yield response to the 160 pounds per acre controlled release fertilizer over the 80 pound application.

NITROGEN MANAGEMENT IN CITRUS UNDER LOW VOLUME IRRIGATION

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

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

Many growers are turning to foliar applications of low biuret urea to their trees in January and February to improve fruit set and ultimate yields. Previous work by Eaks and Coggins has shown that nitrogen applications to navels late in the fruit maturity season greatly increases the incidence on navel rindstain. The threat of nitrate groundwater contamination has changed the way some fertilizer recommendations are made, with several small applications of nitrogen over the season considered less likely to pollute than a single application. Again, the late application of nitrogen could be severely aggravating navel rind quality problems.

Project Objectives

The project's objectives are: a) to determine the effect of nitrogen applications on navel orange fruit quality and leaching losses of nitrogen; b) to compare the effects of foliar versus soil applied nitrogen on fruit quality and leaching losses of nitrogen; c) to evaluate the impact of nitrogen application timing on fruit quality and leaching losses of nitrogen; and d) to determine the effectiveness of various nitrogen application levels and methods on maintaining optimal nitrogen levels in navel orange trees.

Materials and Methods

A site for the study in the Exeter - Woodlake area of Tulare County was identified in March 1996. The experimental treatments for this site are listed in Table 1. The differential nitrogen treatments were imposed commencing January 1997.

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

Monitoring of the water and nitrogen status in selected experimental plots within the study site continues throughout the year. Soil water content is determined using a neutron probe in access tubes. Soil solution samples are collected from suction lysimeters. Collection of data on irrigation, water application, evaporation, precipitation and temperature contribute to the development of water balances for the study site. Weather date is collected from the local CIMIS station located at the UC Lindcove REC (approximately 6 miles east of the site). Data on nitrogen application amounts will be combined with data on nitrogen levels in trees, amounts of nitrogen leaving the rootzone and nitrogen removed in fruit to develop nitrogen balances for the various treatments.

Preliminary Results

Leaf Analysis

The results of the 1996 and 1997 leaf analyses is reported in Tables 2. In comparing the results from 1997 with those of 1996, all constituents differed significantly between years. In some cases, contents in 1997 were significantly greater than 1996 contents (N, Mg, S, Mn, Fe, and Cu) and in others significantly lower (P, K, Ca, Cl, Na, B, and Zn). Differences in leaf constituents across treatments were more prominent in 1997 than in 1996, however, except for nitrogen it is difficult to account for the differences. The differences in nitrogen contents reflect nitrogen treatments. Leaf nitrogen contents (averaged across four replications) for the 25 treatments are plotted as a function of total nitrogen applied in Figure 1. In every case for a given amount of applied nitrogen, foliar application resulted in higher leaf nitrogen contents as compared to soil applied nitrogen. With one exception, continuous application to the soil resulted in higher leaf nitrogen contents as compared to soil applications as a single or split dose.

Yield

The yield at the experimental site in 1998 ranged from 609 to 950 pounds per tree pair. The average yield, 796 pounds per pair, was less than 1997 (872 pounds per pair). While there were significant yield differences among treatments they can not be explained by the nitrogen treatment (Table 3). There is a trend of increasing yield with increasing nitrogen application (Figure 2) but a number of plots with applied nitrogen had yields lower than the control and one treatment (2# N per tree in a single soil application) resulted in the lowest yield of all treatments. Significant differences in fruit size were also found among treatments but again this does not appear related to nitrogen treatments (Tables 1, 3).

Soil Solutions

Soil solution samplers have been installed below the root zone in all plots at the four project sites. Enough data are available to see trends related to the nitrogen treatments. Solutions collected from the samplers have been analyzed for nitrate-nitrogen and chloride. Nitrate-nitrogen is the dominant soluble, inorganic form of nitrogen in soils at the field sites. In order to account for differences in leaching volumes, chloride is used as a reference ion.

Soil solutions have been collected site five times during December 1997 through April 1998. Results of the analyses of these samples are summarized in Table 4. The NO_3-N concentrations leaching below the root zone are dramatically impacted by the nitrogen treatments, especially the soil applied nitrogen. The NO_3-N concentrations increase with increasing nitrogen application. This trend still holds when differences in leaching are accounted for by using chloride in a NO_3-N:Cl ratio. In every case where comparable foliar and soil applications have been made, foliar applications results in lower NO_3-N concentrations in soil solutions leaching below the root zone (Figure 3).

The effect of the winter rains can also be seen in the soil solution data. The chloride concentrations decreased from December (Time 1) to April (Time 5). The chloride concentration of rainwater is less than that of irrigation water. The high Cl concentrations in December are likely due to the 1997 irrigation season. As the rainfall percolates through the soil, the residual chloride is leached out and the Cl concentrations decreased. During the next few months the Cl concentrations should again increase as irrigation water reaches the samplers.

Preliminary Conclusions

Our preliminary data does not show any significant effects of the nitrogen treatment on yield or fruit quality (data not presented). We have collected data, however, which shows the effect of varying methods of nitrogen fertilization and timing on leaf N content and nitrate-nitrogen below the root zone. We plan to collect 2 additional years of data at this site and three auxiliary project sites. The information gathered here will aid us in developing guidelines for California citrus growers for efficient use of nitrogen fertilizer.

Table 1. Schedule of experimental treatments for nitrogen management project near Exeter/Woodlake, CA.

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

Foliar Only

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

Soil Only

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

Combination Treatments

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

[z] **Foliar Application:** Low Biuret Urea will be applied to foliage at a rate of 0.25 lb/tree per application. Trees receiving one application will have urea applied in late May. Trees receiving 2 applications will have an additional application in late winter. Trees receiving 4 applications will have additional applications at the pre-bloom stage and 30 days following the late May application.

[y] **Soil Application:** All applications will be made through the irrigation system: 1 = single application per year in late winter; 2 = split application, late winter and early summer; C = Applied with every irrigation from late winter through summer.

[x] Soil Nitrogen will be applied as in the "C" treatment described above for the soil applications.

Table 2. Analyses of leaf samples collected in Fall 1997 from Frost Nucellar navel orange on Troyer Citrange rootstock.

TRMT	N	P	K	Ca	Cl	Mg	Na	S	B	Zn	Mn	Fe	Cu
			%						ppm				
1	2.599 fgh	0.136 abcde	1.07 ab	4.29 abcdef	0.018 dc	0.495 abcde	121.0 bcd	2980 abcd	42.8 abc	14.0 bc	23.1 ab	106.1 abc	21.3 c
2	2.602 fgh	0.118 defg	1.06 ab	4.20 abcdef	0.021 abcd	0.630 a	161.3 abcd	2870 abcd	37.8 c	15.3 abc	20.3 bcde	97.6 c	31.2 bc
3	2.691 defg	0.133 abcdef	1.03 abc	4.20 abcdef	0.023 abc	0.471 bcde	188.5 ab	3060 ab	37.5 c	16.8 a	22.8 abc	123.0 a	45.2 abc
4	3.301 a	0.138 abcd	1.03 abc	4.04 def	0.023 abc	0.440 de	149.4 abcd	2863 abcd	38.9 bc	13.9 bc	25.0 a	106.9 abc	26.0 c
5	2.553 gh	0.116 defg	1.06 abc	4.27 abcdef	0.023 abc	0.468 cde	137.1 abcd	2800 abcd	39.9 bc	13.9 bc	20.8 bcde	111.3 abc	44.8 abc
6	2.470 h	0.118 defg	0.98 abcd	4.32 abcdef	0.020 abcd	0.594 abcd	161.9 abcd	2698 d	41.4 abc	15.4 ab	18.8 e	105.5 abc	46.8 abc
7	2.637 efgh	0.130 abcdefg	1.01 abcd	4.35 abcdef	0.018 dc	0.514 abcde	103.3 d	2978 abcd	42.9 abc	14.3 bc	21.1 bcde	105.4 abc	26.8 c
8	2.820 cde	0.126 abcdefg	0.97 abcd	4.32 abcdef	0.019 bcd	0.509 abcde	114.1 cd	3071 a	39.4 bc	14.0 bc	22.4 abcd	107.3 abc	24.6 c
9	2.604 fgh	0.119 cdefg	0.99 abcd	4.46 abc	0.025 ab	0.463 cde	152.9 abcd	2810 abcd	41.4 abc	14.0 bc	20.5 bcde	111.0 abc	46.0 abc
10	2.717 defg	0.121 bcdefg	1.03 abc	4.51 ab	0.024 abc	0.479 bcde	158.8 abcd	2856 abcd	38.9 bc	14.5 bc	21.1 bcde	101.9 bc	36.3 abc
11	2.683 defg	0.120 cdefg	0.94 abcd	4.36 abcde	0.019 bcd	0.434 e	171.6 abcd	2759 abcd	39.6 bc	14.8 abc	20.8 bcde	98.3 c	34.3 abc
12	2.640 efgh	0.114 efg	0.99 abcd	4.13 bcdef	0.020 abcd	0.604 abc	141.0 abcd	2773 abcd	43.9 abc	15.1 abc	21.5 bcde	102.5 abc	37.4 abc
13	2.841 bcde	0.130 abcdefg	0.97 abcd	4.35 abcdef	0.020 abcd	0.468 cde	129.1 bcd	2761 abcd	47.0 a	14.4 bc	23.0 ab	98.9 c	32.6 abc
14	2.587 fgh	0.108 g	0.90 bcd	4.42 abcde	0.026 a	0.631 a	194.1 ab	2841 abcd	41.0 abc	14.8 abc	21.1 bcde	106.5 abc	54.7 ab
15	2.639 efgh	0.119 cdefg	1.03 abc	4.41 abcde	0.024 abc	0.449 de	161.6 abcd	2761 abcd	39.6 bc	14.8 abc	20.3 bcde	120.4 ab	59.6 a
16	2.768 def	0.111 fg	0.90 bcd	4.33 abcdef	0.020 abcd	0.619 ab	148.6 abcd	2735 cd	41.8 abc	15.4 ab	19.9 bcde	92.6 c	39.7 abc
17	2.677 defg	0.126 abcdefg	1.08 a	4.19 abcdef	0.020 abcd	0.620 ab	159.9 abcd	2893 abcd	43.3 abc	15.1 abc	19.0 de	99.4 c	38.4 abc
18	2.868 bcd	0.145 a	1.10 a	4.08 cdef	0.021 abcd	0.461 cde	139.1 abcd	2918 abcd	41.8 abc	13.9 bc	21.8 bcde	98.0 c	24.2 c
19	3.294 a	0.130 abcdefg	1.01 abcd	3.96 f	0.021 abcd	0.428 e	177.4 abc	2754 bcd	40.5 abc	14.1 bc	21.0 bcde	90.5 c	31.4 bc
20	2.841 bcde	0.128 abcdefg	1.02 abc	4.31 abcdef	0.015 d	0.440 de	146.9 abcd	2694 d	45.5 ab	14.0 bc	19.5 cde	94.1 c	25.4 c
21	2.996 bc	0.144 ab	1.04 abc	4.02 ef	0.021 abcd	0.466 cde	144.3 abcd	2903 abcd	40.3 bc	13.5 bc	20.9 bcde	91.5 c	20.9 c
22	3.246 a	0.124 abcdefg	0.85 d	4.30 abcdef	0.023 abc	0.439 e	205.4 a	2839 abcd	39.3 bc	14.3 bc	21.1 bcde	95.8 c	41.4 abc
23	2.819 cde	0.121 bcdefg	0.94 abcd	4.43 abcd	0.025 ab	0.460 cde	179.1 abc	2680 d	41.1 abc	14.3 bc	21.0 bcde	94.8 c	38.2 abc
24	3.025 b	0.141 abc	0.96 abcd	4.32 abcdef	0.018 dc	0.486 abcde	142.0 abcd	3049 abc	40.8 abc	14.3 bc	22.1 abcde	97.1 c	25.4 c
25	2.991 bc	0.131 abcdef	0.89 cd	4.55 a	0.020 abcd	0.515 abcde	169.3 abcd	2978 abcd	42.1 abc	13.1 c	22.1 abcde	99.3 c	23.9 c
BLOCK													
1	2.772 b	0.115 b	0.92 c	4.36 a	0.023 a	0.603 a	173.0 b	3076 a	36.9 b	14.0 b	20.7 b	97.9 b	37.5 b
2	2.676 c	0.116 b	0.97 b	4.49 a	0.025 a	0.519 b	198.1 a	2964 b	38.2 b	15.3 a	20.9 b	99.5 b	54.0 a
3	2.880 a	0.137 a	1.06 a	4.17 b	0.019 b	0.443 c	126.8 c	2693 c	44.7 a	14.4 b	22.1 a	101.2 b	24.5 c
4	2.857 a	0.135 a	1.02 ab	4.11 b	0.017 b	0.447 c	119.3 c	2678 c	44.7 a	14.2 b	21.3 ab	110.4 a	24.3 c
TREE													
1	2.800 a	0.126 a	1.00 a	4.29 a	0.020 a	0.505 a	156.5 a	2884 a	40.8 a	14.2 b	21.1 a	101.7 a	35.3 a
2	2.793 a	0.126 a	0.98 a	4.28 a	0.022 a	0.501 a	152.1 a	2822 a	41.4 a	14.7 a	21.4 a	102.7 a	34.9 a
TIME													
1996	2.658 b	0.136 a	1.18 a	4.89 a	0.025 a	0.422 b	154.3 a	2641 b	53.8 a	16.9 a	14.3 b	68.6 b	12.1 b
1997	2.796 a	0.126 b	0.99 b	4.28 b	0.021 b	0.503 a	122.7 b	2853 a	41.1 b	14.5 b	21.2 a	102.2 a	35.1 a

Mean Separation using Duncan's Multiple Range test, P<0.05

Table 3. Yield (lb. of fruit per tree pair) and size distribution from March 1998 harvest of Frost Nucellar naval orange on Troyer citrange rootstock.

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

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

Table 4. Average nitrate-nitrogen and chloride concentrations in soil solutions collected from a Frost Nucellar navel orange (Troyer Citrange rootstock) orchard from December 1997 through April 1998 as a function of nitrogen treatment.

N APPLIED	**NO_3-N**	**CL**	**NO_3:CL**
0.00	2.4 d	16.0 cd	0.15 d
0.25	1.4 d	14.5 d	0.11 d
0.50	3.8 d	36.7 abcd	0.28 d
0.75	6.4 d	17.0 cd	0.51 d
1.00	10.3 cd	23.2 bcd	0.63 cd
1.25	16.0 bcd	43.8 a	0.41 d
1.50	24.7 abc	36.6 ab	0.85 cd
1.75	28.1 ab	40.2 ab	1.22 bc
2.00	39.1 a	35.2 abc	1.69 b
2.25	40.4 a	20.8 bcd	2.38 a
SOIL APP N	**NO_3-N**	**CL**	**NO_3:CL**
0.0	2.1 d	19.6 b	0.14 d
0.5	5.6 d	26.6 ab	0.4 cd
1.0	16.9 c	31.3 a	0.72 bd
1.5	28.3 b	35.8 a	1.05 b
2.0	48.3 a	31.7 a	2.31 a
TIME	**NO_3-N**	**CL**	**NO_3:CL**
1	25.2 a	43.6 a	0.75 a
2	21.8 ab	41.3 a	0.81 a
3	18.0 ab	29.4 b	0.71 a
4	14.3 b	14.6 c	1.07 a
5	15.7 b	15.3 c	1.04 a
REP	**NO_3-N**	**CL**	**NO_3:CL**
1	20.7 a	26.8 b	1.12 a
2	20.2 a	24.5 b	1.11 a
3	15.8 a	29.2 ab	0.64 b
4	19.7 a	35.9 a	0.62 b

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

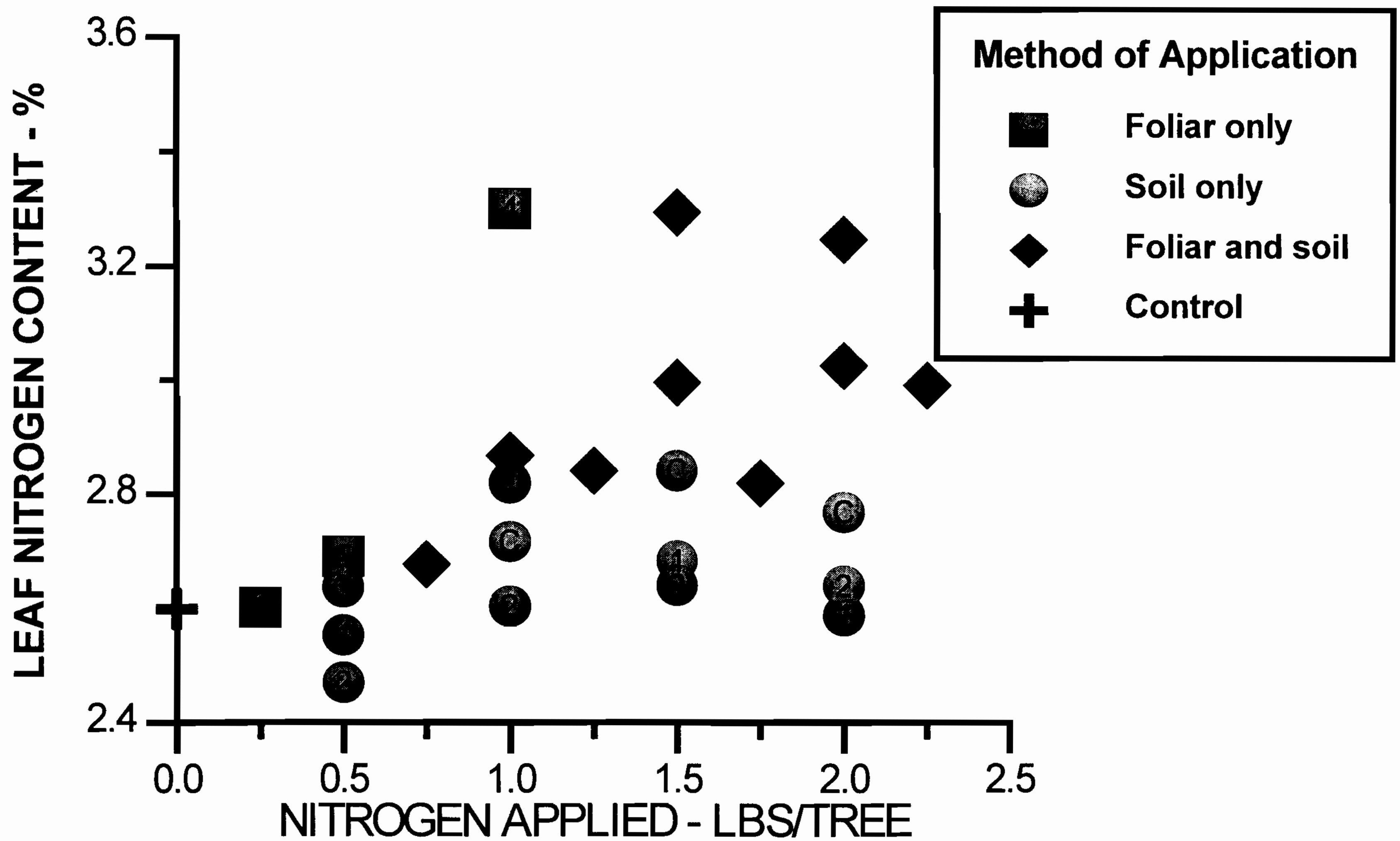

Figure 1. Nitrogen content of leaves collected at Griffith Farms in fall 1997 as related to total nitrogen applied.

