Proceedings

1995
California Plant
and
Soil Conference

Agricultural Production/Environmental Concerns: New Paradigms

California Chapter
of
American Society of Agronomy
and
California Fertilizer Association

January 10 & 11, 1995

Radisson Hotel
300 South Court St.
Visalia CA 93291

CALIFORNIA CHAPTER
AMERICAN SOCIETY OF AGRONOMY
PAST PRESIDENTS

1972	Duane S. Mikkelsen
1973	Iver Johnson
1974	Parker F. Pratt
1975	Malcolm H. McVickar
	Oscar A. Lornez
1976	Donald L. Smith
1977	R. Merton Love
1978	Stephen T. Cockerham
1979	Roy L. Branson
1980	George R. Hawkes
1981	Harry P. Karle
1982	Carl Spiva
1983	Kent Tyler
1984	Dick Thorup
1985	Burl Meek
1986	Stuart Pettygrove
1987	William L. Hagan
1988	Gaylord P. Patten
1989	Nat B. Dellavalle
1990	Carol Frate
1991	Dennis J. Larson
1992	Roland D. Meyer
1993	Albert E. Ludwick

CALIFORNIA CHAPTER AMERICAN SOCIETY OF AGRONOMY HONOREES

1973	J. Earl Coke
1974	W. B. Camp
1975	Milton D. Miller
1976	Malcolm H. McVickar
	Perry R. Stout
1977	Henry A. Jones
1978	Warren E. Schoonover
1979	R. Earl Storie
1980	Bertil A. Krantz
1981	R.L. "Lucky" Lockhardt
1982	R. Merton Love
1983	Paul F. Knowles
	Iver Johnson
1984	Hans Jenny
	George R. Hawkes
1985	Albert Ulrich
1986	Robert M. Hagan
1987	Oscar A. Lorenz
1988	Duane S. Mikkelsen
1989	Donald L. Smith
	F. Jack Hills
1990	Parker F. Pratt
1991	Francis E. Broadbent
	Robert E. Whiting
	Eduardo Apodoca
1992	Robert S. Ayers
	Richard M. Thorup
1993	Howard L. Carnahan
	Tom W. Embleton
	John L. Merriam
1994	George V. Ferry
	John H. Turner
	James T. "Jim" Thorup
1995	Leslie K. Stromberg
	Jack Stone

CALIFORNIA CHAPTER ASA
1994
BOARD MEMBERS

THE EXECUTIVE COMMITTEE

President: Brock Taylor, Vaquero Farms, Inc., 1600 Michelle Way, Escalon, CA 95320.

First Vice-President: Jim Oster, Soil & Environmental Science Dept., UC Riverside, CA 92521-0424.

Second Vice-President: Dennis Westcot, California Regional Water Quality Control Board, 3443 Routier Road, Sacramento, CA 95827.

Past President: Al Ludwick, Potash & Phosphate Institute, 229 Eldridge Avenue, Mill Valley, CA 94941-4554.

Executive Secretary-Treasurer: Shannon Mueller, Agronomy Farm Advisor, UC Cooperative Extension, 1720 South Maple Avenue, Fresno, CA 93702.

COUNCIL MEMBERS

ONE-YEAR TERM:

Wayne Collins, Western Farm Service, P. O. Box 148, Alpaugh, CA 93201.
Bruce Roberts, UC Cooperative Extension, 680 North Campus Drive, Hanford, CA 93230.
Terry Smith, Soil Science Department, Cal Poly State Univ., San Luis Obispo, CA 93407.

TWO-YEAR TERM:

John Law, Tru Green◆ChemLawn LP, 5125 Leona Street, Oakland, CA 94619.
Carol Lovatt, Department of Botany & Plant Science, University of California, Riverside, CA 92521.
Steve Oakley, CPCSD, 30597 Jack Avenue, Shafter, CA 93263.