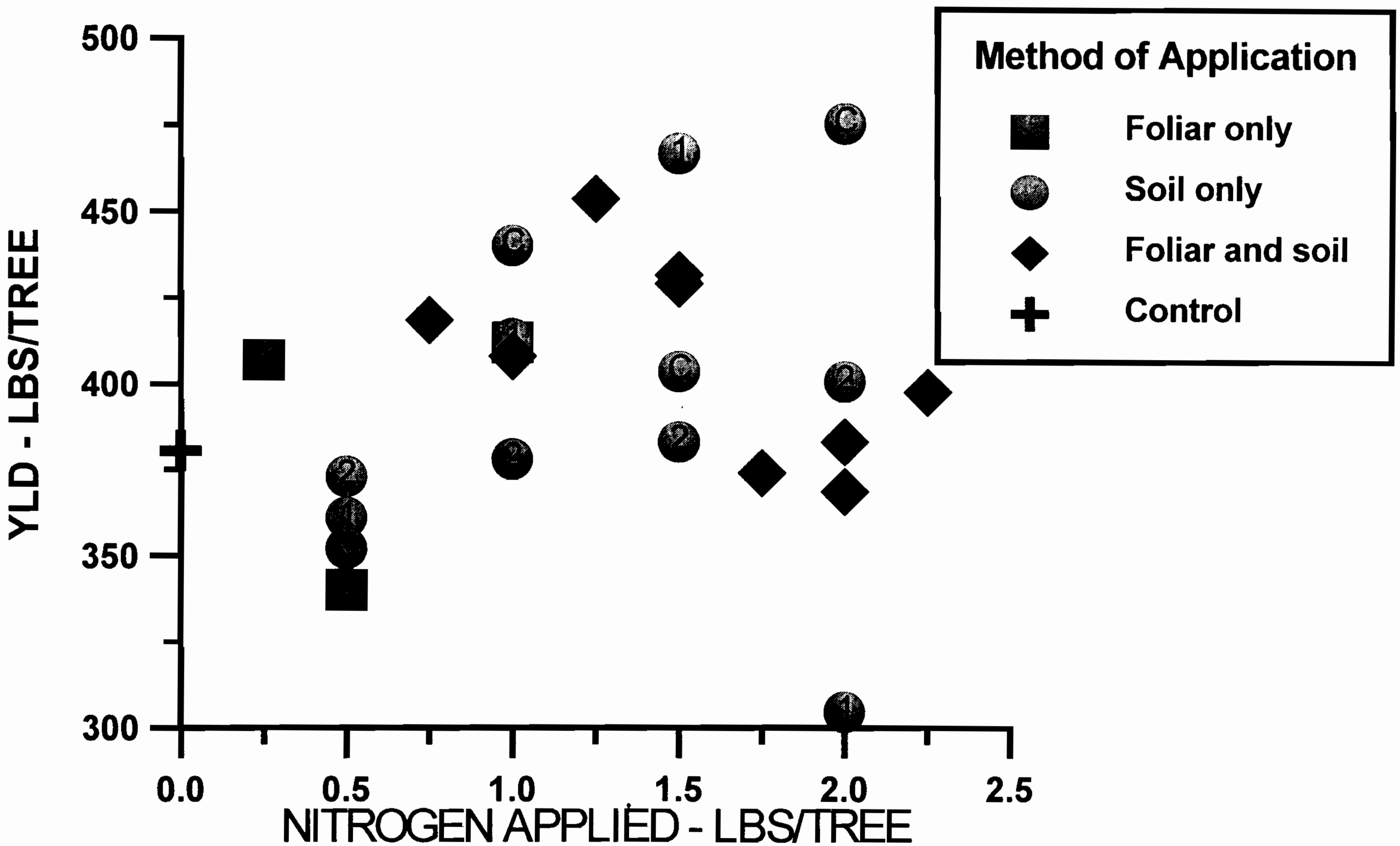

Figure 2. Yield of oranges at Griffith Farms for March 1998 harvest as related to total nitrogen applied.

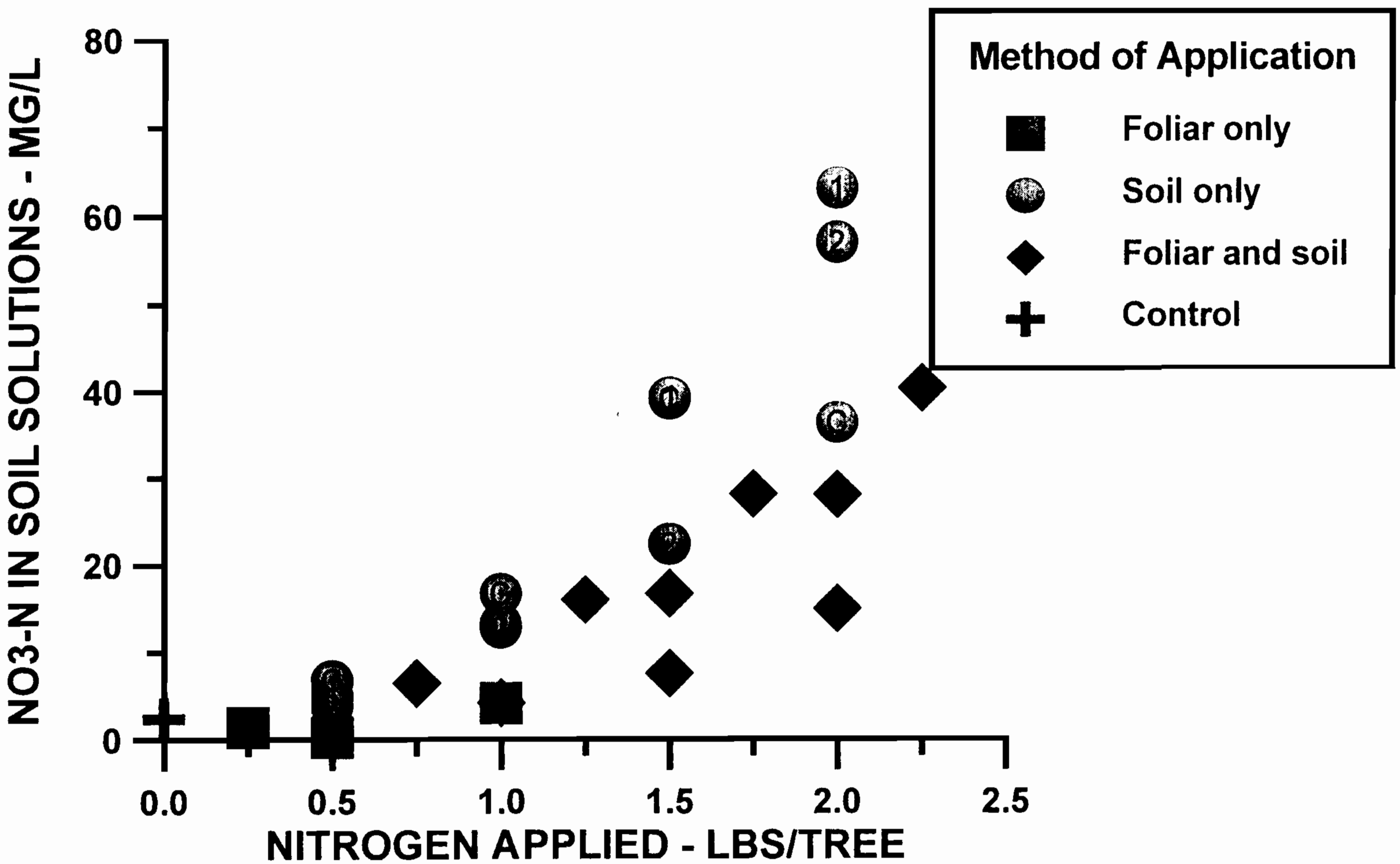

Figure 3. Average nitrate-nitrogen concentrations extracted below root zones as related to total nitrogen applied.

The Impact of Laboratory Accuracy and Precision on Nutrient Recommendation Systems

Robert O. Miller and Janice Kotuby-Amacher[1]

ABSTRACT

Refinement of nutrient management plans has led to increased scrutiny of soil test critical levels and the algorithms used to make nutrient recommendations, yet little attention has been placed on the quality of nutrient tests. Results from both the Western States Laboratory Proficiency Testing and North American Proficiency Testing Programs has indicated the precision of soil tests to be highly variable. Soil nitrate precision is method dependent, with cadmium reduction method having an average precision of 6.4%. Extractable soil nutrient methods such as phosphorus and micronutrients have inter-laboratory levels of precision ranging from 20 - 30%. Evaluation of intra-laboratory precision has shown precision for extractable phosphorus to be 13%. Further refinement of nutrient recommendation systems for site specific farming will necessitate the incorporation of soil test variability in the prediction model and continued improvement in the quality of soil nutrient tests. Development of nutrient maps for site specific management need to incorporate analysis method variance in nutrient maps.

INTRODUCTION

With increasing attention being made to soil analyses and its role in site specific nutrient management greater attention has been place on the quality of laboratory data. In 1992 the Western Coordinating Committee on Nutrient Management Workgroup (WCC-103) initiated a proficiency program for labs in the Western United States. The states of Nebraska, Minnesota, Iowa, Wisconsin, Michigan, Ohio, Michigan and Missouri have initiated proficiency testing programs to monitor laboratory quality. The results of these programs has been to document laboratory proficiency both bias and precision across a range of soils . The objectives of this paper is to model the influence of laboratory quality from the Western States Proficiency Testing Program on nutrient recommendation algorithms.

MATERIALS AND METHODS

In 1993 the Western States Proficiency Testing program was developed to quarterly evaluate the analytical performance of agricultural soil analysis. The program comprised the quarterly exchange of three soil and three plant samples on which inorganic analysis of sixty soil and fifteen plant constituents were performed using established analytical methods. Soils used in the program were collected from across the United States and represented a diverse range of chemical properties as

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depicted by: salinity EC_e, 0.28 - 7.8 dS m^{-1}; pH, 4.8 - 8.5; soil nitrate (NO_3-N), 2.0 - 203 mg kg^{-1}; soil bicarbonate extractable PO_4-P, 2.0 - 125 mg kg^{-1}; and soil ammonium acetate exctractable potassium 10 - 860 mg kg^{-1}. Data was analyzed using robust estimators, median and median absolute deviation (MAD, method of Miller, 1993) as central value and variance. Annually one soil was replicated through the year to evaluate intra-laboratory precision (RSD). Nutrient recommendation algorithims as described by Hergert et al. (1994) and Dahnke and Fanning (1992) were used to model the influence of laboratory analytical precision.

RESULTS AND DISCUSSION

Results of the proficiency testing program indicates that quantitative soil analysis procedures (i.e. soil nitrate, organic matter) are of higher inter-laboratory precision than semi quantitative procedures (i.e. soil extractable phosphorus). Soil nitrate precision is method dependent, with the cadmium reduction method having an average RSD (relative standard deviation) of 6.4%, and the ion selective electrode method and average RSD of 24.9% (Table 1). Extractable soil nutrient methods such as phosphorus and micro nutrients had an inter-laboratory RSD ranging from 20-30%. Evaluation of intra-laboratory RSD has shown precision for soil nitrate by cadmium reduction method to be approximately 4.8% while that of nitrate by ISE (Ion Selective Electrode) to be 18.5%. For soil bicarbonate extractable phosphorus intra-laboratory RSD was 13%. Across soils and analytical methods inter-laboratory RSD was 1.3 - 1.6 times the intra-laboratory RSD.

Results of four years of proficiency testing program indicate that for the range of 48 soils evaluated nitrate inter-laboratory precision (RSD) best explained by an exponential function, increasing with decreasing NO_3-N concentration (Figure 1). Using the University Nebraska nitrogen algorithm for corn fertilization developed by Hergert et al (1995) Eq. #1, a exponential model was developed describing precision of the nitrogen recommendation (NREC) as a function of soil NO_3-N concentration, Equation #2. Using an estimated corn yield goal of 180 bu ac^{-1}, a soil organic matter content (SOM) of 3.0%, zero nitrogen credit and a soil test level of nitrate of 10 mg kg^{-1} (0-24 inches), for a intra-lab RSD of 4.8% (median of the industry) the NREC is 95 ± 6.5 lbs ac^{-1} nitrogen (Figure 2). Realistically a precision level of ± 6.5 lbs ac^{-1} nitrogen is well within the limitation of fertilizer application equipment, thus precision of the test method has minimal impact on the NREC for corn. Using the same parameters but increasing lab precision of 18.5% as noted for labs using the ISE nitrate method, the NREC is 95 ± 25.1 lbs ac^{-1} nitrogen. Overall soil NO_3-N precision had the greatest impact on the NREC model on moderate to high soil test levels.

Eq. 1 $NREC = 35 + 1.2 \times E(Y) - 8 \times (NO_3\text{-}N) - 0.14 \times E(Y) \times SOM - C$ [Hergert et al., 1995]

Eq. 2 $\pm NREC = (0.46 \times \text{Lab RSD}) \times (STN^{0.47})$

A precision model was developed for the soil bicarbonate phosphorus test as described by Knudsen and Beegle (1988). Using the North Dakota State University phosphorus algorithm for corn as described by Dahnke and Fanning (1992), see Eq #3 a model was developed describing precision of the phosphorus recommendation (PREC) utilizing an exponential equation describing RSD as function of soil bicarbonate PO_4-P concentration, see Equation #4. Using a yield goal of 180 bu ac^{-1}, and a soil bicarbonate PO_4-P of 12 mg kg^{-1} test level, a intra-lab RSD of 13% (median of the lab industry) the PREC is 31 ± 14 lbs ac^{-1} P_2O_5 (Figure 3). Relative to this soil test level the variance represents ± 45% of the quantity of P_2O_5 applied. As with soil nitrate soil bicarbonate PO_4-P precision had the greatest impact on the PREC for corn on medium to high soil test levels.

Eq. 3 Olsen PREC = $(0.70 - 0.044(PO_4\text{-}P)) \times E(Y)$ [Dahnke and Fanning,1992]

Eq. 4 ± PREC = $(0.54 \times \text{Lab RSD}) \times (STP^{0\ 30})$

The application of lab precision to recommendation models is independent of the crop or nutrient and is consistently an exponential relationship.

SUMMARY

Method precision levels of 8% or less have a limited impact on the nutrient algorithms models and generally result in levels of precision well within the capabilities of the fertilizer application equipment. With method intra-laboratory precision levels exceeding 10%, variability in the nutrient recommendation becomes very significant even at medium soil test nutrient levels. Overall as soil test nutrient levels approach sufficiency the precision of the soil analysis method results in a loss of precision of the recommended nutrient rate.

Further refinement of nutrient recommendation systems will necessitate the incorporation of soil tests variability in the prediction model and the continued improvement in the quality of soil nutrient tests. For site specific farming there is definite need to recognize variance as a part of the soil analysis test and need to fine tune laboratory precision to improve the recommendation system. This can be achieved through refinement of soil analytical methods, improved laboratory quality control and Proficiency Testing Programs.

Beginning in 1998 a single laboratory proficiency program was developed to serve the agricultural laboratory industry, the North American Proficiency Testing Program (NAPT). This program has been developed for the agricultural lab industry by representatives of groups familiar with and involved in standardizing and recommending soil and plant analysis methods within the U.S., and Canada. These include: Regional Soil and Plant Analysis Workgroups (NCR-13, SERA-6, NEC-67, WCC-103); State / Provincial Depts of Ag; Soil and Plant Analysis Council; American Society of Agronomy (ASA); Canadian Society of Soil Science; USDA & USEPA. This program represents the merging of the Western States Proficiency Testing program, Council of Soil Testing and Plant Analysis Program and state proficiency testing programs of Iowa, Illinois, Minnesota, Nebraska and Missouri. The 1998 NAPT program was based on the quarterly exchange of six soils samples and served 166 laboratories. The 1999 NAPT program continues under the direction of the Soil Science Society of America.

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Table 1. Inter-laboratory and intra-laboratory precision for soil analysis of the Idaho soil sample, Western States Laboratory Proficiency Testing Program.

Soil Analysis	Number[1]	Mean	------ RSD (%) ------		Ratio
			Inter-Lab	Intra-Lab	Inter / Intra
pH (1:1)	48	7.88	2.2	1.4	1.6
NO_3-N (Cad-Rd)	32	34.8	6.4	4.8	1.3
NO3-N (ISE)	25	33.5	24.9	18.5	1.3
Olsen P (Bicarb.)	66	21.1	20.4	12.8	1.6
K (NH_4-oAc)	65	280	11.4	8.2	1.4
Zn - DTPA	71	1.55	12.9	9.6	1.3
SOM (WB)	51	2.05	9.0	7.1	1.3

[1] Number of reporting laboratories, based on four replications of the Idaho soil sample during 1995 Western States Laboratory Proficiency Program. Intra-laboratory RSD based on median of all reporting labs.

Figure 1. Laboratory precision (RSD %) as a function of soil NO_3-N concentration, cadmium reduction method.