THREE-YEAR TERM:

Jack Hodges, Water Resources Control Board, Sacramento
Mark Grewal, J.G. Boswell Company, P. O. Box 877, Corcoran, CA 93212.
Mahlon Hile, California State University, Fresno

TABLE OF CONTENTS

GENERAL SESSION

Cropping Systems in California: Needs and Future Directions. 1
D. W. Rains

Managing Soil and Water Resources for Maximum Production Efficiency and Environmental Protection 7
A. Ludwick

An Integrated Approach Toward Pesticide Regulation 15
J.W. Wells

Concurrent Sessions

I. Pest Management

Compliance Plus 20
Roger A.Yeary

Reduced Herbicide Usage in Perennial Crops, Row Crops, Fallow Land and Non-Agricultural Applications Using Optoelectronic Detection 23
J. Beck

Layby Weed Control in Tomatoes Using Variable Herbicide Rates 33
W. T.Lanini, E.M. Miyao, and B. Correiar

New Technology to Reduce Pesticide Use on Turf and Ornamentals 39
J. Law, Jr.

Intelligent Spray System for Reduced Herbicide Control of Vegetation 43
C. Tauzer, D.C. Slaughter, and D.K. Giles

Yield Monitoring: The New Agronomic Challenge 54
T. Macy

II. Sustainable Agriculture

Development of Innovative Agronomic and IPM Management for Success in the California Melon Industry 55
J. LeBoeuf

A Case for Retaining Pesticides: Microbial Degradation of Pesticides 60
J. D. Helm and T. A. Yamashita

Challenges and Opportunities for Mixed, Conventional, and Organic Production 65
T. O'Neal

Agronomic and Economic Potential of Alternative Production Systems 66
S.Temple

Interaction Between Plant or Soil Conditions and Insect Pests and Natural Enemies Can Combine for Improved IPM 67
K. Daane, L.E. Williams, R.S. Johnson, and J.W. Dlott

Biologically Integrated Orchard Systems (BIOS): A Voluntary Approach to Pesticide Reduction 73
Robert L. Bugg, J. Klein, G. Anderson, R. Eck, L. Hendricks, and C. Lashbrook

I. New Paradigms in Soil Fertility

Can the Total N Needs of a Peach Tree be Supplied by Foliar Urea? 79
R.S. Johnson and H. L. Andris

Plant Potassium Availability in California Soils 85
R.O. Miller

Spatially Distributed Nitrogen Recommendations 90
C.A. Redula, J.L. Havlin, G. J. Kluitenberg, M.D. Schrock, N. Zhang

Long Term Research in Agricultural Systems (LTRAS): A 100-Year Experiment Begins at U.C. Davis 96
R.F. Denison

Soil Microbe Contributions to Plant Nutrition and Soil Quality 100
D.A. Phillips and C.M. Joseph

II. Agronomic Solutions for Problem Soils

Water Uses--General Overview 104
J. Sorensen

Water Quality--Analysis & Instrumentation 105
N. Dellavalle

Equipment Methods of Reclamation 109
H. Collin

Cover Crop Incorporation and Gypsum Applications to Improve Soil Physical Properties in Salinized Soils 114
J. Mitchell, M.J. Singer, T. Prichard, D. Peters, D.M. May, R.O. Miller,D. Munk, and C. Shennan

Drainage in the Tulare Lake Basin 116
D. Davis

Soil and Water Amendments-- Surface vs. Subsoil Applications 117
A. Fulton

III. N Fertilizer/Best Management Practices

Nitrate Nitrogen Losses Below the Root Zone of Irrigated Cotton: Impact of BMP Implementation 121
J. Watson, K. Reffruschinni, M. Sheedy, S. Cordell, B. Anthony, S. Stedman, and R. Gibson

Western States Agricultural Laboratory Exchange Program 126
R. O. Miller and J. Kotuby-Amacher

Effects of Nitrogen Fertilization on Three Diseases of Almond Trees 131
B. Teviotdale

Time of Application of Urea to Citrus Foliate Influences Yield, Fruit Size and Scarring by Citrus Thrips 136
C. J. Lovatt and J.G. Morse

IV. Animal Waste: A Resource or Waste?

Land Application of Manure Waters: Nutrient Content 142
D. Morse and L. Schwankl

Land Application of Manure Waters: Irrigation Uniformity and Efficiency Considerations 147
L. Schwankl and D. Morse

Using Stable Isotopes for Identifying Nitrogen That Originates From Animal Waste as Compared to Other Sources 153
D.E. Rolston, G.E. Fogg, D.L. Decker, and D.T. Louie

Monitoring and Evaluation of Water Quality Under Central Valley Dairy Sites. 158
Harley H. Davis