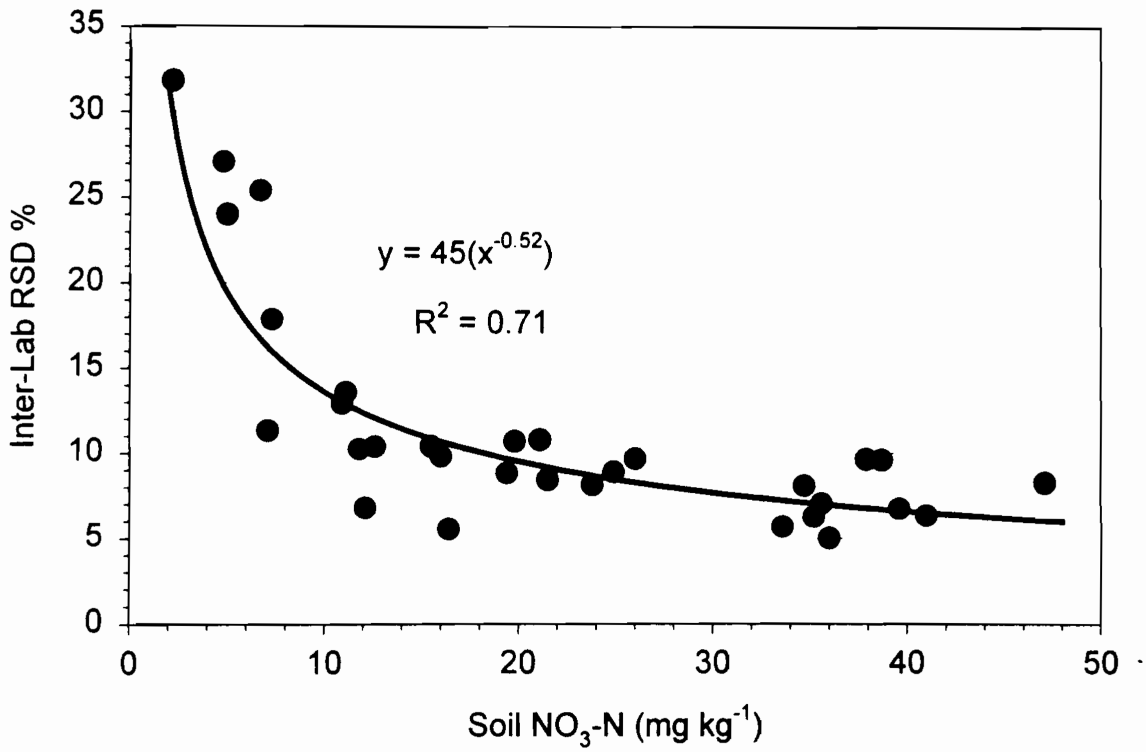


Figure 2. The Impact of soil NO_3-N precision on nitrogen algorithim for corn

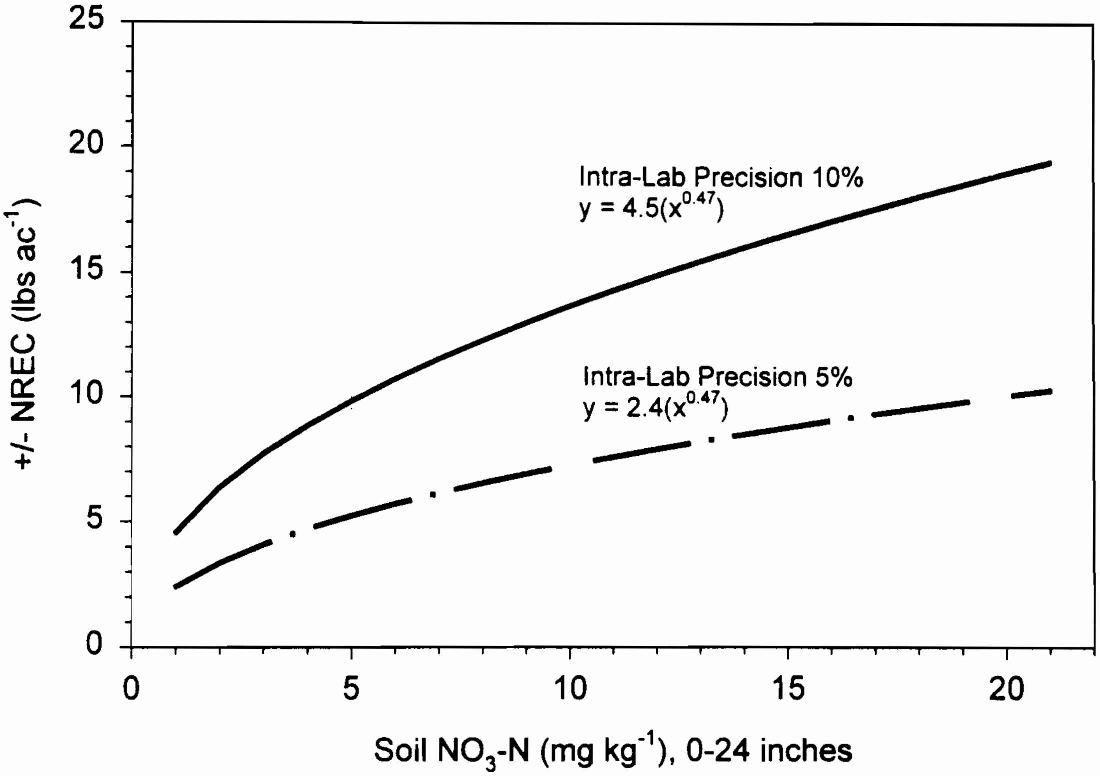
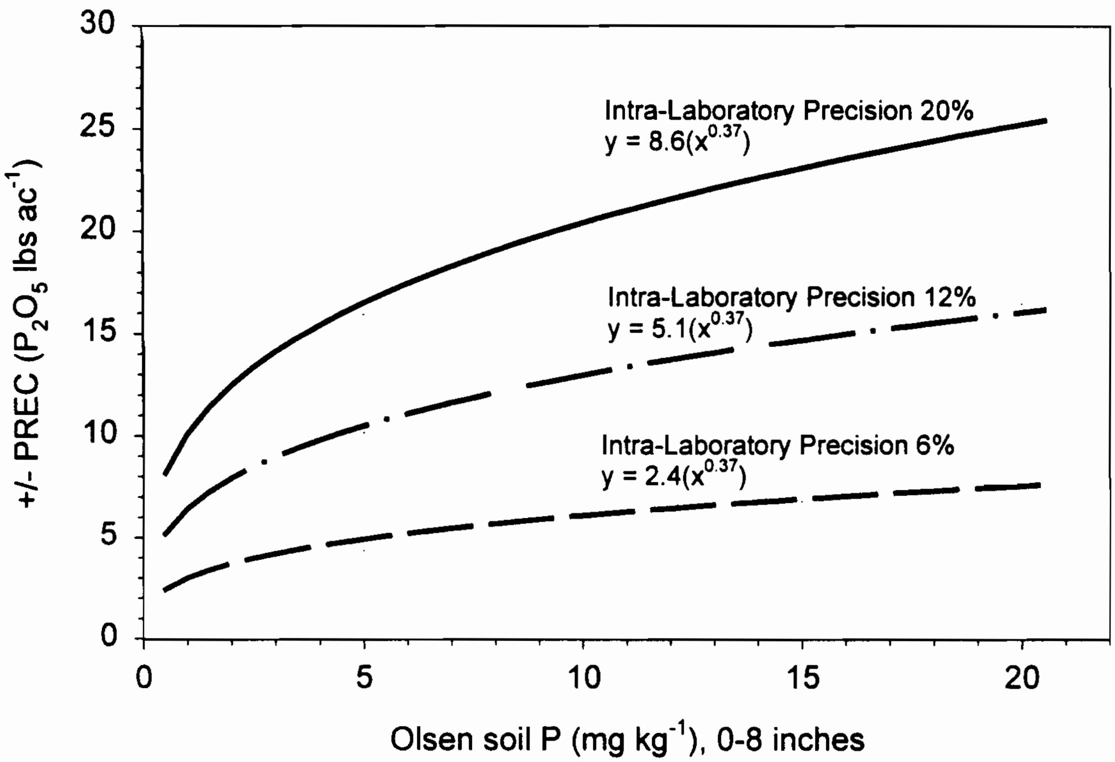


Figure 3. The impact of Olsen soil P precision on phosphorus algorithim for corn.



FERTILIZER USE EFFICIENCY AND INFLUENCE OF ROOTSTOCKS ON NUTRIENT UPTAKE AND ACCUMULATION IN WINE GRAPES GROWN IN THE COASTAL VALLEYS OF CALIFORNIA

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INTRODUCTION

Nitrogen is the fertilizer used most often in California vineyards. Most of the studies conducted on grapevines to determine vine nutritional requirements and the determination of vine nutrient status were conducted in vineyards located in the San Joaquin Valley. In addition, these studies were conducted on vines growing on their own roots. Little nutritional research has been conducted on vines growing in the coastal regions and those that have been conducted were with vines growing on rootstocks that are not currently in high demand (i.e. in replant situations).

Vine nutritional status of grapevines is usually measured by analyzing nutrients in petioles opposite the cluster at a particular pehnological stage (generally bloom or veraison). This technique is also used to determine the efficiency of a fertilizer application in fertilizer experiments. Unfortunately, petiole analysis only gives an instantaneous measure of the vine nutrient status at the time the samples are taken and does not provide quantitative measures of the efficiency of application of the particular nutrient being studied. Other methods have also been used, such as the analysis of the amino acid arginine in the fruit. The use of this technique may be a more appropriate method to determine vine nutritional status. The only way to definitely determine N fertilization used efficiency in a field situation is to use ^{15}N labeled fertilizer. ^{15}N labeled N is a non-radioactive isotope of nitrogen. The amount of ^{15}N present in plant tissues can be quantified with the use of a mass spectrometer.

OBJECTIVES

1. Quantify total uptake of nitrogen and potassium in Chardonnay and Cabernet Sauvignon scions grafted onto various rootstocks at different locations.

2. Use isotopically labeled nitrogen (^{15}N) to determine fertilizer use efficiency of premium wine grapes on different rootstocks in the coastal valleys of California.

3. Compare the efficiency of N fertilizer uptake and total N and K uptake by various scion/rootstock combinations with other means to determine vine nutritional status (for example, petiole analysis at bloom and cluster N and K analysis at harvest).

4. Develop fertilization recommendations for premium wine grapes grown in the coastal regions of California.

SUMMARY

This study will use ^{15}N labeled ammonium nitrate to determine fertilizer use efficiency of two wine grape cultivars (Chardonnay and Cabernet Sauvignon) grown in coastal valleys on different rootstocks. Two different locations will be used per cultivar and at each location similar rootstocks will be used. The rootstocks for the Chardonnay cultivar are 110R, 5C and Freedom. The rootstocks for Cabernet Sauvignon are 110R, 5C and 3309 at one location and 110R, 5C, 1103P, 140 Ru and Freedom at the other location.

The study was initiated in May, 1997, for the Chardonnay vineyards and in June, 1997, for the Cabernet vineyards (shortly after berry set for each cultivar). The fertilizer was applied beneath the emitters while the vineyard was being irrigated. The vines were irrigated at full evapotranspiration (ET). ET was determined by multiplying potential evapotranspiration (Et_o) by a crop coefficient (k_c). The k_c was developed on Chardonnay vines grown in the Carneros district of Napa Valley. To determine the amount of N to apply at berry set vineyard yield was estimated from previous years' harvests and total N required for fruit growth was determined. The amount of ammonium nitrate required to replace the estimated amount of N removed in the crop at harvest in 1997 was applied to six individual vine replicates of each rootstock. This amounted to anywhere from 30 to 45 kg per ha (27 to 40 lbs per acre). The actual amount of N removed in the fruit at harvest in 1997 averaged across rootstocks at the four sites was 33, 31, 22, and 21 kg per ha (29.4, 27.6, 19.6 and 18.7 lbs per acre). The difference in N applied to actual N at harvest was an overestimation of final yield and the amount of N removed from the vineyard in one ton of fruit. It was assumed that one metric tonne of fruit contained 1.5 kg N (3 lbs/ton) while the actual amount of N per unit weight of fruit ranged from 1.58 to 0.98 kg N per tonne (3.15 to 1.96 lbs/ton) of fruit.

Prior to applying the fertilizer, petioles were sampled to determine vineyard nutrient status using the traditional method with total N in the fruit at harvest, the leaves as they fell from the vine and the pruning wood. This included an analysis of petiole nitrate N and total K. Other elements measured on the petioles were: phosphorus, zinc, sodium, chloride, boron, calcium and magnesium. There were large differences in petiole nitrate nitrogen among vineyard locations and among rootstocks at a single location. For example, petiole nitrate nitrogen averaged across rootstocks was 59, 664, 815 and 7070 ppm (on a dry weight basis) at the Oakville, Monterey, Carneros and Paso Robles sites, respectively. At the Paso Robles site, petiole nitrate nitrogen averaged 4042, 6090, 7462, 7878 and 9876 ppm for the 110R, 5C, 140 Ru, 1103P and Freedom rootstocks, respectively. The percentage of total N in the clusters at harvest, averaged across rootstocks, was 0.426, 0.522, 0.531 and 0.639 (on a dry weight basis) at the Oakville, Monterey, Carneros and Paso Robles sites, respectively. At the Paso Robles site, percent cluster N averaged 0.565, 0.6, 0.669, 0.684 and 0.677 for the 110R, 5C, 140 Ru, 1103P and Freedom rootstocks, respectively. The results would indicate that there does appear

to be a relationship between bloom-time petiole analysis and total N found in the fruit at harvest (and also leaf N at leaf fall and cane N at pruning; data not given). However, there is a certain petiole nitrate level in which a further increase do not result in a further increase in tissue total N levels. This petiole nitrate value probably lies in the range from 1000 to 1500 ppm. It is unknown at this time whether a reduction below the above range would negatively impact vine productivity. Further study is required and it is anticipated that data collected in this project for the current growing season (1998) and next year (1999) will refine the specific petiole value.

The total amount of N in the vines (i.e. the N found in the vine's clusters, leaves after leaf fall and canes at pruning) averaged 58.7, 47.2, 43.7 and 44.7 kg per ha (52.3, 42.0, 38.9 and 39.8 lbs N per acre) at the Carneros, Monterey, Paso Robles and Oakville sites, respectively. It is apparent that these values were not related to the petiole nitrate levels recorded at those sites. Many assume that a high value of nitrate in the petiole is associated with a greater uptake of nitrogen. In addition, petiole nitrate levels of individual rootstocks were not associated with total N accumulated by an individual rootstock. For example, at all locations scions on the 5C rootstock had greater petiole nitrate levels than those on 110R. However, Chardonnay scions on 110R accumulated more N in the clusters, leaves and canes than those on 5C, while Cabernet scions on 110R accumulated less nitrogen than those on 5C.

Fertilizer use efficiency (FUE) (ratio of applied ^{15}N to ^{15}N taken up by the vine) was calculated for all rootstock/scion/location combinations. There were little differences among rootstocks at a given location. This was anticipated as all rootstocks were culturally treated the same (i.e. vertical trellis system, shoot positioned, hedged at a certain height and drip irrigated according to best estimates of vine water requirements). All fertilizer applications were such that the nitrogen was applied directly beneath an emitter while irrigating. There were somewhat larger differences in fertilizer use efficiency among locations. Fertilizer use efficiency, when averaged across rootstocks, was 10.3, 3.81, 3.45 and 11.5% at the Carneros, Monterey, Paso Robles and Oakville sites, respectively. There are several explanations for the differences among sites. The extremely high petiole nitrate levels at the Paso Robles vineyard may indicate an abundance of soil nitrogen at that site thus diluting the uptake of fertilizer N. At the Monterey site, the cooperator applied a NPK fertilizer without my prior knowledge again diluting the ^{15}N fertilizer I applied at berry set. The higher FUE at the Carneros and Oakville sites may have been due to the fact that neither vineyard had been fertilized since planting and the Oakville vineyard had very low petiole nitrate levels when sampled at bloom (an average of 59 ppm).

The above FUEs seem quite low compared to a FUE of approximately 40% the PI found on Thompson Seedless grapevines grown in the San Joaquin Valley. It should be pointed out that the FUEs presented in this summary were based upon N found in the fruit, leaves and prunings while those on Thompson Seedless also analyzed the root system, trunk and fruiting wood. Those three organs contained approximately 40% of the total ^{15}N labeled fertilizer taken up by the vines in that study. It is anticipated that the labeled fertilizer in the trunk, cordons and root systems of the vines used in this study will be remobilized and found in the clusters, leaves and pruning when those organs are harvested at the end of the 1998 and 1999 growing seasons. That is why it was important that this study be conducted for at least three growing seasons. In addition, currently I have permission to harvest the entire vine at two of the locations so I will be able to determine if any residual ^{15}N remains in the trunk, cordon or root system after three years.

REMOTE SENSING IN COTTON PRODUCTION

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INTRODUCTION

Remote sensing provides an important component of the information used in developing site-specific crop management strategies and tactics. In particular, it can be effectively combined with yield monitor data and point sample data to determine the factors underlying yield spatial variability. Knowledge of the relationship between crop stress status and remote sensing data is necessary to interpret these data for management purposes. Data at a resolution suitable for precision agriculture must come from aircraft-based systems, either through direct digital imaging or through film-based infrared aerial photography. Because of its relatively low cost and widespread availability, it is likely that film-based aerial photography will play an important role in the initial application of aerial remote sensing to precision agriculture.

There have been relatively few studies relating aircraft-based remote sensing data to crop production. Moran et al. (1997) give a general review of applications of remote sensing in production agriculture. Much of the work involving the interpretation of remotely sensed data for crop production involves the normalized difference vegetation index, or NDVI. This quantity is defined as

$$NDVI = (IR-R)/(IR+R),$$

where IR is the intensity of infrared radiation and R is the intensity of red radiation (Tucker, 1979). Wiegand et al. (1994) showed a strong correlation between NDVI and lint yield in cotton. Denison et al. (1996) showed similar relationships between NDVI and corn grain yield. Denison et al. also used the concept of NDVI-days to interpret corn grain yield data. NDVI-days are computed by integrating daily NDVI over time, or estimating this integral based on available data. The theoretical argument in favor of NDVI-days is that NDVI has been related to photosynthetic rate (Wiegand et al., 1991, Sellers, 1989) and to biomass production rate (Tucker, 1979). Therefore, the time integral of NDVI should represent total biomass. To the extent that the harvest index is constant, this quantity should then be related to crop yield. Wiegand et al. (1991) show a correlation between yield and PVI (a related index) summed over the season. Prince (1990) shows a high correlation between biomass and summed NDVI.

In the application of aerial remote sensing to site-specific field crop management in California it is natural to begin by investigating cotton production systems because of their high value and complex production requirements. Among the cotton management practices that may be influenced by film-based remote sensing are irrigation and defoliation. The two most important decisions in cotton irrigation management are the scheduling of the first and the last irrigation of the season. In particular, the timing of the last irrigation is crucial to effective harvesting. Timing of defoliation is important since early defoliation will kill the plant before all harvestable bolls are set while late defoliation may delay harvest and increase the risk of being affected by winter rains.

In this paper we give a preliminary report based on one year's data of a study of the relationship between remotely sensed information and crop growth and yield. The overall objective of the study is to determine how remote sensing may be used effectively in crop management decision making. During 1997 we took aerial infrared photographs of field experiments at several locations in the San Joaquin Valley. In this paper we only describe results from one site, located in Fresno County. Further information may be found in Plant and Munk (1998).

MATERIALS AND METHODS

Fig. 1. Black and white reproduction of a false color aerial photo of the Fresno County site.

A sequence of false color infrared aerial photographs was taken of irrigation timing experiments conducted in 1997 in a 60 ha commercial field in Fresno County, (latitude 36.4°N, longitude 119.9°W). The variety was Acala Maxxa. The experiment involved three final irrigation dates (August 11, August 25, and September 5). The experiment was laid out as a randomized complete block with four blocks and four treatments per block. There were 2 September 5 treatments in each block. Fig. 1 shows a black and white image of a false color infrared aerial photograph of the site taken on August 26. Each plot spanned the length of the field (approximately 780 m) and consisted of 16 0.76 m rows. The field soil type was predominantly Traver sandy loam with two large sandy streaks, appearing as the lighter regions in Fig. 1. The sandy soils are classed as Hesperia sandy loam. A portion of each experimental plot was located in a sandy streak as shown in the figure. The field was maintained according to normal commercial production practices.

False color infrared aerial photographs were taken of the site from an altitude of approximately 1525 m using Kodak 2443 film. The site was photographed on June 19, July 28, August 13, August 26, September 15, and September 30. Photographs were taken at mid-day, and skies were generally cloud-free. Positive images were scanned at 600 dpi using an Agfa Arcus II scanner. The resulting image files were imported into the Idrisi geographic information system (Clark University, Worcester, MA) where they were band separated and georegistered. Georegistration was carried out using reference points obtained with a Trimble Pro-XL global positioning system (Trimble Navigation, Sunnyvale, CA). During georegistration the images were resampled so that the number of image cells per crop row width was adjusted to the whole number nearest to the original image. Data were analyzed using Idrisi, Microsoft Excel (Microsoft Corp, Redmond, WA), and Minitab (Minitab, Inc., State College, PA). In statistical analysis of plot data only the cell values from the middle rows of each plot were used.

RESULTS

NDVI vs. Time

NDVI was computed for each experimental plot on each date. An ANOVA table was generated for each date with NDVI as the response variable. Irrigation date did not have a significant effect on NDVI ($P > 0.1$) except for a marginally significant effect ($P = 0.084$) on September 30. Fig. 2 shows the time course of plot mean NDVI vs. time for each irrigation treatment. NDVI was computed separately for the east (sandy) and west (loamy) ends of the plots. The computations on the east side of the field were based on the average value in the sandy section of each individual plot. The computations on the west side were based on strips of approximately the same length.

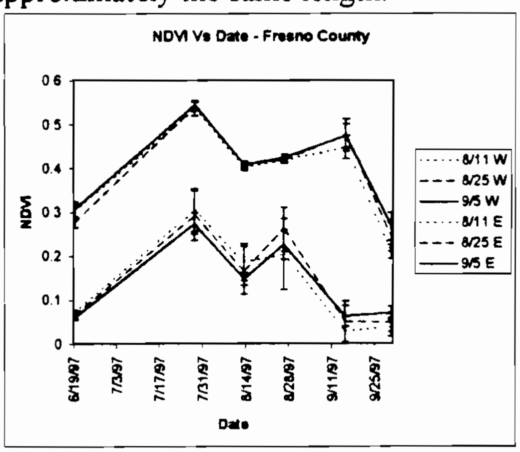

Fig. 2. NDVI vs. date

Yield vs. NDVI-days

Lint yields were measured for each plot. NDVI-days were estimated for each plot using by integrating mean NDVI against time using the triangulation method. This method estimates the integral by connecting data points with straight lines and computing the integral of the resulting curve. Based on the expectation that the loamy soils would contribute more to yield than the sandy soils, NDVI-days were computed only for the west side of the site. Fig. 3 shows the plot of lint yield vs. west side mean NDVI-days for each of the plots in the site. Also shown is the least-squares regression curve Yield = $991.27(1-e^{-1.003(NDVI-24.02)})$ ($R^2 = 0.61$).