Management Practices: Their Regulation and Economic Impact 165
V. J. Mellano

POSTERS

Potential for Utilizing Blended Drainage Water for Irrigating West Side, San Joaquin Valley Pistachios 167
L. Ferguson, B. Sanden, and S. Grattan

Evaluation of Regulated Deficit Irrigation for Pistachio Orchards 168
D. Goldhamer, C. Greene, and H. Li

An Organic Versus Conventional Farming System in Kiwifruit 169
J. K. Hasey, R. S. Johnson, R. D. Meyer, and K. Klonsky

Irrigation and Middles Management in Almonds 170
B. Sanden and M. P. Gonzalez

Agricultural Use of Methyl Bromide. I. Quantifying Emissions 171
S.R. Yates, F.F. Ernst, J. Gan, A. Mutziger, and F. Gao

Agricultural Use of Methyl Bromide. II. Experimental Design 172
F.F. Ernst, J. Gan, A. Mutziger, F. Gao, and S.R. Yates

Agricultural Use of Methyl Bromide. III. Soil Gas Transport 173
A. Mutziger, F. Gao, F.F. Ernst, J. Gan, and S.R. Yates

Multi-Port Soil Water Extractor for Monitoring Solute Transport Through Soil 174
J. A. Jobes and P.J. Shouse

Designing and Building a Crop Salt-Tolerance Database 175
A. L. Ulery and M. Th. V. Genuchten

Improved Precision in ^{15}N-NO_3 Diffusions 176
D.J. Herman, M.L. Hanes, and P.D. Brooks

Soil N-Dynamics in a Sierra Nevada Subalpine Meadow 177
T. Balser, T. Dudley, and M.K. Firestone

Development and Testing of a Combined Tension-Solution Probe 178
S.J. Essert and J.W. Hopmans

Subsurface Drip Irrigation Studies for Common Westside Crop Rotations 179
D. Munk

A GIS-Based Approach to Evaluate Soil Salinity in the Broadview Water District of Central California 180
H. Wang, D.L. Corwin, L.J. Lund, J.D. Rhoades, P.J. Vaughan, and D.G. Cone

Selenium Partitioning in Soil-Plant-Atmosphere System 181
M. Camps and J.W. Biggar

Consumptive Water Use, Biomass Accumulation and Sugar Yield of Fall-Planted Sugarbeets in California 182
S.R. Kaffka, P. Langner, D. Peters, and G. Peterson

Transient Three-Dimensional Root Growth, Soil Water Flow and Nutrient Transport and Uptake 183
F. Somma, J.W. Hopmans, and I.P. King

Analysis of Soil Water and Solute Distribution Around an Almond Tree Under Drip Irrigation 184
L. Andreu, J.W. Hopmans, L. Schwankl, and J. MacIntyre

Fugitive Dust Characteristics From Agricultural Operations in California 185
R. Higashi, T. Fan, R.J. Southard, M.J. Singer, and H. Clausnitzer

A Proficiency Testing Program for Agricultural Laboratories--Results of the 1994 Program 186
J. Kotuby-Amacher and R.O. Miller

Sorption Processes Controlling as Solubility in Ground Water, Tulare Basin, California 187
S. Gao, A. Chalmers, K.K. Tanji, and R. Fujii

Response of 'Hass' Avocado to Differential Irrigation Treatments 188
D.E. Stottlemyer, M.L. Arpaia, J.L. Meyer, G.W. Witney, and G.S. Bender

Drip Irrigation and Fertigation Management Can Minimize Nitrate Leaching Losses 189
T.K. Hartz

Shallow Groundwater Use by Row Crops 190
S.S. Vail, R.B. Hutmacher, J.E. Ayars, R.A. Schoneman, and D. Dettinger

Subsurface Drip Irrigation: Eastern San Joaquin Valley 192
Allan Fulton

Cropping Systems in California: Needs and Future Directions

D. W. Rains

Agronomy and Range Science

University of California, Davis

Agricultural production systems (agroecosystems) are managed ecosystems. An agroecosystem is a disturbed natural ecosystem in which physical and biological resources are manipulated (farmed) to provide desired outputs (products) for the benefit of the farmer and society (Rains and Cassman, 1990). Historically, societies that did not sustain a resource base on which agriculture depends failed. The Babylonians salted and silted themselves out of the Fertile Crescent (Hillel, 1991). The Phoenician civilization fell with the Cedars of Lebanon. Today, due to population pressures, the slash and burn farming systems in the tropics are now at risk (Greenland and Nye, 1959).

In California's vast central Valley, a Mediterranean climate, water for irrigation and deep alluvial soils provided the basis for development of intensively managed, crop production systems which represent the forefront of modern agriculture in the U.S. The rapid adoption of innovative technology, however, far exceeds our understanding of the longer-term effects of these practices on the soil characteristics that determine both productivity and resource use efficiency. Indicators of potential long term effects in California are: Salinization, reduced infiltration of water, nitrates in well water, increased bulk density of soil, perched water tables, nutrient deficiencies (other than nitrogen and phosphorus), are a few examples.

Of paramount concern is whether interventions such as irrigation, laser land leveling, use of fertilizers and pesticides improve, diminish or maintain the soil resource when considered in sum as integrated components of a cropping system (Rains and Cassman, 1990). Any attempt to evaluate the effect of these numerous interventions on agricultural systems requires assessment at the cropping system level.

For the following discussion cropping systems refer to a systematic way of growing crops so that they interact with available resources and managerial skills of the practitioner (farmer) for profitable and sustained crop production in any given environmental setting.

Cropping systems forms one segment which when integrated with other segments (dairying, poultry, livestock) form a farming system. Krantz (1974) defined farming systems as "the entire complex of development, management and allocation of resources as well as decisions and activities which, within an operational farm unit or a combination of such units results in agricultural production, and the processing and marketing of the products".

The primary question is what are the long term effects of present crop management systems on evolution of soil characteristics and resource use in irrigated agriculture as practiced in California. Are present cropping systems and crop rotations appropriate; are these practices improving, maintaining or degrading soil properties which are important determinants of production and resource use efficiency?

How does one evaluate the functioning of these systems?

Longterm Studies

Management of agricultural systems attempts to concentrate a scarce resource so that it "exceeds its threshold of activity" (Loomis and Conners, 1992). In turn, this results in a non uniform distribution of resources in space and time. The potential effect of this non uniformity in agricultural resources on productivity and surrounding enviornments will require long term evaluations to assess the management necessary to sustain productivity.

In this presentation examples of long term research will be discussed; specifically, the processes that determine behavior and the potential for sustaining productivity. These discussions will also include description of cropping systems currently employed and others proposed as future management systems.

Cropping systems embody a number of management protocols. Crop rotation is a historical and highly successful technique, particularly in pest management and soil remediation. Ongoing studies in California are providing significant information on the value of alternative crop management systems including crop rotations (Temple et al., 1994). There is increasing information on integrated crop and livestock systems and the value of these improved systems (Luna et al., 1994). Information from these and other studies will be presented and discussed. Intercropping, an alternative cropping system, has been important in areas where there are restrictions on resources (water, nutrients) and restriction on space. In particular, intercropping (polycropping, multiple cropping) has been an essential part of subsistence farming throughout the world. Conceptually this system utilizes resources in a more homogeneous way, extracting temporally and spatially those resources needed by the crop species occupying that space. If indeed homogeneous resource allocation is a feature of intercropping then what might be the effect of such a cropping system on resource use efficiency, productivity and the surrounding environment (Aggarwal, et al., 1992). Examples of other systems include relay cropping and alley cropping. These systems will be described and analyzed as potential management alternatives for California and the possible impact on crop productivity and resource use efficiency.

In any discussion on alternative approaches, however, one needs to recognize that the costs, returns and risks associated with improved management systems will dictate the rate of adoption by farmers.

References

Greenland, D. J. and P. H. Nye. 1959. Increases in the carbon and nitrogen contents of tropical soils under natural fallow. J. Soil Sci. 10:284-99.

Hillel, D. 1991. Out of the earth. Civilization and the life of the soil. Univ. of Calif. Press, Berkeley.

Rains, D. W. and K. G. Cassman. 1990. Long-term research: An overview. In: Proc. Sust. Agric. Calif.: A Res. Symp., UC SAREP Publ. #334. Pp. 5-1 to 5-8.

Loomis, R. S. and D. J. Conners. 1992. Crop ecology productivity and management in agricultural systems. Cambridge Univ. Press.