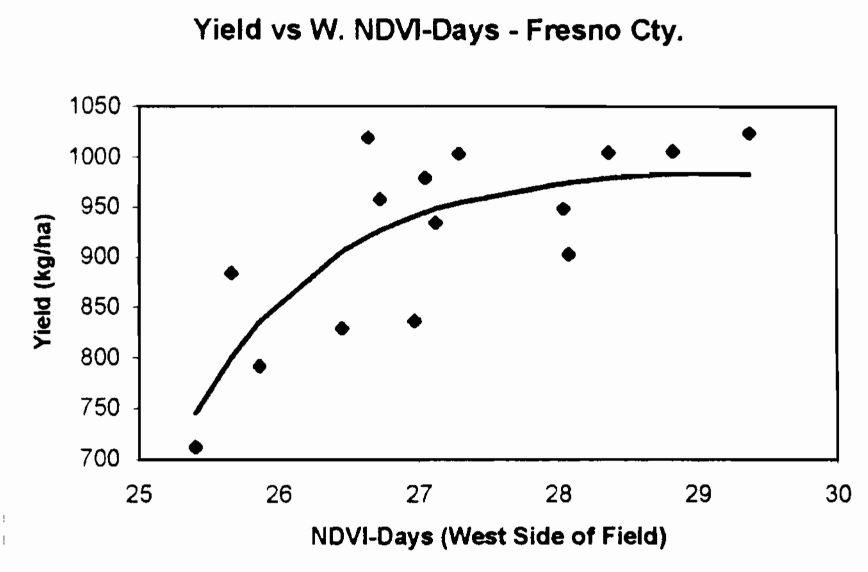

Fig. 3. Yield vs. NDVI days on the west side of the experimental plot

DISCUSSION

Caution must be used in comparing data from aerial photographs taken on different days. Plant and Munk (1998) found that although the scanner setting did not have a very large effect on computed NDVI, the effect of aperture setting was substantial, ranging from 15 to 32 percent. Despite the problems with aerial photos taken at different dates, it is evident from inspection of the yield vs. time plot in Fig. 2 that these photos contain potentially useful information. Indeed, the pattern in this plot is generally consistent with expected behavior if NDVI reflects crop photosynthetic rate. It generally rises early in the season, peaks, and then declines as the crop senesces. A second, lower peak follows this, and then a final decline. It is tempting to try to correlate this time course with known end-of-season behavior of cotton. As the cotton crop matures, it shifts carbohydrate allocation from vegetative to reproductive structures (Kerby and Hake, 1986). This results in leaf senescence, which begins at mid-season and accelerates as the season progresses. The combined effects of decline in carbohydrate production caused by leaf senescence and increased demand by fruiting structures cause the crop to reach cutout, at which no further production of harvestable bolls occurs.

Based on nodes above the white flower data, the loamy area of the field reached cutout between August 8 and August 11, and the sandy area reached cutout on about August 1. This earlier date is consistent with increased plant stress and lower soil water holding capacity in the sandy region. From Fig. 2, the cutout dates fall between the higher NDVI July 28 image and the lower NDVI August 13 image. It is therefore possible that there is a relation between the time course of the NDVI plots and the occurrence of cutout, but the temporal resolution is insufficient to tell for sure. It is likely that the steep decline in NDVI observed at the end of the season corresponds with boll opening. The fact that NDVI in the east end of the Fresno County field declines before NDVI in the west end is again consistent with the more rapid maturity in the sandy soil. The reason for the late season increase is unknown, but may be due to the transformation of flowers to green bolls.

Remote sensing time course data may potentially assist in two important end-of-season management decisions, applying the final irrigation and scheduling chemical defoliation. Determining the date and amount of the last irrigation requires a knowledge of the cutout date. Therefore, if a connection can be established between landmarks on the NDVI vs. time curve and cutout, this information can be used to assist in scheduling the final irrigation. Scheduling the date of defoliant application may be done by determining the number of nodes above the highest cracked boll (NACB) (Kerby and Hake, 1986). Future research will be done to determine the correlation between NACB and the end-of-season decline in NDVI.

In highly heterogeneous fields, remotely sensed information together with a GIS can be used to determine the effects of heterogeneity on economic yield. The farmer can use this information to determine whether mitigation measures such as microirrigation are economically worthwhile. Reclassifying the September 15 NDVI image indicates that on that date approximately 12 percent of the field, that is, about 7.2 ha, have and NDVI less than 0.25. In this region the average number of NDVI-days is 16.6, which is outside the range of validity of the regression model. We can get a bound on the yield loss by assuming this region produced no yield at all. The average yield for the experimental region in 1997 was 922 kg/ha. At a price of $1.65/kg this translates into an economic loss of approximately $11,000.

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Mobilized Soil Conductivity Assessment Systems: an overview of some common system design and data interpretation issues

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Introduction

Mobilized soil conductivity assessment (MSCA) systems have been used approximately ten years now for the purposes of mapping and monitoring field-scale spatial soil salinity patterns (Rhoades, 1992). More recently, MSCA systems have been increasingly used to map and /or catagorize a wide range of physical / chemical soil properties. This increase in the use and acceptance of such systems is directly related to the current interest in acquiring rapid, accurate precision farming related information.

This article presents a brief overview of some pertinent MSCA system design and data interpretation issues. Included here is a review of the basic MSCA system components, some simple system integration concepts, and a general summary of the most commonly used methods for interpreting, modeling, and / or calibrating soil conductivity survey data.

System Design

The overall design of any type of MSCA system is determined by two primary factors; (1) the basic system components, and (2) the system integration specifications. Together, these two factors will determine the final system cost, complexity, and ultimate surveying capabilities. Detailed below are the various available options associated with each aforementioned factor, and some suggestions for optimizing the overall MSCA system design.

Basic system components

Intrinsic to the design of every type of MSCA platform are four basic types of system components. These components include (1) one or more soil conductivity sensors, (2) a GPS (global positioning system) receiver, (3) hardware interfacing, and (4) some type of transport vehicle or physical platform on which the above sensors can be mounted. However, variations in the design of each of these components can be significant, as described below.

The first decision which must be made concerns which type of conductivity sensor to employ. Three types of portable instruments have been developed for measuring the apparent electrical conductivity of the soil: (1) direct contact four-electrode sensors, (2) remote electromagnetic (EM) induction sensors, and (3) time domain reflectometric sensors. The first two sensor types are by far the most popular, since the commercial development of a mobilized time domain reflectometric sensor which can measure soil root-zone conductivity "on-the-go" has not yet been achieved. Direct contact four-electrode sensors can take the form of either insertion probes or surface arrays; the latter being the most common configuration for mobilized applications. Examples of such sensors include the modified Martek™ SCT-10 unit (used in the U.S. Salinity Laboratory Mobile Wenner four-electrode system) and the sensor technology used in the Verris™ 3100 soil conductivity system.[1] Commercial examples of electromagnetic induction sensors include the Geonics™ EM-38 and EM-31 meters, both of which can be easily mobilized.[1] Four-electrode and EM type sensors each present various advantages and disadvantages with respect to mechanized survey applications. However, in general, both types of sensors can be used to accurately map soil electrical conductivity.

Like conductivity sensors, there are basically two types of GPS systems which can be incorporated into most MSCA platforms; (1) self-contained systems, or (2) receivers specifically designed for precision agriculture applications. However, the difference here is not in the GPS receiver technology, but rather the interfacing. Self-contained GPS systems typically include data loggers and software programs which allow the user to record, modify, and/or store GPS coordinate data independent of any other sensors or hardware interfacing. On the other hand, receivers specifically designed for precision agriculture applications typically must be connected to (i.e., interfaced with) some type of computer or electronic controller in order to store and/or process any sort of GPS coordinate data. The latter type of GPS systems tend to be significantly less expensive, but also less versatile. The Trimble™ Pathfinder Pro-XRS and Trimble™ Ag132 GPS systems represent one commercial example of these two types of GPS systems.[1]

Hardware interfacing considerations arise due to the need to merge the conductivity sensor and GPS coordinate data, and/or to control the timing of the data acquisition. In most cases, the complexity of the hardware interfacing depends on the type and number of sensors which much be integrated, along with the amount of real-time data processing which must be performed. Hence, most hardware interfacing tends to be rather system specific and often quite expensive. However, in simple MSCA systems (systems with only one conductivity meter) it is often possible to bypass the need for separate hardware interfacing entirely. This can be achieved if the conductivity meter can be modified to directly output real-time sensor data through an RS-232 serial connection, because most stand alone GPS systems (such as the Pro-XRS) have the ability to "capture" and merge such digital signal data directly into the GPS coordinate data file.

The final MSCA component which must be specified is the transport platform itself. Again, there are basically two types of platforms in commercial use; motorized (i.e., self propelled) systems and platforms which must be towed by an external vehicle. The Mobile EM

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[1]Mention of trademark or proprietary products in this manuscript does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

Sensing Systems (developed by the U.S. Salinity Laboratory and the Australian Cotton Research Institute) are two examples of motorized platforms (Rhoades, 1996; Triantafilis and McBratney, 1998). Both systems use a stripped down version of a hydraulically driven spray tractor as a base platform, which in turn has been custom modified to hold and integrate multiple types of conductivity and GPS sensors. Likewise, the Mobile Wenner and Verris 3100 represent two examples of platforms which must be towed. In most cases, motorized platforms tend to be more sophisticated, versatile, and more expensive to develop than towable platforms. This trade-off between sophistication / versatility and cost represents one of the primary factors to consider when choosing a transport platform design.

Overall system integration

Once the basic system components have been selected, the overall system integration specifications can be determined. In general, the basic components tend to determine the design specifications for the system integration. However, it is important to realize that the MSCA system integration can still be somewhat customized in order to optimize the ultimate survey objectives.

Most system integration approaches can be viewed as process falling somewhere between one of two possible extreme situations. At one extreme is a fully hard-wired (interdependent) system. In such a system all of the conductivity sensors and GPS equipment is either build directly into the transport platform, or attached in such a manner that makes it difficult (if not impossible) to use any one sensor or component in an independent manner. By design, these types of systems tend to rely almost exclusively on extensive hardware interfacing and a central computer or controller to manage the data acquisition and data storage. At the other extreme is the fully autonomous component system. In this latter system, the GPS receiver and each conductivity sensor can be easily removed from the platform and used independently when necessary. These types of systems may also require hardware interfacing and some type of centralized computer, or one of the components (typically the GPS data logger) may be used for storing the various survey data inputs.

The advantages (and disadvantages) of each type of system depend primarily on the type of survey applications one expects to typically encounter. For example, in soil salinity survey applications, it is often possible to gather useful preliminary information about a survey area by acquiring a few, carefully selected hand held conductivity readings. This makes autonomous component systems highly versatile (and hence desirable), since each of the conductivity sensors can be easily removed and used in a hand-held manner. Likewise, autonomous systems tend to be more reliable, at least in the sense that a malfunctioning conductivity sensor can easily be swapped out with another working sensor in a short amount of time. (In the worst case scenario -- the transport vehicle / platform breaks down -- everything can be removed and operated by hand, abet at a much slower pace). On the other hand, interdependent systems are often considered to be simpler to operate. By design, all of the hardware interfacing between the conductivity sensors and GPS receiver is already in place in an interdependent system. Hence, these systems require very little set-up time and / or user input, and have tended to be the most popular design for collecting automated precision farming survey information.

Data Interpretation

Regardless of the type of MSCA system which is employed, proper data interpretation represents a critical component of any survey process. Good data interpretation ultimately represents the difference between simply collecting soil conductivity data versus collecting assessment data which can be used to address soil and water management issues.

There are numerous technical articles which document the relationships between soil electrical conductivity and various soil physical / chemical properties, including soil salinity (Rhoades, 1996; 1992; 1989; Lesch et al., 1995a; Williams and Baker; 1982), clay content (Williams and Hoey, 1987), depth to clay layers (Doolittle et al., 1994), nutrient status (Suddeth et al., 1995), and moisture content (Kachanoski et al., 1988). Additionally, there are articles documenting the use of conductivity survey information to determine salt loading and field irrigation efficiency (Rhoades et al., 1997), estimating deep drainage (Triantafilis et al., 1998), and the design of optimal salinity sampling and monitoring strategies (Lesch et al., 1995b; 1998). Nearly all of the data analysis and interpretation presented in these articles can be classified into one of the two data modeling categories described below.

Deterministic (theoretical) modeling approaches

Deterministic conductivity data modeling and interpretation can be carried out either from a geophysical or (more commonly) a soil science approach. In the geophysical approach, mathematically sophisticated inversion type algorithms are generally employed. These approaches, which rely heavily on geophysical theory, have met with only limited success for the interpretation of near surface soil conductivity data. Part of the reason for this lack of success is that most geophysical inversion approaches assume that (a) there are multiple conductivity signal readings available for each survey point, and (b) that some form of detectable, physical strata exists within the near surface soil horizon. Neither of these conditions are typically satisfied in most applied agricultural survey situations.

A common interpretation technique used in the soil sciences is to employ some form of deterministic "conductivity-to-salinity" model; i.e., an equation which converts conductivity to salinity, based on knowledge of additional soil physical properties. Probably the most useful and well known model of this type is the DPPC (Dual Pathway Parallel Conductance) model developed by Rhoades (Rhoades et al., 1989; 1990; Rhoades, 1992). This model is based on the idea that the conductivity of the soil can be modeled as a multi pathway parallel electrical conductance equation, and has been shown to be applicable for a wide range of typical agricultural situations. Additionally, this model demonstrates that soil electrical conductivity can be reduced to a nonlinear function of five soil physical / chemical properties: ECe (soil salinity), soil water holding capacity (SP), volumetric soil water content, bulk density, and soil temperature. In Rhoades et al., (1990) this modeling approach was used to estimate field soil salinity levels, based on soil conductivity survey data and measured or inferred information about the remaining soil physical properties.

Empirical (statistical) modeling approaches

Empirical types of conductivity data modeling and interpretation are also commonly employed in many survey situations. In general, empirical models are based on some form of direct sampling methodology used in conjunction with statistical calibration techniques.

Various conductivity sampling and modeling approaches have been suggested in the literature. Traditional design based sampling plans are often used to select calibration sites (such a simple random sampling, stratified random sampling, or systematic sampling). However, typically it makes more sense to use the acquired soil conductivity survey data to help generate some form of model based sampling plan (Lesch et al., 1995b). This latter point becomes especially important when future monitoring sites must be selected, and these sites can be selected in a non-random manner.

Nearly all empirical modeling approaches tend to be statistical in nature. The most common types of calibration equations are spatially referenced regression models, universal kriging models (sometimes also referred to as spatial random field models), and co-kriging models. Most practical survey calibration equations are nothing other than spatially referenced regression models, since these are the only models which can be reasonably estimated with a limited number of soil samples ($n < 20$). Yates et al., (1993) describe the various types of geostatistical modeling approaches which can be used in the description of salt-affected lands (when large numbers of soil samples are available), while Lesch et al., (1995a,b) describe a comprehensive, regression based sampling and calibration methodology specifically for use with soil conductivity survey data. The latter approach requires the sampling of only 10 to 20 calibration sites within the survey area, and hence represents a cost-effective direct sampling / calibration methodology for salinity assessment and / or precision agriculture surveys.

Software to perform the regression based sampling / calibration methodology described above is available from the U.S. Salinity Laboratory (ESAP software package, Lesch et al., 1995c). The Windows 95 version of this software (available after January, 1999) will also include programs which employ the deterministic DPPC conductivity model described earlier, in addition to the stochastic sampling and calibration algorithms released in the 1995 DOS based version. Additional information about this software can be obtained from the U.S. Salinity Laboratory web site at *www.ussl.ars.usda.gov*.

Conclusion

In this article some pertinent mobilized soil conductivity assessment (MSCA) system design and data interpretation issues have been examined. The issues reviewed here included basic MSCA system components, some simple system integration concepts, and the most commonly used methods for interpreting and modeling soil conductivity survey data.

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BIOTECHNOLOGY IN CROP AGRICULTURE

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INTRODUCTION

Plant biology currently is undergoing revolutions in two distinct but interacting areas. In plant science and technology, fine details of the structures of plant genomes gradually are being revealed, ultimately to the nucleotide sequence level of resolution. Similar efforts are analyzing the genomes of plant pathogenic bacteria and fungi. Experimental and computational tools are being advanced for analyzing proteins and other macromolecules and for relating nucleotide sequences to the structures and actions of protein molecules. Some of these tools provide unprecedented throughput and small sample size for detecting specific proteins and analyzing gene expression, giving insight into gene-gene interactions and plant reactions to its environment, i.e., the core of phenotype. When the entire nucleotide sequence of a crop species becomes available and is analyzed for likely gene functions, many research problems will be viewed in very different ways than they are at present. Although the described advances will not displace all current research approaches, they do constitute a paradigm shift. They are capable of connecting the nucleic acid blueprints of the cell to the phenotype of the plant and have already made conventional plant breeding unconventional. Plant transformation bridges the species barrier, allowing genes from other plants, other kingdoms, and synthetic sequences to be introduced into transgenic crop plants. More recently, researchers have learned to shut off specific plant genes reliably, allowing undesirable characters to be suppressed. The implications of these capabilities are significant for crop improvement and for even the creation of new minor crops with nutritional, medical or industrial applications. The second revolutionary area is corporate. New corporate mergers and rumors of mergers are monthly events. Several new plant biotechnology institutes and companies have been founded in the past few years. Old, new and reformed companies and institutes are establishing proprietary positions not only in technology platforms but also in genes and even gene fragments. These developments are changing the way public sector crop research is conducted and will necessitate more extensive university-private sector interactions in the future. For some crops, a significant fraction of the available acreage was planted to transgenic lines this past Northern Hemisphere growing season, and demand for transgenic seed is high. Nevertheless, environmental and regulatory concerns, which are based in part but certainly not wholly on research results, remain strong. There will continue to be tension based on suspicion of, and accusations about, profit motives, crop biotechnologists' zeal, and divergent notions about what constitutes safe food, a sound environment, or "tampering with nature."

Expression of Designer Anti-Microbial Peptides in Crops to Improve In-Season Disease Management and Post-Harvest Quality

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Antimicrobial peptides (AMP's) are produced by a number of plant and animal species as a first line of defense against microbial attack. First described in the late '70's as extracts from a variety of organisms, these peptides have received broader attention for their potential use in agricultural applications from roughly 1990 on, as greater breadth and depth of activity has been described. Mycogen is currently investigating the utility of these peptides in our transgenic seed and sprayable biopesticide businesses through a partnership with Demegen Corporation (Pittsburgh, PA).

These peptides are generally chains of 15-50 amino acids. In comparison most insecticidal toxins from *Bacillus thuringiensis* (Bt) are composed of roughly 1000-1200 amino acids. Naturally occurring forms of AMP's are separated into 3-6 classes based on peptide architecture, amphipathy, charge density relative to "N" or "C" terminus, steric configuration and biological origin. Cecropins, magainins, defensins, attacins and mellitins are major peptide classes and range in length from 20 to 40 amino acids arranged sterically as an α-helix. Many of these natural peptides demonstrate significant *in vitro* anti-microbial activity on a variety of animal and plant pathogens. Roughly 100 of these natural peptides have been described from plants, insects, amphibians, mollusks and mammals. Their anti-microbial activity is facilitated through binding to microbial cell membranes via charge-charge interactions, followed by an ordered reconfirmation in which the peptide "bores" a pore into the cell membrane and ultimately facilitates cell lysis.

An interesting aspect of these peptides is that new leads, unlike new Bt toxins, do not need to be isolated and cloned from natural sources. This reduces the cost and complexity of the discovery process, as well as the time necessary to move them through a development program. The small size of these peptides lends itself to technically straightforward *in vitro* manipulation of structure by directed or combinatorial chemistry, and subsequent *in vitro* screening for activity optimization. These manipulations are conducted by simple substitution of one L-amino acid for another or deletion/addition of an L-amino acid along the peptide chain. Synthetic genes to code for these new peptides in plants can also be made *in vitro*. Data collected thus far by other labs working on pharmaceutical applications of AMP's suggest activity increases of 10 to 100 fold over natural forms are possible through combinatorial synthesis programs. *In vitro* tests of our initial synthetic peptides show unique activity on economically important plant pathogens and mycotoxin producing fungi in the approximate minimum inhibitory concentration (MIC) range of 0.5 - 5.0 uM. However, we are finding that *in vitro* testing protocols are in need of significant optimization in that the physical properties of these peptides (strong positive charge, low solubility, etc) result in experimental artifacts that can increase the apparent MIC of these peptides relative to their actual *in vivo* activity.

In concert with several collaborators we have expressed these initial "designer" AMP's in a variety of plants. Significant changes in phenotype have been seen with recombinant tobacco, peanuts, potato, antherium and rice. These plants are healthy, fertile and show full-to-partial tolerance to important pathogens in greenhouse and in some cases, field trials. Several other species have also been transformed but with limited disease testing thus far.

Effects on non-target micro-organisms are also being investigated and a resistance management strategy developed. Development of useful immunoassay techniques are also a necessary with these peptides. Their size and electronic charge properties provide for unique challenges in raising antibodies and optimizing ELISA based assays to support development, introgression and regulatory activities.

The challenge in obtaining stable changes in disease resistance phenotype are numerous, but involve much more than the simple selection of a peptide active on the appropriate microbial pathogen. The peptide must also be selective to plant membranes, stable to internal plant proteolytic enzymes and expressed in etiologically appropriate plant tissue relative to the infection court of the microbial pathogen of interest. We are conducting studies to resolve these issues in our targeted crops. Primary Mycogen targets are corn, cotton, rice and sunflowers, with significant interest in peanuts, soybeans and alfalfa but other crops such as fruits and vegetables are being addressed via third party relationships.

APPLYING TECHNOLOGY TO IMPROVE THE ECONOMICS OF COTTON PRODUCTION IN THE SAN JOAQUIN VALLEY

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INTRODUCTION

California is second only to Texas in total bales of upland cotton produced and leads the nation in Pima production. Cotton acreage in California's fertile San Joaquin Valley has declined from a peak of 1.17 million acres in 1995 to a low 820,000 acres in 1998. A portion of the decline has been due to poor weather conditions at planting during the past 2 seasons. A much longer-term element leading to the reduction in planted acres is poor economic return from cotton production. Yield increases of new cotton varieties approved for production in the San Joaquin Valley have simply not kept pace with skyrocketing production costs. Of these, the most critical components are the costs associated with controlling insects and weeds. High productions costs, coupled with low prices for cotton fiber on the world market, are causing farmers to shift from cotton into other crops such as vegetables, corn for the State's large dairy herds, and even some permanent crops including trees and vines. Some of the cotton acreage lost to other crops will be recaptured once Asian markets, which historically have been strong purchasers of San Joaquin Valley Cotton, recover from their present financial turmoil and move back into the market. This should have the effect of shoring up the demand side of the price equation. Longer-term, however, cotton growers will not enjoy a good economic return from cotton farming without the development of high yielding varieties offering value-added traits that provide a significant reduction in costs associated with production.

We are seeing sweeping changes in the laws governing the planting of cotton in the San Joaquin Valley. The call for change has been precipitated by the perception in the industry that the Valley's growers need access to technologies carried in transgenic cotton varieties being grown in other regions of the U.S. Cotton Belt. Furthermore, many cotton farmers want the option of planting a portion of their acreage to non-Acala cottons they perceive as offering higher yield than the current Acala varieties. The simple reality is that in the current economic climate, with their livelihoods at stake, growers want to decide for themselves what to grow and they want every available technological advantage placed at their disposal. The purpose of this paper is to provide an overview of the traits that are being introduced into cotton varieties targeted for the San Joaquin Valley and to take a look at the way such traits may be expected to impact the economics of cotton production.

PRESENT SITUATION

Growers report that it now costs between $600 and $800 per acre to produce cotton in the San Joaquin Valley. At $0.72 per LB, growers, growers need to average between 1.7 and 2.2 bales per acre just to cover their costs of production. With yield forecasts for 1998 now at 1.7 bales Valley wide, there will be few growers who actually make money on their cotton crop. It is easy to understand why cotton farmers are anxiously awaiting the development of any technology, which will help them improve the economics of cotton production.

NEW TECHNOLOGY

New technologies being brought to bear in cotton improvement will be discussed. These include "input" or so-called agronomic traits including insect resistance, herbicide tolerance, nematode tolerance, and pathogen resistance. These are factors that will help growers through the lowering production costs and by improving yields by reducing losses attributable to certain pathogens.

A second set of traits, so called "output" traits, will also be considered. These include modifications to fiber, oil and meal in such a way so as to help growers get a higher return per unit production by enhancing the down-stream value added.

Finally, new technologies will be considered which are being employed to speed new·variety development. Studies have shown that cotton yields have advanced at about 1.5% per year over the last several decades. Although significant, this rate of increase in productivity is simply not keeping pace with rising production costs. New procedures including molecular markers will enable cotton geneticists to introgress traits from transgenic lines and wild cotton species more efficiently and thereby get them into the hands of cotton growers much more quickly.

ECONOMIC IMPACT

In the final analysis, the future health of our cotton industry is dependent upon the extent to which new technologies being applied to cotton increase the value of the products produced by growers and the extent to which the per unit costs of production are lowered. Technology development is expensive. Estimates will be provided on the potential costs of development for certain of these new traits, the extent to which users of the technology will be expected to share in those costs, and how these factors can be expected to impact net return.

EXPERIMENTAL REGIONAL CLIMATE PREDICTION FOR CALIFORNIA
November 1997 - April 1998

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Back in May 1997, as the El Nino was getting stronger, a group of scientists in the Campus Laboratory Collaboration (CLC) Program on California Water Resources met at the University of California, Davis, and decided on an ambitious project of making an experimental seasonal climate prediction for the winter season of 1997-98. UC Davis participated in this experiment as a partner with Lawrence Livermore National Laboratory (LLNL), National Center for Environmental Prediction (NCEP) and UCLA. The climate prediction starts from the Sea Surface Temperature (SST) prediction by NCEP, which drives the global general circulation model of UCLA, which in turn drives the Mesoscale Atmospheric Simulation (MAS) model of UC Davis/LLNL. All of the predictions are made using observed weather and SST data from October 1997. The prediction of the MAS model is made over the area of California using a 20 km grid resolution. The prediction period is from November 1997 to April 1998.

A climate prediction, unlike a daily weather forecast, is not expected to provide correct information on day to day weather. For example, using October 1997 data, the models will not be able to predict if it is going to be clear or rainy on Picnic Day, 1998. The prediction is considered successful if it can distinguish a wet season from a normal or dry season. The MAS model did predict 80 inches of precipitation over both the Northern and Southern Sierra Nevada and 30 inches of precipitation over the Los Angeles area for this six-month period (Figure 1). These values are close to the observed values. However, the model under predicted the amount of precipitation over the Coastal Ranges and the Central Valley. A possible explanation is that the model has a tendency of under predicting convective precipitation, which were quite prevalent during that year. The UCLA global model, which drives the UC Davis/LLNL regional scale MAS model, also tends to under predict the amount of moisture available for cloud formation.

The most exciting information contained in the prediction is illustrated by looking at the observed daily precipitation at Blue Canyon (Figure 2) and the MAS model predicted rainfall at the same location (Figure 3). The observation shows that the rainy season started with a wet period in November followed by a dry period in December. There were two periods of persistent and heavy precipitation in January and early February, which caused a wide spread flood over the Central Valley. The rainy season lingered on and off after that time and lasted through the end of May. The prediction shows a similar trend. It started with a wet period, followed by a dry period, then periods of heavy precipitation, and finally lingering on and off precipitation until the end of the prediction. The predicted dry period came later and lasted longer than the observed dry period. But overall, the trends of the observed and predicted precipitation are quite similar. Table 1 shows the observed and predicted precipitation over two ten-day heavy precipitation periods. The predicted total precipitation over the two heavy precipitation periods is 31.9 inches, which is very close to the 31.0 inches of the observed total precipitation. The two heavy precipitation periods were observed to be 10 days apart and predicted to be 9 days apart. This amount of precipitation over a 30-day period indicates a potential of flood in the 1997-1998 rainy season and the MAS model correctly anticipated this coming event.

In summary, the model has correctly predicted the following:

1. The 1997-1998 rainy season starts with a wet period followed by a dry period.
2. Two heavy precipitation periods follow the dry period. The total precipitation over these two periods is more than 30 inches at Blue Canyon, and this amount of precipitation indicates a great potential for flood in the Central Valley.
3. The rainy season lingers on and off after that through at least the end of April.

This work has shown the skill of the regional climate prediction over the strong El Nino year. During non El Nino years, the signal given by SST is weak and the prediction may not be as accurate. Since the two big floods of 1986 and 1997 happened in non El Nino years, it is important and it is also a challenge to study if these flood events can be predicted several months ahead of time through a concerted effort of SST, global circulation and regional climate predictions.

TABLE 1: Observed and predicted precipitation at Blue Canyon for two 10-day heavy precipitation periods.

Blue Canyon Precipitation (inches)

Observed Daily Precipitation				Predicted Daily Precipitation			
Jan 09	1.8	Jan 29	1.8	Feb 09	1.0	Feb 28	1.8
Jan 10	3.3	Jan 30	0.0	Feb 10	3.2	Mar 1	1.0
Jan 11	3.4	Jan 31	0.1	Feb 11	1.7	Mar 2	1.8
Jan 12	0.2	Feb 01	1.4	Feb 12	1.1	Mar 3	0.7
Jan 13	1.7	Feb 02	2.3	Feb 13	0.7	Mar 4	2.3
Jan 14	2.5	Feb 03	2.1	Feb 14	2.5	Mar 5	2.9
Jan 15	1.6	Feb 04	0.5	Feb 15	0.7	Mar 6	3.0
Jan 16	1.0	Feb 05	1.2	Feb 16	1.0	Mar 7	0.6
Jan 17	0.3	Feb 06	2.4	Feb 17	1.1	Mar 8	2.4
Jan 18	1.6	Feb 07	1.8	Feb 18	1.8	Mar 9	0.6
Total	17.4		13.6		14.8		17.1

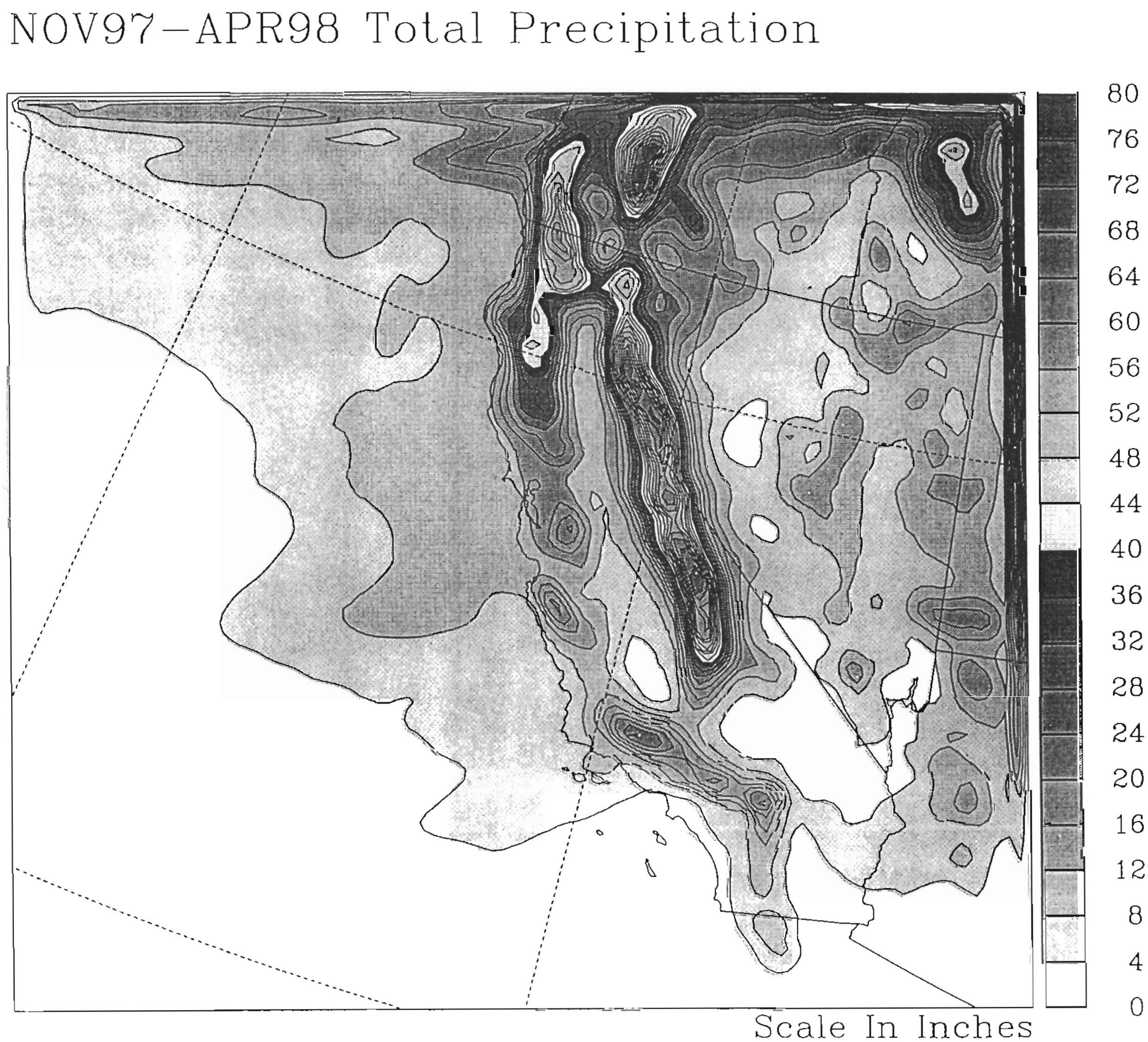

Figure 1. The predicted total precipitation for November 1997 to April 1998.

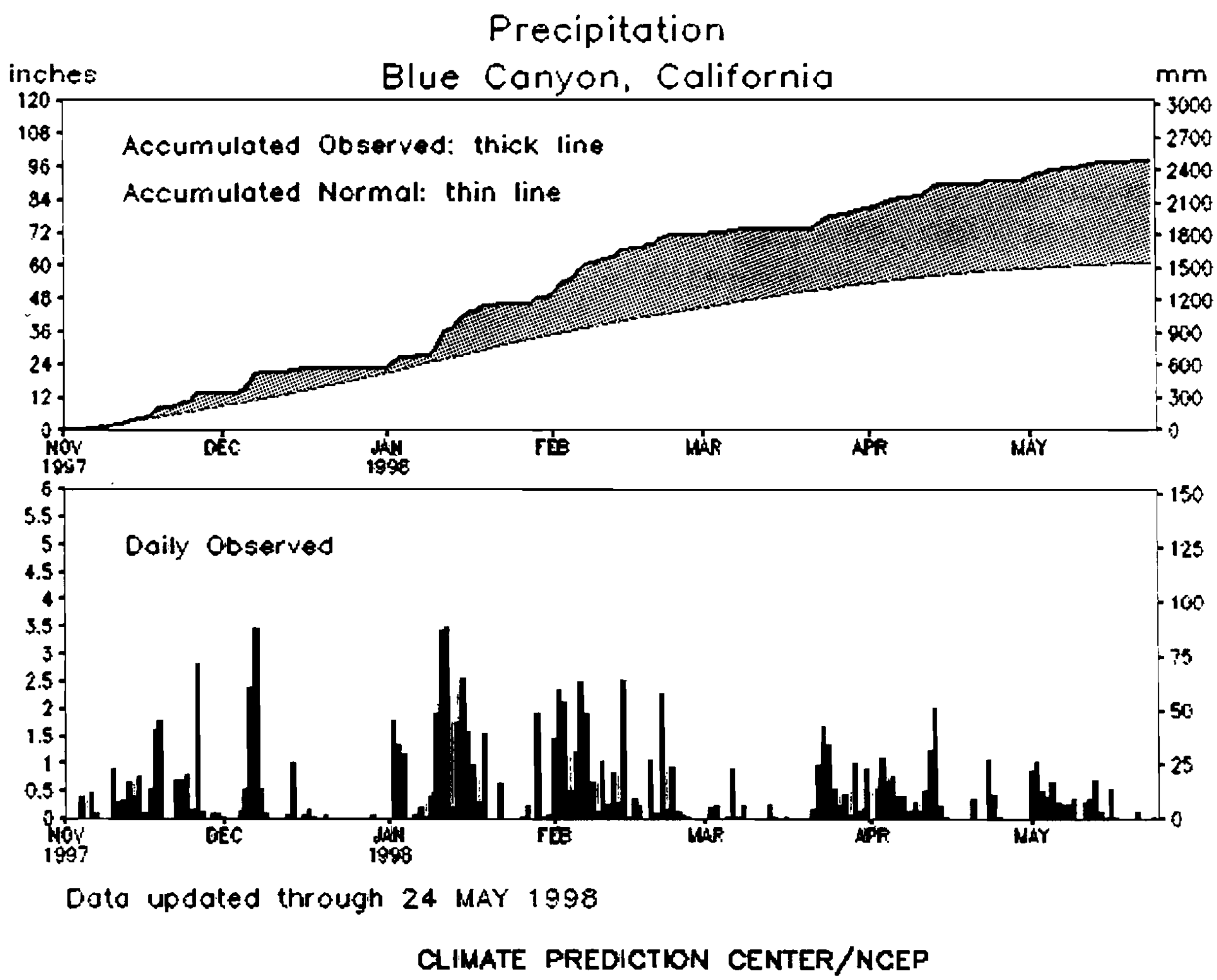

Figure 2. The observed precipitation at Blue Canyon.

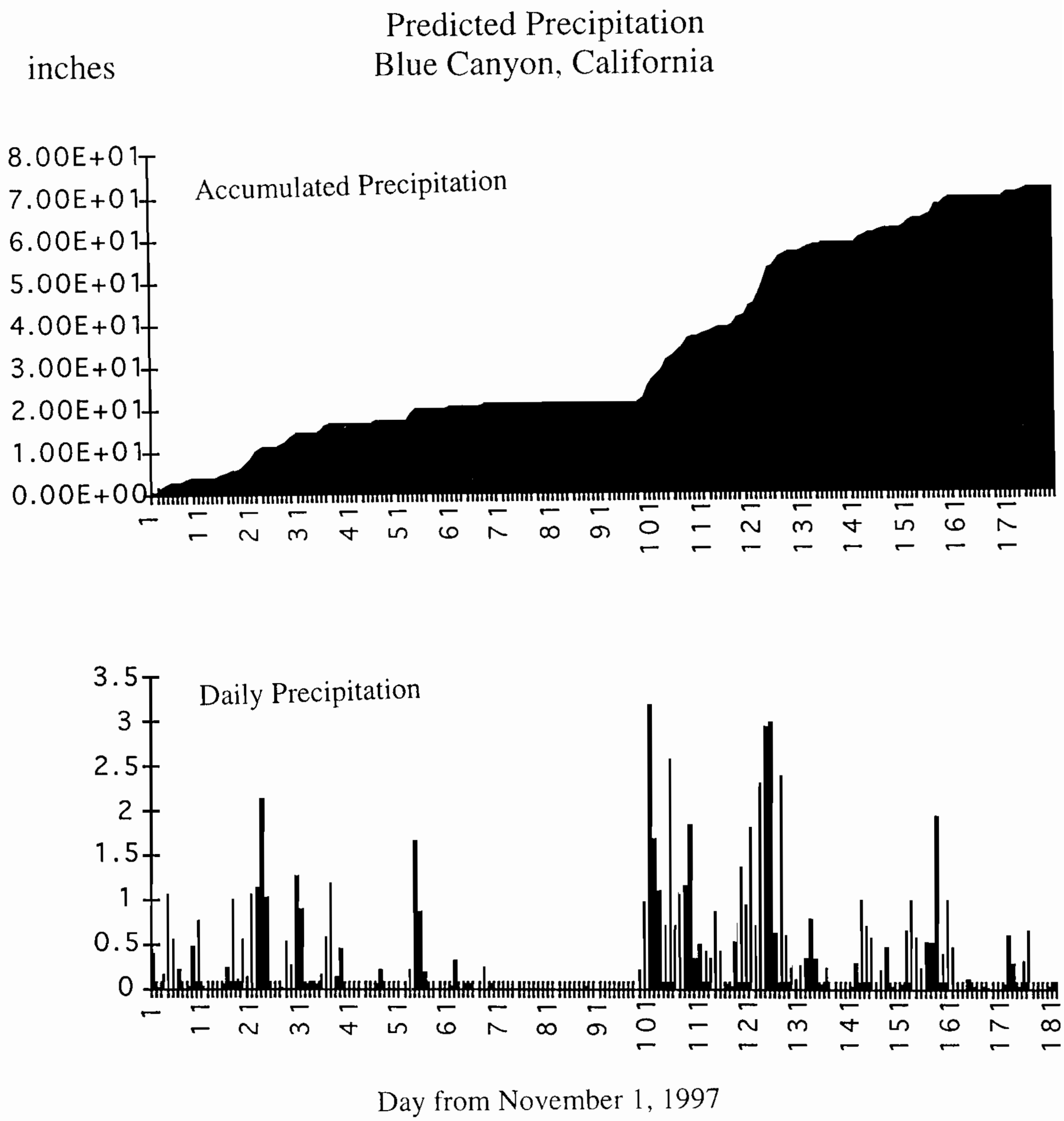

Figure 3. The predicted precipitation at Blue Canyon.