Krantz, B. A. 1974. Cropping patterns for increasing and stabilizing agricultural production in the semi-arid tropics. Hyderbad, India, Intl. Workshop on Farming Systems, ICRISAT.

Luna, J., V. Allen, J. Fontenot, L. Daniels, D. Vaughan, S. Hagood, D. Taylor and C. Laub. 1994. Whole farm systems research: An integrated crop and livestock systems comparison study. J. Alt. Agric. 9:57-63.

Temple, S. R., D. B. Freedman, O. Somasco, H. Ferris, K. Scow and K. Klonsky. 1994. An interdisciplinary, experiment station-based participatory comparison of alternative crop management systems for California's Sacramento Valley. J. Alt. Agric. 9:64-71.

c:\Rains\CropSyst.wp

Managing Soil and Water Resources for Maximum Production Efficiency and Environmental Protection

Albert E. Ludwick
Western Director, Potash & Phosphate Institute

Introduction

Question: Why manage soil and water resources for maximum production efficiency? ...or, for that matter, why conduct maximum yield research (MYR) with the goal being to intensify the production system? *Answer*: To feed a growing world population.

The above response may seem simplistic, but it is fact none-the-less. Yet many continue to question the merits of high yield production and MYR as if there were viable alternatives to feed our world.

Dr. Norman E. Borlaug was awarded the Nobel Peace Prize for his work in plant breeding and improvement; he is considered a leader of the "Green Revolution" which brought tremendous increases in wheat and rice yields in Asia beginning in the 1960s. He is presently Senior Consultant, International Maize and Wheat Improvement Center (CIMMYT), and President of the Saskawa Africa Association (SAA). Dr. Borlaug and Dr. Christopher R. Dowswell, Director for Program Coordination of SAA, presented the keynote address at the 61st Annual Conference, International Fertilizer Industry Association (IFA), May 1993, in New Orleans. The authors observed (3):

"The only way for agriculture to produce sufficient food to keep pace with population and to alleviate the hunger of the world's poor is to increase the intensity of agricultural production in those ecological conditions which lend themselves to intensification while decreasing the intensity of production in the more fragile ecologies.

Most of the yield increase in food production needed over the next several generations must be achieved through yield increases on land now under cultivation. Moreover, these yield increases must be achieved through the application of technology already available or well advanced in the research pipeline. This will not only lead to economic development but it will also do much to solve the serious environmental problems that come as a consequence of trying to cultivate lands that are not suited for crop production. Fortunately, many of the more-favored agricultural lands currently under cultivation are still producing food at yield levels far below their potential."

Cassman (4) points out that world population is expected to double in the next 45 to 50 years. Also, there is little potential arable land to bring into production except for the acid-infertile grazing lands and rain forests of the tropics. Therefore, food production must be doubled in the next 50 years with much of the added production coming from the intensification of existing crop land to produce greater yields per unit of land area:

Cassman states, *"The greatest challenge, however, is to understand how soil fertility management affects soil quality, and to apply this knowledge to integrate all aspects of crop* *management to optimize yield and input utilization efficiency over the long term. Soil fertility management governs plant nutrition, which in turn influences susceptibility to disease, plant growth, and yield."*

Substantial progress has been made over the past several decades in improving our crop production systems as reflected in increased yields. Research has provided farmers with the necessary tools to keep pace with demand and to even improve per capita food availability (4, 14). For example, world food production doubled from 1963 to 1988 while population increased about 60 percent, from 3.2 to 5.1 billion (2). However, cereal grain production slowed during the 1980's and the actual per capita consumption was less in 1990 than in 1980.

Maximum Yield Research (MYR) in Perspective

Maximum yield research is the study of one or more variables and their interactions in a multidisciplinary system that strives for the highest yield possible for the soil and climate of the research site. It is an approach to research that attempts to take into account the overall production system. The purpose is to gather information spanning the entire yield curve under optimal production conditions so that input efficiencies may be better understood and production opportunities defined. This information is essential to create meaningful farm plans embracing best management practices (BMPs).