SHALLOW GROUNDWATER QUALITY UNDER DAIRIES IN MERCED AND STANISLAUS COUNTY

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INTRODUCTION

The number of drinking water supply wells removed from use due to nitrate (NO_3-N) contamination is almost an order of magnitude larger than those removed from use due to industrial contamination (Metropolitan Water District of Southern California, 1987). In nitrate contaminated subsurface areas where the depth to groundwater is less than 50 feet and the soils are relatively permeable, NO_3-N levels commonly exceed the maximum contamination level (MCL) of 10 mg/l. In addition to fertilizers and septic tanks, animal wastes from confined animal facilities are a significant source of nitrate and salts to groundwater. In California, dairies are the leading confined animal industry with a total herd size of 1.2 million dairy cows (more than 10% of the national herd size). These dairies occupy a significant portion of the agricultural land located in the San Joaquin Valley, especially in Tulare (southeastern San Joaquin Valley) and Stanislaus (north-central San Joaquin Valley) counties. Stanislaus and neighboring Merced County, in particular, have a long history of nitrate and salt problems in their groundwater (Lowry, 1987). Groundwater supplies in these areas are susceptible to nitrate contamination because of their predominantly sandy soils and shallow depths to groundwater (Page and Boulding, 1973).

Sustainable management of dairies is critical to the economic health of California's agricultural communities. The dairy industry, in cooperation with the regulatory community, has recently stepped up efforts to develop improved waste management practices for the protection of its surface water and groundwater supplies. However, little is known about the current quality of groundwater underneath dairies in the San Joaquin Valley and its relationship to

- groundwater quality outside dairy facilities
- waste management practices in corrals, ponds, and fields.

We have recently established a research project to address these issues. This paper presents results from an ongoing water quality monitoring program on five cooperating dairies in Stanislaus and Merced counties. We describe the monitoring well network, estimate the extent of the source area associated with the monitoring wells, analyze the relationship between source area landuse and groundwater water quality, and illustrate the variability of groundwater quality data encountered.

METHODS

In 1993, a groundwater monitoring project was initiated by the Central Valley Regional Water Quality Control Board (RWQCB). On the five cooperating dairies, a network of 44 monitoring wells was established by the RWQCB (RWQCB, 1998). The dairies are well managed and their operation and geographic environment are representative of many other dairies in the northern San Joaquin Valley. Monitoring wells were strategically placed a) upgradient and downgradient from fields receiving manure water, b) near ponds, and c) in corral areas. Wells are constructed with PVC pipe (2 inches in diameter) installed to depths of 20 - 25 feet. The tops of the well screens are located at depths of 5 - 10 feet. The water table in the project area typically fluctuates between 5 and 15 feet below ground surface. Consequently, water samples collected in these monitoring wells are representative only of the shallowest groundwater located between 10 and 15 feet below the land surface. Shallow groundwater on these dairies originates primarily from percolation of excess irrigation water (including manure water) applied within and adjacent to the dairies (see "Source area of monitoring wells").

The initial RWQCB study, which was based on quarterly sampling over a 15 month period, showed elevated levels of nitrate in many of the shallow monitoring wells around the dairies (RWQCB, 1998). Since November 1995, groundwater samples have continually been taken on a 4-6 weekly basis. Before sampling, groundwater levels are determined using a calibrated groundwater level meter with an accuracy exceeding 0.02 feet. Well water is then purged with a submersible pump and continuously monitored for pH, temperature, conductivity, and dissolved oxygen using an inline water quality meter. Water samples are collected after a minumum of 5 well volumes of water have been pumped and once the water quality readings have stabilized. This procedure assures that water samples taken are representative for the aquifer formation surrounding the well. Water samples are cooled to 1°C and shipped to UC DANR Analytical Laboratory in Davis for analysis of NO_3-N and total Kjehldahl nitrogen (TKN). TKN is a measure of the sum of ammonium-N and dissolved organic nitrogen in the water samples. For quality control, blank, duplicate, and diluted duplicate samples are prepared in the field from approximately every 10th well water sample.

RESULTS AND DISCUSSION

Source area of monitoring wells. The source area of a monitoring well is defined as the area from where well water originates as recharge (Figure 1). The source area depends on the local hydrogeologic properties of the aquifer, the regional direction of groundwater flow, recharge from rainfall and irrigation, and pumping in the vicinity of the well. These factors determine the direction and velocity of groundwater flow to the monitoring well.

The hydrogeologic properties of the shallow aquifer were previously estimated from borehole samples obtained during the construction of the monitoring wells and from small-scale well tests performed in the monitoring wells (RWQCB, 1998). Estimates of the hydraulic conductivity range from approximately 50 to 400 ft/day. These estimates are consistent with values for predominantly sandy and loamy sand sediments. The direction of groundwater flow on these dairies is measured using the distribution of water levels in the monitoring network and regional water level maps. In our project area, groundwater generally flows from the east-northeast to the west-southwest. The average hydraulic gradient of the water table ranges from approximately 0.5 ft per 1,000 ft to 1.5 ft per 1,000 ft. Based on hydraulic gradient data and hydraulic conductivity estimates, average groundwater velocities vary from 100 ft/year to 700 ft/year (RWQCB, 1998). Recharge to groundwater from irrigated fields ranges from 0.5 - 2 ft/yr assuming irrigation efficiencies of 50 - 70%. All participating dairies use flood irrigation. Assuming an effective porosity of 15%, the vertical displacement of recharge water ranges from 3 - 12 ft/yr. Given that the water table is only 5 - 15 ft below the ground surface, the average time required for excess irrigation to reach the water table is less than one year. Leakage rates from corral areas and ponds are not known.

Locally, groundwater velocity and flow direction will vary due to pumping in nearby irrigation or drinking water wells and to recharge from irrigation in nearby fields. On one dairy, high water levels in a nearby stream caused a temporary reversal of the flow direction near some monitoring wells. Small temporal changes in flow direction and groundwater velocity as well as uncertainty about actual recharge rates prohibit us from accurately estimating the source area of contamination associated with each well. For practical purposes, these source areas are estimated using a simple hydrologic model (Figure 1). The upgradient extent of the source area is approximately equal to the penetration depth of the well multiplied by the ratio of the groundwater velocity to the recharge velocity (vertical displacement). The penetration depth of most wells is 15 feet. The ratio of groundwater velocity to vertical displacement ranges from 10 to 200. The upgradient extent of the source area is therefore estimated to range from 150 to 3,000 feet. If the monitoring well is in a location with negligible recharge, then the source area may extend even further upgradient. The lateral extent of the upgradient source area is considered to be on the order of a few tens of feet and depends on subsurface heterogeneity and temporal changes in groundwater flow direction. If irrigation occurs within less than 10 feet downgradient from a monitoring well, the vertical downward movement of water from the irrigation application through the unsaturated zone to the water table may temporarily raise the water table under the field high enough to push recharge water towards the monitoring well even though the field is downgradient of the well with respect to typical regional groundwater gradient.

The fields, ponds, and corrals located within or adjacent to the dairy are defined here as the dairy landuses. The monitoring wells are all located along the edges of access roads which physically separate these landuses. When the source area encompasses a number of these landuses, it becomes difficult to identify contributions of individual ponds or corrals to the measured groundwater NO_3-N concentrations. In some cases, ponds and corrals can be identified as significant contributors by observing changes in groundwater quality between a well upgradient and a well downgradient of a source. If the two wells are located along the same groundwater flow path, any downgradient increase in NO_3-N concentrations (relative to NO_3-N concentrations in the upgradient well) is the result of nitrogen leaching from a surface source located between the upgradient and downgradient well.

Shallow groundwater quality as a function of dairy location.

To estimate the contamination contributions of the dairy landuses, we classified the monitoring wells by the landuse occurring in its source area. In addition to the corrals, ponds, and fields, we also consider any areas upgradient of the dairy as a separate "upgradient" landuse category. Our working hypothesis for well classification by these landuses is that the source area extends 500 feet upgradient from the well. If a well is located immediately at the edge of a field receiving manure water, it is given a landuse category "field" regardless of whether the field is upgradient or downgradient from the well. Wells that are upgradient of any dairy areas receiving manure water are designated as "upgradient" wells. Of the 44 wells, 29 are classified as "field" wells, 10 are classified as "corral" wells, 2 are classified as "pond" wells, and 3 are classified as "upgradient" wells. For consistency, we focus the discussion on total nitrogen concentrations, denoted hereafter as N. It is equal to the sum of NO_3-N and TKN concentration. In most well samples TKN is negligibly small, and N concentrations are equal to NO_3-N concentrations (see discussion below).

Average N concentrations in shallow groundwater underneath are high under both corrals and fields (Table 1). The fact that, on average, levels of N under corrals and fields are rather similar can be explained in two different ways. First, N leaching rates under corrals could be of similar magnitude as N leaching rates under fields that receive manure water at one time or another, therefore leading to similar levels in shallow groundwater quality as observed in the "field" monitoring wells. Secondly, the recharge rates within the corral may not be significant. Consequently, N values in corral wells would reflect N that is leached in a "field" source area more than 500 feet upgradient from the corral well. Currently, we know too little about actual recharge and N leaching rates underneath corral areas to reach a definitive conclusion. On three of the five dairies, N concentrations within the corrals can be compared to those upgradient from the corral wells. Significantly larger concentrations are found in some corral wells, which would be compatible with the first interpretation. Other corral wells are of similar or even much smaller concentrations than the upgradient "field" wells, indicating the validity of the second scenario or a mix of both.

landuse	mean N [mg/l]	# of obs.	std.dev. N [mg/l]
corral	68.6	224	38.2
field	65.5	715	39.8
pond	26.9	52	16.9
upgradient	15.3	54	16.2
all	61.7	1045	40.2

Table 1: Mean total nitrogen concentration of all samples collected, grouped by the four landuse categories.

Two wells were tentatively identified as "pond" wells. The two wells are located within the outside slope of the same pond wall. No fields with manure water applications are located in the estimated source area of these two wells. Their average N value is much lower than the average of the corral and field wells. However, unlike in other wells, a significant amount of N in one of the two pond wells is in form of TKN. In that well, the average TKN concentration is 28.8 mg/l compared to 37.0 mg N /l (the average N in the second pond well is 16.8 mg/l). Significant amounts of TKN (> 5mg/l) for nearly all sampling dates were found in only two other wells (average TKN of 11.2 and 40.9 mg/l, respectively), each located at the downgradient edge of two other ponds. The latter two wells are within the respective outside pondwall, yet a large part of their respective source areas are fields receiving manure water (hence the designation as "field" wells). In both wells, average N concentrations are similar to those found upgradient of the pond.

Presence of TKN in groundwater samples is only possible if the pathway of the TKN from the source to the well is predominantly anaerobic (i.e. inhibiting nitrification).The persistent presence of TKN in these three shallow monitoring wells is a strong indicator for leakage of manure water from the three ponds, possibly from cracking of the clay liner during dry cycles in these ponds. In the case of one of the three wells, leakage may also stem from a solids manure waste pile adjacent to the monitoring well which at times covers the sealed well. The data are not sufficient to determine the actual leakage rate from these three ponds. Overall, the contribution of N from the ponds is less than the average contribution of N from corral and field areas.

Only three wells were tentatively identified as "upgradient" wells, with a source area that did not receive any manure water. However, two of the wells are immediately adjacent to a downgradient corral area, which may occasionally influence the water quality in the monitoring well. The remaining well (average N concentration of 3 mg/l) is the only shallow monitoring well with an average N concentration of less than 10 mg/l. A single monitoring well, however, is not a representative sample for upgradient groundwater quality. Alternatively, for a conservative estimate of the maximum possible upgradient N concentration, the N concentration of the uppermost one or two wells on each dairy can be considered regardless of their proximity to manure treated fields, corrals, or ponds. Seven wells with a total of 154 observations averaged 29 mg/l (standard deviation = 19.6). Nitrogen concentrations in these wells range from 5 to 80 mg/l. Conversely, the wells furthest downgradient of each dairy (8 wells with 201 observations) averaged 52 mg/l N (standard deviation = 37.1). There, N concentrations range from 5 to 140 mg/l and in one well to over 200 mg/l. Given the high variability over time and between wells, average concentrations must be interpreted carefully. However, the data clearly suggest that N concentrations in shallow groundwater significantly increase as groundwater is recharged across the dairy. As shallow groundwater moves off the dairies, it mixes with recharge from non-manure irrigation excess water. NO_3-N may also be subject to denitrification. Both processes reduce N levels in shallow groundwater, although rates of N reduction are currently not known (ongoing work).

Temporal changes and trends

The nitrogen concentrations in shallow groundwater are found to be spatially and temporally quite variable. Mean concentrations for individual wells vary from 3 to 157 mg/l. Figure 3 illustrates the spatial variability of the nitrogen concentration (expressed by the variable median concentration of individual wells) and the degree of temporal variation for each well (expressed by the range around the median concentration). Corral wells generally exhibit no seasonal pattern (i.e. no yearly recurring pattern of changing concentrations). However, some corral wells show significant changes over time. Field wells experience the largest temporal changes in N and the most pronounced seasonality. Many field wells exhibit their highest concentrations from early winter to early summer, while lower concentrations are typically observed in late summer and fall. These results are reflected in the monthly mean concentrations (averaged over all wells) which vary from 52 to 72 mg/l (Figure 2). Periods of high nitrogen concentrations are coincidental with times when large imbalances between manure nutrient applications and crop nutrient uptake exist. Apart from seasonal variations, no significant trend in nitrogen concentration is observed over the three year period.

For a few wells, the source area appears to be dominated by a single field check. In those cases, comparison of manure water applications, fertilizer applications, irrigation dates, and the groundwater nitrogen concentrations over time show a significant correlation. Most prominent are long-term changes in two wells that are downgradient of fields that only recently have begun to receive manure water applications. In both cases, nitrogen concentrations in groundwater significantly increased over the 1.5 year period following the commencement of manure applications.

Despite frequent sampling, concentrations in some wells change erratically with differences of 25% or greater over consecutive months. In other wells, concentrations vary by less than 5% from month to month. Large changes in concentration (by up to a factor 2 or more) occur only over several sampling periods and are well captured by the monthly sampling program. Monthly sampling (as opposed to the more common practice of quarterly sampling) proved helpful in explaining concentration changes with manure management events in the immediate upgradient area of some wells.

CONCLUSION

This groundwater monitoring project has enabled us to study the contamination problem in shallow groundwaters underlying San Joaquin Valley dairies located in Merced and Stanislaus counties. It has also provided a baseline dataset useful to ongoing and future research work. Data collected during the past three years confirms that shallow groundwater quality below these dairies is degraded by high levels of nitrate. The spatial and temporal variability of nitrogen is also extremely large. The exact location and extent of the source area of each monitoring well is difficult to determine in practice, although some useful estimates can be made. With the limited amount of monitoring wells on each dairy, it is difficult to prove direct links between particular dairy management activities and individual groundwater quality responses without extending the monitoring well network. On a larger scale, monitoring has demonstrated that manure applications to fields have the most impact on groundwater quality. The impact of current corral and pond designs on groundwater quality remains much less certain and is difficult to distinguish against the background N levels created by manure applications in surrounding fields. Elevated levels of TKN found at the outside edge of three of the five ponds indicate that ponds are not impermeable and leach significant amounts of N. Finally, we emphasize that the monitoring network captures only the shallowest groundwater. Data are not representative of groundwater quality outside the dairies or at depths more than 25 feet. Regionally, water quality in production wells is much lower than reported here (Lowry, 1987).

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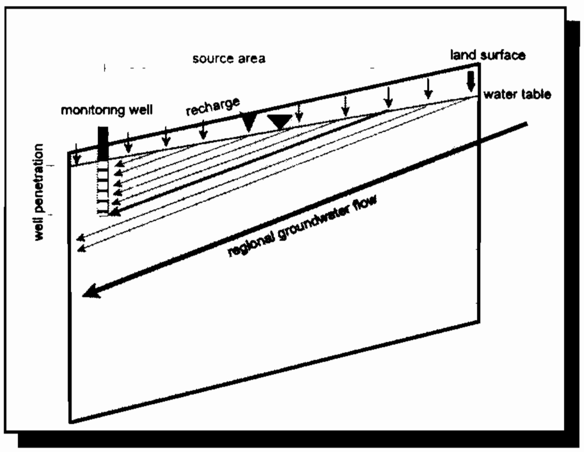

Figure 1: Schematic cross-section through a shallow aquifer to demonstrate estimation of the upgradient extent of the source area.

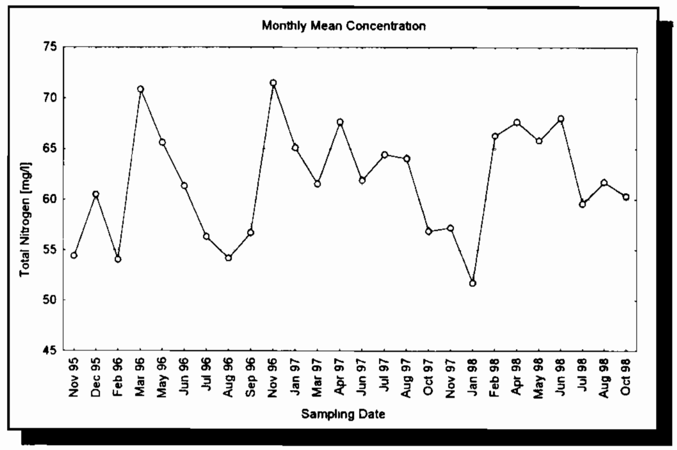

Figure 2: Temporal changes in nitrogen concentrations averaged over all monitoring wells.

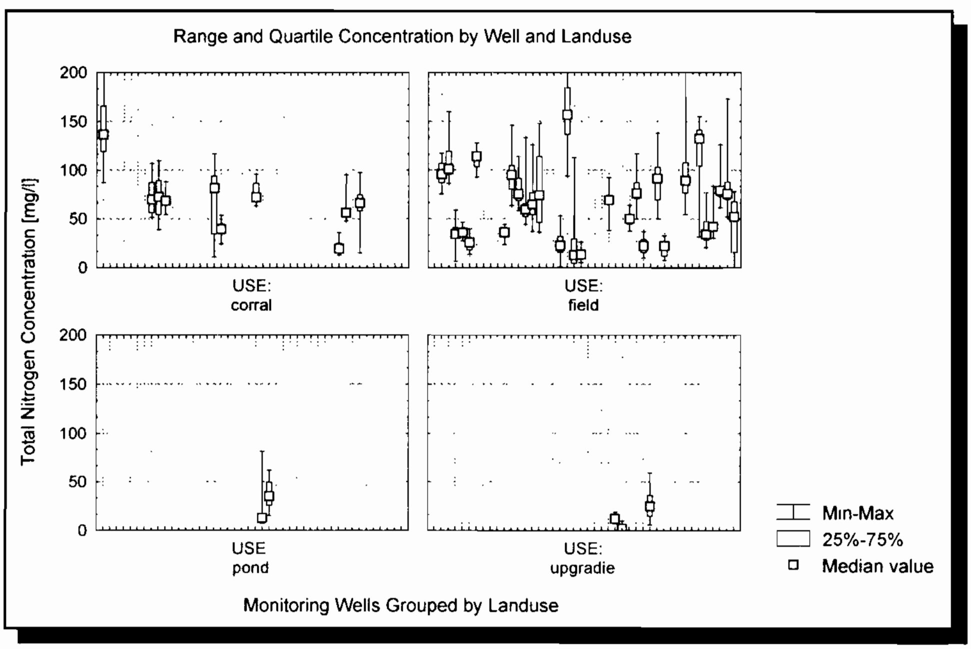

Figure 3: Range and quartile concentrations for individual monitoring wells grouped by landuse.

COMPOSITION OF SOLID AND LIQUID DAIRY MANURE

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INTRODUCTION

A great deal of discussion will be given to Comprehensive Nutrient Management Plans (CNMPs). At this point, USDA NRCS and U.S. EPA indicate that NRCS has been doing CNMPs and that a template exists for such plans. At this writing, it is unclear where said template resides and who is trained to accomplish CNMPs.

As described in the current draft USDA, U.S. EPA Unified National Strategy for Animal Feeding Operations a CNMP includes six components: feed management, manure handling and storage, land application of manure, land management, record keeping, and other utilization options. The manure handling and storage section is further segregated: divert clean water, prevent leakage, provide adequate storage, manure treatments, and management of dead animals. Inherent in the concept of CNMP is an ability to quantify manure nutrient concentrations as well as the ability to place these nutrients where and when they are needed. Furthermore, it is assumed that once placed, the nutrients will be utilized by the plant system and not lost to the environment.

The majority of dairy producers responding to a written survey in the South San Joaquin Valley indicated they applied liquid manure to land to meet crop needs. However, few obtained soil samples and none reported sampling of manure solids or liquids (Morse et al., 1997). It is important that nutrient composition of both solid and liquid manure be known if manure nutrients are to be incorporated into a CNMP.

SOLID MANURE

Differences in herd nutrition and animal management affect concentration and quantity of nutrients excreted from animals. Furthermore, manure nutrient concentrations vary depending on collection, storage, treatment, transportation and utilization techniques. Cattle housing determines how manure is collected. Solid manure is collected from open lots, pens with bedding (maternity area) and settling basins. Solid manure is also collected from mechanical separators which remove few of the solids (larger particles) from the liquid manure stream.

The unique management and features of each dairy farm requires that each manure source should be sampled prior to or during land application. There are no good book values for manure nutrient concentrations.

Obtaining a representative sample is the critical component of sampling solid manure. The amount of soil and debris contained in solid manure affects the organic matter and nutrient concentration. Initially, the various sources of solid manure (e.g. corral, separator solids, settling basin, pond, bedding, aged manure) should be sampled separately. Once a farm database has been established, sampling frequency may be altered.

Obtain manure samples with a soil auger or shovel and bucket. Tools and containers should be clean and dry to reduce the chance of contaminating the samples. Contact your analytical laboratory prior to sampling to find out the desired volume of material for analysis and any special handling requirements. Usually, small samples (cup to pint size) are taken from various locations within the pile. It is important to sample the inside as well as the surface of the pile. Otherwise, the moisture content of the sample will not represent the moisture content of the pile. Sample from 4 to 12 locations around the pile. Samples from each solid manure source should be commingled, mixed thoroughly, and a sub-sample removed for laboratory analyses.

Samples should be handled to maximize the reliability of the data. Seal samples in zip-lock bags to prevent moisture from escaping. Store in a cool environment not exposed to direct sunlight. Samples should be stored in a refrigerator or freezer if there is a delay between sampling and delivery to the laboratory.

Numerous solid manure samples taken on California dairies between 1993 and 1997. A large variation existed in moisture concentration as well as ash content. The greatest variation in moisture was observed in old or piled manures. The average moisture was 38.9% with a deviation of 29.5%. Some very dry samples were found to have less than 5% moisture while other samples that appeared dry were 80% moisture. Fresh manure contained 84.2% water. Manure fiber from mechanical separation was 83 to 85% moisture after separation.

An example of the importance of testing solid manure for moisture content is in Table 1. Large variations in moisture content have been observed under field conditions. For this example, we assume manure was either 35 ro 65 percent moisture and 2.1 or 2.4 percent organic-N. Actual pounds of organic-N applied per acre ranged from 441 to 936. At a given moisture concentration, the difference in organic-N applied based on variation in organic-N concentration was 117 (35% moisture) and 63 (65 % moisture) lbs/ac. Yet, at a given organic-N concentration, the variation in nitrogen applied was much greater based when moisture content varied (378 lbs/ac difference at 2.1 % organic-N; 432 lbs/ac difference at 2.4% organic-N). This example shows the importance of estimating moisture concentration, thereby providing emphasis to obtain a representative sample from the manure and to handle the sample appropriately to not lose moisture. The other highly variable component of solid manure was ash content. Organic nitrogen, although not as variable, is still important to evaluate.

Table 1. Comparison of the importance of sampling for moisture or organic-N in solid manure when applications rates are 30 tons/acre.

Moisture (%)	Organic-N (%)	Organic-N (lbs/ac)
35	2.1	936
35	2.4	819
65	2.1	504
65	2.4	441

Three major forms of nitrogen (N) were evaluated in these samples: Organic-N, ammonium-N, and nitrate-N. Organic-N concentration was the largest and least variable N fraction. Concentration of ammonium-N was greater than the concentration of nitrate-N. Tremendous variability existed in nitrate-N concentration of solid manure samples. The average nitrate-N concentration of separated solids ranged from .0004% to .0017%. The concentration of nitrate-N in dried manure averaged .0129% with a range from .0002% to .0939%. Five of the 16 samples contained more than .01% nitrate-N and the remaining samples contained less than .005%. Although these ranges are large, they amount to few lbs/ac compared to the organic-N component.

LIQUID MANURE

Management practices (diet fed to animals, age, breed and production status of animals, nutrient content of excreted manure, amount of manure collected, dilution of manure with flush, wash or fresh water, recycling of water for flushing, retention time in holding pond) all act to have an effect on the nutrient composition of liquid manure. ***The high variation in the nutrient content of liquid manure makes using an average value inappropriate.***

The frequency of sampling liquid manure varys depending on water management. Ponds should be sampled prior to large dewaterings. ***A minimum of spring and fall sampling is encouraged.*** Additionally, sampling should occur during summer months when large amounts of fresh water are added to the manure pond or when the quantity of manure collected changes (i.e., cows use corrals instead of freestalls)..

Obtaining a representative sample is essential. For the average pond there is no ideal location to sample liquid manure. Ideally, samples should be obtained prior to irrigations to allow nutrient analyses to occur before the nutrients are applied. Then, application rates can be altered through irrigation practices to apply near the desired amount of nutrients. In most situations, this would be some desired amount plus or minus 50 to 100 lbs of N/ac. For ponds with multiple outlets, it is important to sample liquid manure from a source that is located near the outlet for field irrigations. Facilities that pump water into a standpipe may be able to collect undiluted liquid manure at the standpipe. Other facilities may need to run undiluted liquid manure through a field valve to get a sample. Water should run for at least 10 minutes before sampling. If an agitator is used during irrigations, it should be used prior to sampling. Another alternative is to collect recycled flush water if it comes from a similar outlet area in the pond. Surface sampling of the pond is the least desirable sampling location and it is not recommended for most ponds.

A representative sample of undiluted liquid manure should be collected directly into the container that will go to the laboratory. Check with the analytical laboratory prior to collecting the sample. Some laboratories will provide sampling containers. Others will let you know how big a sample is needed. Containers should have at least one inch of air space. Lids should be sealed and the samples should be stored in a cool place out of sunlight. As with solid manure, samples should be stored in a refrigerator or freezer if there is delay between sampling and delivery to the laboratory. Dairy manure storage ponds are usually anaerobic (have no oxygen). As a result there is little opportunity for the formation of nitrate-N and values of pond water are usually small (<1 ppm).

An example will be used to stress the importance of sampling and of obtaining a representative sample. Data obtained from a study of liquid manure from 19 farms has a range between 40 and 339 ppm for ammonium-N (Table 2). The average value was 171 ppm. Approximately 9 or 77 lbs of ammonium-N would be applied per ac-in of liquid manure applied if the extremes were the actual nutrient concentration. The average value would be 39 lbs/ac-in of liquid manure applied. Over the course of a summer irrigation it is not unusual for 4 to 8 in of liquid manure to be applied. If "an average" ammonium-N concentration was used for an average depth of water applied at 6 in, 233 lbs/ac of ammonium-N would be applied. However, the range would be from 36 lbs/ac (40 ppm and 4 in/ac) to 615 lbs/ac (339 ppm and 8 in/ac). The crop may require additional N at the lower concentration and application rate and would have had excessive amounts of N applied at the high concentration and application rate.

Table 2. Nutrient concentration (ppm) of liquid manure from 19 dairy manure holding ponds sampled in July and August, 1996.

Value	Ammonium-N	Total N	P	K
Low	40	114	9	56
Average	171	318	58	325
High	339	847	146	759

SUMMARY

Theoretically, it is possible to utilize manure nutrients in a cropping system. In practice, it is also possible to utilize manure nutrients as crop nutrients. However, the nutrient manager must be aware of nutrient concentrations, application rates, as well as losses to the environment (leaching or volatilization). Additionally, it is imperative that individuals realize there is tremendous variability in nutrient concentration within a pond at a given time as well as throughout the year. Based on variability in nutrient concentrations in ponds under California conditions, it is unrealistic to believe a CNMP would be able to determine application rates to exactly meet crop nutrient needs with current technologies available for a reasonable cost. In fact, CNMPs should recognize that the average value for a given nutrient in a pond may be +/- 20% or when drastic changes occur, +/- 50%. This does not mean to ignore sampling and analysis. In fact, it merely means that frequent samples may be needed if large changes occur in pond dilutions.

SUPPORTING INFORMATION

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Using Dairy Lagoon Water to Replace Commercial Fertilizers

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Introduction

Despite the rich nutrient content of dairy lagoon water, many corn silage growers in the Northern San Joaquin Valley have been reluctant to rely on it as the sole or main source of nitrogen for their corn, due to perceived reductions in yields when they have done so. This project, begun in spring 1998, was aimed at developing methods of measuring and metering dairy lagoon water nitrogen in order to use this as a nutrient source for the corn without overapplication.

Project Design

Replicated Plots: In a border-check irrigated field, four of eight irrigation checks (each measuring approximately 150 feet wide by 1200 feet long) were farmed according to the standard local procedure which utilizes commercial water run anhydrous ammonia as the primary fertilizer (control checks). The remaining four checks were farmed using dairy lagoon water as the primary nitrogen source (manure managed checks). Treatments were assigned in a randomized complete block design with four replications.

Because soils in this area are prone to leaching, it is common practice to apply the water-run anhydrous ammonia in several split applications in the irrigations prior to tasseling. On the control checks, the cooperating grower followed this practice but also added an additional application in the first irrigation after tasseling to better supply the crop with nitrogen during grain fill. In the manure managed checks, the lagoon-water nitrogen applications mimicked the grower's intended anhydrous nitrogen application schedule. Lagoon water was applied in the first, second, third, fourth, and sixth irrigations. Anhydrous ammonia was applied to the control checks during the same irrigations except the first when the tank malfunctioned. In accordance to common practice in the area, dairy lagoon water was applied to three of the four control checks during the preirrigation according to the flow rate set by the grower.

Field Plots: In addition to the field with multiple replications (Rep field), fertilization of corn using lagoon water was done on an entire 20 acre field of a nearby dairy under the same management (manure managed field). A second field of about the same size was managed using solely anhydrous ammonia for the crop irrigations (control field).

Nitrogen Application: Most of the readily available nitrogen in dairy lagoon water is in the ammonium form. Because information on the mineralization rate of the organic fraction of the nitrogen in the lagoon water was unavailable, the amount of nitrogen applied was based only on the ammonium fraction of nitrogen in the lagoon water and the organic nitrogen fraction used as a "safety net" to compensate for application errors. This project was designed primarily to develop and test techniques of lagoon water nitrogen measurement and application. For this reason, nitrogen already existing in the soil prior to the season was not taken into account when determining target application rates.

All irrigation and irrigation decisions were made by the grower and the irrigators. Because there is no drainage for the fields, it is common practice to compensate for over- or under- irrigation at the end of one check by cutting through the border to allow excess water to flow into or out of the adjacent check. While this practice improved irrigation uniformity, it interfered with precise measurement of water application and irrigation uniformity. Notations were made when this occurred, however, no attempt was made to measure water moving from one check to the next or to adjust calculated per check water applications.

Using Pond Drop to Measure Lagoon Water Nitrogen Applications

To avoid either under- or over-application of nitrogen, it is necessary to have a practical method for measuring and regulating pond water flow. The pond drop method requires the least amount of capital inputs. A sample of lagoon water is taken ahead of time, usually captured from the flush system where lagoon water is reused for washing lanes. It is analyzed at a commercial laboratory for (at a minimum) NH_4-N and total nitrogen. The number of inches of pond drop needed to apply the desired amount of nitrogen on each check or field is then calculated.

As part of this study, we sampled straight pond water and measured pond drop in order to compare this method with other methods of pond water application. We found that, in some circumstances, measuring pond drop could be very accurate, while in other situations the measurements were less trustworthy.

Some considerations when using pond drop to measure lagoon water output are:

- A ruler to measure vertical pond drop must be established. This may be difficult to install and/or to accurately read.
- In small ponds the pond water depth can change rapidly. If the measurement does not occur at precisely the time the change is made, error can be introduced.
- Other inflows and outflows in the pond also influence measured pond drop. It may not be practical to turn off all pumps during an entire irrigation.
- Depending on the distance from the pond to the pipeline, there can be a time lag before the effect of an adjustment in flow reaches the field.
- It may be difficult to calculate area of oddly shaped ponds.
- Very large ponds may have no practical way to measure pond drop.

Ammonium nitrogen applied to the field as measured by flow meter and quick test

Flow Measurements: The method of measuring nitrogen application used in this project was to calculate a target nitrogen concentration based on flow, N concentration, acres applied and the estimated time over which the application was expected to occur. In this project, three methods of measuring flow were compared. Flow measurement method options were primarily constrained by the existing access points to the underground pipeline. Flow meters were attached to a rod and inserted into concrete vents in the underground pipeline. Measurement of the mixed district and pond water was possible only for Rep field checks 1 to 4 because the only standpipe downstream of the pond water entry point was at check 5. The final mixed flow was recorded on each check using a Marsh-McBirney Flo-Tote Model 260II B datalogging open channel flow meter. The meter was repositioned to record incoming flows for lagoon water checks above check 5 as well as for most of the anhydrous checks. Instantaneous (spot meter) readings of flow velocity of unmixed incoming district water were made with a Marsh-McBirney Flow Mate 2000 meter using a formula based on the velocity measured at three points on the pipeline cross section. The spot meter was also used to calibrate the recording flow meter, as well as, when possible, to give an additional reading of the mixed flow. Pond drop over time was used to calculate outflow from the pond, and this was added to the incoming flow measurements for checks where direct measurement of total flow was not possible.

Ammonium Measurements: In order to measure concentration, a quick test based on the Nessler method of measuring ammonium was adapted for use in the field. This method consists of taking a sample of water entering the field from the irrigation valve and using a disposable micropipet to measure 100 microliters into a vial. The vial contains a pre-measured amount of distilled water for dilution of the sample. Three reagents are added and mixed with the sample in the vial, then the color is allowed to develop for two minutes. The vial is inserted into a hand-held colorimeter and the concentration of ammonia is displayed on the meter, based on an equation relating absorbance to NH4 concentration.

In the field, the Nessler quick test was used to check ammonium concentrations against a target concentration. For the initial irrigations, a target ammonium concentration was determined based on a quick test of pure pond water (taken either at the flush or at the beginning of the irrigation), the size of the check, the estimated run time (according to the growers' previous experience) and an estimate of the flow based on the district prediction of CFS added to the predicted CFS needed from the pond (based on the quick test of the pure pond NH_4-N concentration). While the first quick tests were being taken, the actual flow was measured with the spot meter, and the target concentration was revised accordingly. On subsequent irrigations, we used flows and times based on previous irrigations to calculate an initial target concentration, modified by actual measured flows.

Yields: Yields were measured by weighing all silage trucks coming from each project check and measuring the size of the harvested area. The entire check was weighed with the exception of the first rows along the borders and the headlands at either end. Two to three samples were taken either from the silage pit or from silage deliberately blown onto a tarp for this purpose. These were weighed and dried to determine moisture and yields adjusted accordingly.

Results

Mixing of Opposing Flows: Two project fields were originally planned to be used for fertilization with pond water. The irrigation valves on one of the fields had the district water and pond water coming from opposite directions. Each check was split with a border so that only one valve would run at a time. Lagoon water was expected to mix with the district water at the valve. However, we discovered during the preirrigation that adequate mixing did not occur at the valve. Instead, half of the check was irrigated with slightly diluted pond water, while the other half received only slightly mixed district water (tenfold difference in total dissolved solids including N). Correcting this situation proved to be too cumbersome and expensive so anhydrous ammonia only was used for fertilization and the grower's flow and N application monitored. The discovery that flows do not mix at the valve is significant because many dairies have similar pipelines where district and pond flows come from opposing directions. These irrigation systems will need to be modified before dairy lagoon water can be used efficiently as a crop nutrient source on these fields.

Lagoon water nutrient content: On the Rep field dairy, the average ammonium content of the pond water was 343 ppm. Over the course of the season, this concentration varied only slightly (less than 5%), except during the preirrigation where 318 ppm ammonium was measured. Except for the preirrigation, the organic nitrogen fraction was relatively small, accounting for only 48 of the average total 307 lbs/N per acre applied with the lagoon water. If these relationships were to hold true for other dairy production systems, it would make management of lagoon water nitrogen much less complex, because less adjustment of the application flows would be necessary and the uncertainty surrounding organic fraction mineralization rates would be less of an issue.

Flow rate variability: Flow was determined more by distance from canal (friction loss), and slope of pipeline than by the water level in the canal. On the Rep field, each check had its own flow rate, varying from a low of 13.8 for the check farthest from the canal to 19.6 CFS in the nearest project check. These differences were unusually large because of non-uniform slope in the pipeline. Initially, the system needed constant adjustment to keep it within the target concentration due to different district water flows in each check and due to the dependence of pond discharge on the depth of water in the pond. Once we were familiar with the system, we found that if we irrigated the checks which had the highest district water rate first, while the pond was fullest, we greatly minimized the number of pond water flow adjustments needed.

Application rate adjustment: On the larger (1.9 acre) of the two ponds, 1.3 inches of pond drop were needed to obtain a target of 50 lbs/A N applied in a typical irrigation. The smaller (.8) acre pond needed a 3.3 inch drop for the same application. It was very difficult to measure the pond drop in the larger pond. When the flush system sump pump discharged into the pond during irrigations, the pond did not drop at all. If we had been using pond drop alone to regulate lagoon water application, irrigation of several checks would have been necessary before the proper side gate setting could be established.

For the larger pond, a 1 to 1_ inch side gate opening (as measured by the threaded stem) was needed to obtain the target concentration. On the smaller pond, the proper opening was between 1_ and 1_ inches. Adjustments of _ to 1/8 inch were necessary to keep the quick test reading within 10 ppm of the target (usually between 45 and 65 ppm). Because there was around two inches of play in the side gate stem handle, it was necessary to first raise the side gate by at least 2 inches and close it down to the desired opening each time an adjustment was made. The same side gate opening did not necessarily give the same quick test reading over the course of an irrigation because 1) the play in the valve made it impossible to be certain subsequent settings were equivalent, 2) plugging of portions of the opening changed the amount of flow coming through, and 3) head pressure decreased as the water level in the pond dropped. In addition to this, the narrow opening resulted in frequent plugging on the pond with the bottom outlet, especially in the first spring irrigations.

<u>Nitrogen application</u>: The Nessler method of testing for ammonium proved to be very practical for field use. We were able to make relatively rapid adjustments in pond water flow based on the quick test results. Such rapid adjustments would not have been possible if we had relied solely on pond drop as a method of metering pond water. The accuracy of the field test in currently beingdetermined.

<u>Soil Nitrogen and Crop Uptake</u>: The Rep field has a long history of receiving large amounts of lagoon water. Therefore, background soil nitrogen concentrations were high. There was considerable mineralization of organic nitrogen over the course of the season. Regardless of the nitrogen application regime, plant tissue nitrogen remained adequate at all sample dates even when an anhydrous application was missed due to a malfunctioning tank. Soil test data clearly showed that large amounts of nitrate were present below the expected functional rooting depth of the crop. Target nitrogen application rates were based on the expected crop uptake from a 30 ton silage corn crop of 259 lbs N/acre, and the average nitrogen applied for both the anhydrous and lagoon water sources came very close to this target. However, the crop yielded over 42 ton/A and the average crop nitrogen uptake was 364 lbs N/A, more than 100 lbs N/A higher than expected. The difference in nitrogen was supplied from soil reserves.

<u>Yields</u>: On the replicated field, the average yield for the corn silage was 41.6 T/A for the anhydrous control and 44.5 T/A for the pond water N. Yields are adjusted to 70% moisture from the harvest moisture of 75.6%. Although the average yield for the pond water nitrogen corn was 3.1 tons higher than that of the anhydrous N corn, the difference was not significant ($P = .15$). The yields for this trial are well above the 1997 Stanislaus County average of 27.2 tons per acre.

Conclusions

The systems used in this project were typical of many in Merced/Stanislaus Counties. With care, systems such as these can be used by a grower to manage lagoon water if a relatively large margin of error and some inconvenience can be tolerated. This would be a considerable improvement over the common practice of not considering the contribution of lagoon water nitrogen at all. Major system improvements are planned by the cooperating dairies for the upcoming season (larger pond, dairy-wide use of manure management). A better system of regulating lagoon water is planned for next season. The Nessler ammonium quick test and flow meters performed adequately in the field to adjust nitrogen application. Yields of both nitrogen application regimes were outstanding for the area.