Maximum yield research benefits the environment through the development of more efficient and intensified cropping systems. The goal of such research is not just higher yields, but higher yields through improved input efficiencies and precision crop management. In this way inputs are not wasted through careless or inappropriate use, but they are utilized to their maximum. Maximized utilization by crops results in minimized amounts left in the environment following harvest. This is economically advantageous to farmers and environmentally desirable for us all. Potential benefits of MYR include improved plant nutrition, increased water use efficiency, increased nutrient use efficiency and higher soil organic matter content. Such benefits translate into ground water protection, erosion control and improved nutrient supplying power of the soil. Specific examples are given later in this paper under the section entitled "Environmental Benefits of BMP Systems".

Sustainable Agriculture

In recent years there has been much said and written about sustainable agriculture. Concerns over the environment have led to suggestions by some that agriculture is too dependent on chemical inputs. Low input sustainable agriculture (LISA) became the focus of many environmentalists. Frequently the arguments were based on emotion rather than scientific evidence. Sustainability and environmental issues continue to be of concern and rightly so. However, LISA has lost much of its following simply because a growing world population can not be fed on a diminishing food supply. Dr. Robert Fox, the eminent soil scientist from the University of Hawaii tells the old Turkish story about Nazri Din Hodjia, a famous teacher (13). In the story Nazri experiments with feeding a donkey less each day, expecting that ultimately the animal would not require any food at all. The experiment went very well in the initial few days, but unfortunately the donkey eventually died. Dr. Fox asks, *"Do we need to continually repeat the Nazri Din Hodjia donkey* experiment? We are dealing with matters far more important than donkeys." In the long run sustainability will be judged by performance, that is, what systems get the job done. This will undoubtedly mean more, not less, fertilizer and other inputs. The research focus will be on intensification of the farming system and increasing efficiency.

Sustainable innovations in crop management are a continuously evolving process. They are an integral part of conventional agriculture and contribute to greater yield potential. A few examples are (10): conservation tillage, crop rotations, soil and tissue testing/fertilizer application systems, computer records and applications (VRT, variable rate technology), variety/hybrid improvements, and integrated pest management.

Environmental Benefits of BMP Systems

If benefits or at least environmental safeguards are not part of a production system, then it is not a BMP system.

Organic Matter

Intensive crop production does not necessarily mean that soil organic matter levels are destined to dramatically decline. Soil and residue management are important factors in determining long-term soil organic matter trends and crop productivity.

The Morrow Plots at the University of Illinois, the oldest crop management experiment in the United States and Canada, continue to provide information on the long-term benefits of crop rotation and sound fertilizer management as part of a BMP system for maintaining productivity and profitability of crop production (Figure 1).

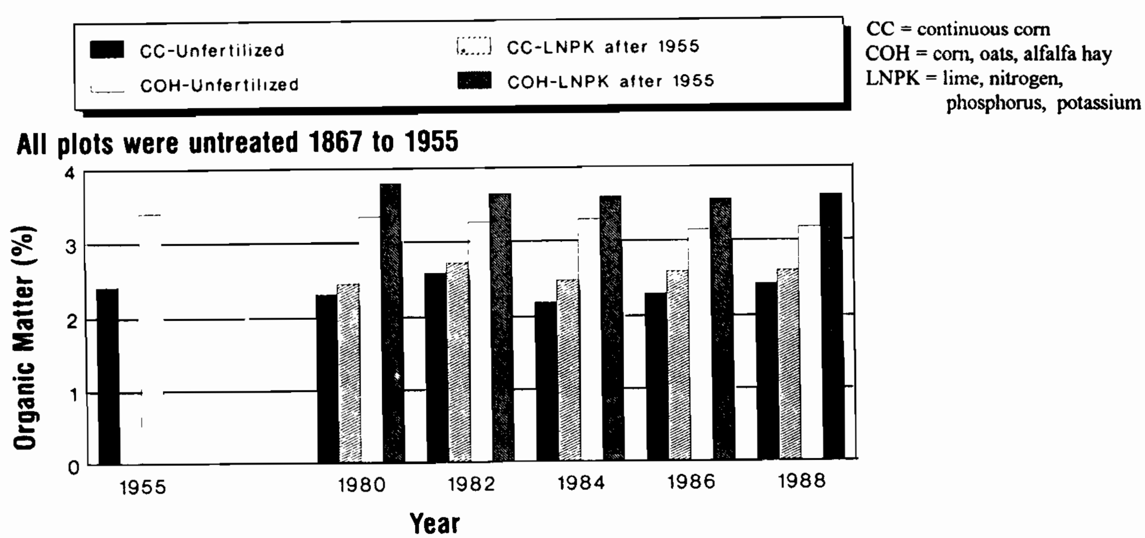


Figure 1. Organic matter content of various treatments in the Morrow Plots as affected by fertilizer since 1955 (11).