Acknowledgements:

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Lagoon Water Nitrogen Application, Uptake and Yield

	N measurement method ammonium – N lbs/A					
Check number	pond drop	Quick test + flow meter	Lab test + flow meter	Organic N applied	lbs N/A removed[2]	Yield (T/A @ 70%)
1	211	263	229	45	409	47.30
4	351	334	275	59	357	41.37
5	286	313	279	46	371	42.98
7	254	288	255	41	399	46.22
Average[1]	276	299	259	48	384	44.47

Anhydrous Ammonia Nitrogen Application, Uptake and Yield

Anhydrous N application only

	N measurement method ammonium – N lbs/A			
Check number	Quick test + flow meter	Lab test + flow meter	lbs N/A removed[2]	Yield (T/A @ 70%)
2	271	265	347	40.15
3	265	244	347	40.15
6	277	238	351	40.62
8	279	254	393	45.48
Average[1]	273	250	360	41.60

Anhydrous N + preirrigation lagoon water N applications

	N measurement method ammonium – N lbs/A				
Check number	Quick test + flow meter	Lab test + flow meter	Organic N applied	lbs N/A removed[2]	Yield (T/A @ 70%)
2	368	368	44	347	40.15
3	420	403	84	347	40.15
6	370	345	32	351	40.62
Average[1]	386	372	53	348	40.97

[1]total NH_4-N is on top of 10 lbs N as starter at planting
[2]lbs N removed is an estimate based on 9% protein; tissue N results not yet available

1988 Crop Management Summary, Replicated Field

Soil type: Hilmar Loamy Sand/Delhi Sand
Variety: Pioneer Brand 3223
Herbicide: Accent®
Miticide: Comite®
Planting Date: May 21, 1998
Harvest Date: September 11-12, 1998

Pest Control Technology:
Where are we and where are we going?

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Introduction

Pest control technology is the link between the fundamental knowledge of the biology of the pest to be controlled, the commodity being produced, the interaction of those elements, and the large scale application of that knowledge for the production of safe and healthy food, feed, and fiber. Application technology allows users to put into practice the collective wisdom and experience of growers, PCA's, product registrants, regulators, researchers, and the applicator.

To identify the functions of application technology, it is useful to think of pesticide application as a continuous process. Several articles have been written describing various schemes for breaking the process into steps and analyzing each of the steps. The design chosen here identifies the steps as 1) Mixing; 2) Atomization; 3) Transport; 4) Collection; 5) Deposit formation and migration; 6) Interaction with pest; and 7) Biological effect. If there is a breakdown in the process and any of the steps are skipped or incorrectly completed, the continuous process will be broken and the desired effect, the biological effect of pest control, will be lost. Poorly completed steps, such as incomplete collection of the material by the target, can result in incomplete pest control, off target movement and environmental contamination, or other undesired side effects of the pesticide application.

Engineers and those working in the area of application technology have influence over the steps of atomization, transport, and collection. The effectiveness of these steps can be modified by the choice of equipment, procedures, and practices both before and during the application process. Recent and future innovations in technology are leading to improvements in these steps and more efficient and efficacious applications.

Current and Historical Technology

Nozzles have been the subject of several new developments over the past few years, after many years of little, if any, innovation. The conventional nozzle serves three basic functions: to regulate the flow of liquid; break the mass of liquid into individual droplets; and disperse those droplets into some initial pattern. Hydraulic nozzles use liquid pressure against a shaped orifice to achieve those goals. The limitations of past technology were largely associated with the wide spectrum of droplets produced and the resulting difficulty in controlling the motion of droplets with a wide size range. A wide range of droplet sizes results in some small droplets which contain a sub-lethal dose and are too small to be controlled, and also some which contain far more chemical than necessary and are too large to do anything except fall directly to the ground. This implies less than optimal placement and deposition patterns on the target.

Recent innovations with conventional nozzles have focused on more uniform droplet size production, using separate orifices to meter the flow and create the droplets, and air injection to control the process. New dispersal patterns also allow reducing the distance between the nozzle and the target, more thorough canopy deposition, and precise placement of products.

Rotary atomizers, electrostatic atomization, and other techniques also have a niche in pesticide application. Their primary strength is in small droplet creation, making them suitable for many insecticide and fungicide applications, but having disadvantages for herbicide and growth regulator applications.

Fans have been and continue to be used for transporting droplets from the point of atomization to the target. Recent innovations in row crops include the use of tunnels to direct air down into the canopy drive the spray droplets deep into the canopy, thus increasing deposition quantity and uniformity and reducing off-target movement. In orchard sprayers, expanding use of volutes and distributed fans promotes more accurate direction of the air to the critical areas of the canopy while minimizing the portion of the spray that misses the tree.

Electrostatics has been around for many years and continues to be promoted as a solution for problems related to pesticide application. While it can be helpful in increasing deposition, electrostatics is not a "silver bullet" that will cure all problems and turn a poor application into a good application. Improvements will continue to be made in electrostatic systems in the future, and research will delineate appropriate uses, operating procedures, and equipment innovations to improve the reliability of electrostatic spraying systems.

Formulations and drift control agents continue to be a source of innovation that is beyond the influence of the applicator, but has a profound influence on the effectiveness of the applicator. The use of drift control agents, deposition aids, spreader – stickers, and other adjuvants should be evaluated on a case – by – case basis. These adjuvants should be used only when the additional cost can be justified by increased efficacy or efficiency, a reduction in undesirable side effects, or when required by registrants, regulators, or written recommendations.

Near-term options. In the near future (defined as within the next five years) several innovations will be become commercially available to growers and applicators. Several of them are discussed below, but the reader should remember that predicting the future is risky and some of these may drop out or new and extremely effective innovations may appear with little advance notice or fanfare.

Sensors are currently being used to detect the presence or absence of trees, green plants, or other objects in the field of view. Ultrasonic sensors or infrared, laser, or visible light sensors are currently commercially available as options on sprayers. Generally, these devices serve simply to turn on the spray liquid when an object meeting the target specifications is located and to turn off the spray liquid at other times. Software innovations and improved sensors may add to the versatility and degree of control available in the future.

Nozzle innovations will continue to be offered. Most current innovations are aimed at reducing drift, but many also can serve to increase efficacy as well. The production of narrow droplet size spectra will result in the ability to closely control transport of the droplets and subsequent deposition on target.

Controllers are increasingly being used, primarily as rate controllers. In their simplest form, these devices vary the flow rate of liquid when sprayer travel speed varies, such as going up or down hill. Limitations of these systems center on a time delay between detection of a speed change and the time that the reduced liquid pressure is noticed at the nozzle orifice with the resulting flow rate change. Controllers also are limited in range, as most operate on changing pressure, an inefficient but simple way to change flow rate through an individual nozzle. For broadcast spraying, pressure changes also change the pattern produced by the spray.

The commercially available Capstan™ system is based upon a concept patented by Dr. Ken Giles of UC Davis. This system starts with a pulsed supply of spray liquid to the nozzle. The applicator has the option of cycling the liquid on or off as frequently as 10 times per second. This on and off cycle does not change the pattern or droplet size emitted due to the fast action of the solenoid. Thus, the applicator can choose flow rates from the full flow as specified in nozzle catalogs to as low as 20% of full flow. This adjustment can be made without changing pressure. A second innovation of the Capstan™ system is the ability to change pressure as the sprayer moves across a field. This action does change the droplet size and pattern, if the nozzle would normally exhibit such changes in operation. The heart of the Capstan™ operation is the linking of these two concepts. An operator can reduce pressure to increase droplet size to reduce the danger of drift, for example, and compensate for the change in flow, by increasing the duty cycle, or percentage of time that the nozzle is "on." Similarly, an increase in pressure can be used to increase canopy penetration, while a decrease in the duty cycle will result in a constant application rate per acre. This system is commercially available on new sprayers and also as a retrofit for existing sprayers, with or without other brands of controllers.

Dr. Giles and Dr. David Slaughter of UC Davis have developed a variable yaw nozzle. This uses a standard fan nozzle and mounts it in a nozzle body that can be rotated about the vertical axis. When in normal conditions, the nozzle is virtually perpendicular to the direction of travel, as on a standard boom, and sprays over a fixed width, depending upon the nozzle angle and height above the target. The variable yaw nozzle provides for rotating the nozzle so that the width of the spray pattern is reduced. The width of the pattern is given by $w\cos(\theta)$, where θ is the angle of the nozzle relative to the boom, varying from 0°normally to 90° when the long axis of the pattern coincides with the direction of travel, and w is the normal width of the pattern. This technique, when coupled to the variable duty cycle component of the Capstan™ system, can be used to reduce the area covered when completing a banding application, and thus reduce off target application and wasted product.

There are currently two weed sprayers operating on the principle of requiring a sensor to "see" the color green before activating a nozzle. The Patchen Company developed one, and the other was developed at UC Davis with support from CalTrans. The Patchen system uses its own light source and detects the return of specific wavelengths, which indicates the presence of a green plant. The system is compact, carries its own light source, and can operate under adverse conditions. However, one sensor is required for each nozzle and must be close to the target. The CalTrans sprayer uses a color video camera to collect an image of the target area. A computer analyses the image to detect the color green within range, and, if it does detect green, activates the appropriate nozzle to spray that area. This system can operate with boomless nozzles and a single camera and computer controls the entire array of nozzles. However, it relies on ambient light for illumination, requires more time for data processing, and will detect and activate the sprayer for any green object within the field of vision, even if it is not on the ground.

Still to Come. In the future, but probably not within the next five years, we may see several innovations become widely commercially available for use in pest control. Some may reach the market sooner, and some may never make it, but these systems are under development and should succeed in making a difference in our professional lifetimes.

Injection systems have been under development for many years, and are not yet widely used because of two limitations. First, a truly useful injection system would use some version of a refillable, round trip, or "pay for only what you use" container. Secondly, injection at the nozzle body is the only way to make rapid changes in product mix or application rate, and to date, injection at the nozzle body does not give a uniform distribution of product over the pattern or within the droplets emitted by the nozzle. Injection system mixing is just not yet as thorough as tank mixing.

Removing the first limitation would require cooperation among all product registrants to set and comply with industry standards for dry disconnect couplers and container sizes. If this were to happen, the benefits to applicators would be enormous. In this scenario, the grower would get a written recommendation for products X, Y, and Z from the PCA, with perhaps Z only used around the outer 50 feet of the field. The grower would go to a farm supply store, and get one or more containers of products X, Y, and Z, depending on the container size, application rate, and field size. The grower would then install the containers in the sprayer and hook up the lines with the dry disconnect couplers with no exposure to herself or himself or to the environment. The sprayer would be programmed with the specified application rate for each product, and the field would be sprayed. At the end of the application, the partially full containers would be disconnected, again with no spillage, and returned to the supply store. After weighing, the grower would be charged for only the weight of product actually used. There would be no year-to-year on-farm storage, no excess tank mix to dispose of, and no worries about changes to labels, cropping patterns, or the cost of keeping an inventory of chemicals on site. The bad news here is that such industry cooperation is not is sight.

Fully remote controlled applications may be a reality soon. Major tractor manufacturers are researching remote operation, both to be controlled by a person in real time and also guided by GPS controllers. Pesticide applications make a great deal of sense as an early application of this technology. Operator exposure to chemicals could be eliminated, much application work is repetitive within and between seasons, and the fact that guidance accuracy of a foot or less is sufficient for orchard applications (although not for vineyard or row crop applications) all argue for remote controlled pesticide applications.

Vision systems are being upgraded to include plant recognition. This could be used to locate a row of crops within a weed-infested field, precisely guide a spray onto the crop (for a fertilizer, fungicide or insecticide application), or identify individual weeds to be sprayed in a large field of cereals or grains. This could also be coupled with an injection system to deliver a variable choice of herbicides if resistance is a problem with one or more species.

Links between pest scouting, yield monitors, soil, water, fertility, and other sensors, and GIS mapping are improving everyday. Fertilizer can already be applied at a variable rate based upon the previous crop yield, soil type and fertility, and likelihood of leaching or runoff. Herbicides are also being applied at variable rates in response to changes in soil organic matter content, as measured in real time. These improvements will undoubtedly continue at an accelerating rate over the coming years.

Application technology for biological pest control agents has only recently become widely researched and the subject of concerted development efforts. Devices to apply eggs, larvae, bacteria, mature insects, viruses, and other biological agents are under development, and some have reached commercial stage. This is clearly a barrier to more widespread adoption of biological pest control, but the requirements for applying biological agents are more rigorous than traditional chemical applications. Some must be handled gently, others cannot be immersed in water, and still others cannot move, so must be placed precisely where the pest is found. Private individuals and small companies are leading this effort, and supporting much of the research without support from large companies or government agencies. Much of this work is both organism and crop specific, leading to narrowly defined niche markets. Much of what is learned here will be useful to the general subject of pest control technology, but the technology transfer will be relatively slow due to the financial and time constraints of the innovators and the lack of wide exposure for their efforts. These individuals and small companies are where most of the innovation in pest control technology is occurring today.

More regulations are also undoubtedly in the future. Drift, volatilization, dust, runoff, leaching, and residues are just some of the topics currently well regulated. Yet these issues do not go away. In fact, many become more contentious every year, in dealings between farmers, regulators, food wholesalers, neighbors, environmental advocates, and the general public. These are not simple issues that can easily be solved, but rather they will continue to attract attention and effort. Technology that can help to eliminate or alleviate these conflicts will continue to be sought.

New chemical products will continue to be developed both in the near term and also in the long term. Some of these new products will come with specific application technology that must be used to apply them in an efficacious manner. Sprayer technology will have to be implemented to gain the advantages offered by these new products. Some changes may be relatively simple, but others may require altering our whole way of thinking about application technology. Low rates, precise placement within a plant canopy, use of diluents other than water or oil, limited handling in sprayer pumps and fittings, and other similar restrictions may appear in the future as part of the use requirements for new products.

On a non-technical, but reality-based topic, the future will also undoubtedly continue to see more conflict with neighbors, other uses, and priorities of a diverse population with limited experience and knowledge of agriculture. Use of agricultural aircraft already brings complaints, and stories of persons who claim to have been poisoned by chemical use are legion. The reality is that pest control will have to adapt to avoid the practices perceived to be the most risk to the environment and the general public. Perception will drive the beliefs and actions of many people, and widely held perceptions make it difficult to establish and retain regulations and laws based solely upon science and compromise between the multitude of goals of a diverse, growing, and increasingly urban and suburban society.

Conclusions

Technology will bring rapid and pervasive change to pest control. Society is likely to continue to expect increased precision and safety in pest control operations, and will presumably expect applicators to use the same level of technology that they use in their lives. This implies more use of computers and sensors, and more importantly, this probably means that a discussion will occur relative to the current assumption that spray technology should be inexpensive and that each person should be able to complete their own applications, should they choose to do so. The corollary to this is that regulations should be designed so that the lowest common level of technology can be used and the applicator can comply with regulations by exercising minimal care.

If current and new technology is widely adopted, either through market forces or regulatory requirement, application equipment will certainly become more expensive and more narrowly focussed in its suitability. That is, the range of crops that can be treated with a single piece of equipment will be limited, as could the types of materials to be applied through the equipment. This will inevitably lead to specialization and probably, fewer applicators for each crop or each class of pest control agents. Custom applicators will probably become more numerous, and quick to upgrade equipment and seek to fill market niches as they open, from changes in pest control agents or the introduction of new crops in a particular community. The custom applicator will probably market their professionalism and specialization as a way for the grower to know that products are being applied with the best available technology and by applicators who are fully trained, both in the use of the technology and the product.

But, this is time to restate the caveat that predicting the future is risky and that at least some of the predictions in this paper will probably be proven to be in error. We do know that technology will continue to advance, that sprayers will continue to change, and that the equipment manufacturers, growers, and pest control agent producers will all continue to seek technological innovations to help them more effectively, efficiently, and safely protect food, feed, and fiber.

Scholarship Essay

How will your academic training in agricultural technology benefit the environment and the lives of Californians in the 21st century?

Sherry D. Schliskey
Student, Plant and Soil Science Department
California State Polytechnic University, Pomona
Hometown: Orange

Agriculture is the science, art, and business of cultivating the soil to produce crops. Technology is the application of methods and materials to achieve an objective. My academic training gives me not only the principles of farming but the practical application of those principles as well. With this training, I believe I can benefit the lives of Californians by working to help California's agricultural industry achieve three important objectives in the 21st century.

I believe the first and most important objective of California's agricultural industry in the 21st century is to remain profitable. Agriculture in California is a twenty-two billion-dollar industry that directly and indirectly affects the lives of all Californians. I believe it is possible for farmers to increase their crop yields, maintain crop quality, and decrease costly inputs. With the development and institution of cropping systems and integrated pest management programs, farmers can increase their productivity, maximize their profits, and optimize long-term use of their farmland.

The second objective of California's agricultural industry in the 21st century is the protection of the environment and the sustainability of natural resources. Farmers can reduce chemical inputs such as fertilizers and pesticides with a greater understanding of the crop-environment relationship. Farmers must also conserve and sustain natural resources such as soil and water. Approaches to cultural, irrigation and other production practices should be chosen based on their respective short and long-term environmental impacts.

The third objective of California's agricultural industry in the 21st century should be an increased awareness of and greater response to consumer demands. Californians have recently shown a growing demand for ethnic and specialty food crops and safer, high quality crops. Crop diversity combined with improved production and marketing techniques along with postharvest technology will allow farmers to take advantage of these growing markets.

I believe California's agricultural industry will face many challenges in the 21st century trying to achieve the three objectives I have discussed. The training and experience I am receiving in the biological, physical, chemical, and economic aspects of agriculture will prove invaluable to me as an active and contributing member of this industry working to help achieve those objectives.

Scholarship Essay

How will your academic training in agricultural technology benefit the environment and the lives of Californians in the 21st century?

Darci D. Sagara
Student, Crop Science Department
California Polytechnic State University, San Luis Obispo
Hometown: Woodland

I believe that my academic training in agricultural technology will benefit the environment and the lives of Californians in the 21st century by promoting peacefulness and understanding between the agricultural and urban sectors.

I believe that there is an overwhelming need for Public Relations in agriculture. One of my goals is to promote good relations toward people in the agricultural industry. I have a strong desire to educate and "bridge the gap" between the "non-agricultural" people of the cities and the farming community of the agricultural industry. I would like to attain this goal by truly understanding and being able to explain how and why farmers do the things they do. For example, why farmers harvest a crop at night, spray pesticides on their crops, do ground preparation work which creates large amounts of dust, etc. I feel that I can accomplish this be earning a degree in Crop Science with a minor in Agribusiness.

I chose to major in Crop Science with a minor in Agribusiness at Cal Poly in order to learn first-hand about the operations of a farm and how to run an agribusiness. I know that this experience will give me the creditability I need to help me be successful in the public relations aspect of agriculture.

Because I have chosen to pursue a university education, I have taken the necessary steps to network with fellow students and industry-related people. Thus, I have begun to amass a solid foundation of contacts that will be critical to my success in the agricultural industry. I am a well-rounded student, not focusing on just one aspect of agriculture, but on many areas and also on things that I enjoy. I work hard to earn good grades, and when given a task, I perform it to the best of my abilities. I feel secure that this sound work ethic will carry over into my chosen career.

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CALIFORNIA CHAPTER - AMERICAN SOCIETY OF AGRONOMY

PLANT & SOIL CONFERENCE QUESTIONNAIRE

Please complete and return this form to the registration desk or to a board member.

1. What session topics do you recommend for future conferences.

   a. ____

   b. ____

2. Please suggest Chapter members who would be an asset to the Chapter as Council members.

   Name Address Phone

   a. ____

   b. ____

3. Who would you like to see honored by the Chapter? The person should be near to the end of their career. Provide their name and a brief statement regarding their contribution to agriculture.

   ____

   ____

4. Who can tell us about your proposed honoree?

   Name Company Phone

   ____

5. Please list people who are not now Chapter members who might be interested in joining CA - ASA.

   Name Address Phone

   a. ____

   b. ____

   c. ____

6. a. How do you rate the Poster Session? Good ___ OK ___ Poor ___

   b. How do you rate the Poster Reception? Good ___ OK ___ Poor ___

8. Do you have a preference for next years Conference location?
   (Check one or rank by preference)
   Modesto ___ Fresno ___ Visalia ___ Bakersfield ___ Sacramento ___ Other ___

9. You may list additional comments on the back side of this form.