Reetz et al. (11) have summarized data over a 113 year period illustrating that improved fertilization and the resultant higher yields improve organic matter content and reverse its decline. They conclude:

- Without soil fertility treatments, crop production reduces soil productivity.
- Crop rotations without addition of fertilizers help maintain soil organic carbon and N levels, but do not maintain high productivity.
- Treatments of manure, lime, N, P, and K are necessary to maintain nutrient levels and soil productivity.
- When nutrients have been depleted, addition of adequate fertilizers can reverse the trend of soil organic matter depletion.
- A combination of crop rotation and fertilization supports the highest corn yields. Fertilizer addition does not completely offset the effect of crop rotation.
- Crop rotation plus fertilization produce the highest crop yields and maintain the highest soil N and organic matter levels.

Erosion Potential

The intensification of crop management systems can result in higher yields and improved protection of the soil when proper BMPs are used. Reducing tillage and maintaining a residue cover increased water storage and reduced erosion potential by 70 percent or more in studies by Peterson et al. (7) in the low rainfall area of the Central Great Plains. Yields and profits were increased with a more intensive management system which substantially increased surface crop residues.

Reduced tillage and cover crop systems are being developed in many areas, including the Cotton Belt. Research trials have shown that cotton can be grown in reduced and even no-till systems and produce equal or higher yields than in conventional (clean tilled) systems as illustrated in Table 1 (6). Systems are highly varied due to the diversity of soils, weather, pest problems, and farmers across the area and the need to be site specific.

Quicker plant establishment and canopy cover and more extensive rooting systems associated with higher yields are also credited with better soil erosion protection.

Dr. A. L. Black, USDA-ARS, Mandan, North Dakota , notes the relation of P nutrition with residue management (9): *"Long-term studies in North Dakota have shown beneficial effects of adequate available P from one-time high rate broadcast applications of P fertilizer to grain and residue yield. The key to soil resource conservation from the hazards of wind and water erosion is crop residue production and maintenance on the soil surface during fallow or idle periods between crops."*

Watershed studies involving tillage systems with natural rainfall were summarized by Fawcett (5). Mulch-till systems reduced soil erosion by 68 percent and no-till reduced it by 93 percent compared with moldboard plow systems. Pesticide movement off site was reduced by 70 percent using mulch-till and no-till comparing 38 treatment-site-years of data. Crop residue management continues to grow in popularity with US farmers. In 1992 mulch-till and no-till was practiced on 85.4 million acres or 30 percent of the annually planted farmland, a 24 percent increase over 1989.

Table 1. Cotton production with conventional versus conservation tillage systems.

Location	Years evaluated	Avg. lint yield
		lb/A
Louisiana-Sharkley clay		
Conventional	4	1,145
No-till (no cover crops)	4	1,195
Ridge-till (wheat cover)	4	1,190
Tennessee		
Conventional	10	894
No-till (no cover crops)	10	910
Conventional	12	847
No-till (wheat cover)	12	867
Texas High Plains		
Conventional	7	684
No-till (wheat cover)	7	732

Water use Efficiency (WUE)

Irrigation is an important tool in BMP systems in arid and semi-arid regions. An advantage over rain-fed systems is that yield goals may be selected with greater confidence because soil moisture is controlled rather than left to nature. Higher yielding crops utilize more total water such as in the following example from Arizona (Table 2). However, WUE is substantially increased. Water lost by evapotranspiration in this experiment was replaced for each treatment when available profile moisture reached 70 percent depletion (12).

Table 2. Higher wheat yields increase water use efficiency.

Fertilizer N	Grain yield	Water applied	Water use efficiency
lb/A	lb/A	inches	lb grain/inch water
0	3,410	23.41	146
75	5,800	26.78	217
150	7,210	29.24	247
225	7,640	30.80	248
300	7,080	31.41	225

Arizona

Nitrate Accumulation

Efficient uptake of nitrogen by crops has been an important consideration in fertilizer management for many years. It is important from both the standpoints of production economics and the environment. Maximizing nitrogen uptake by crops minimizes the opportunity of residual nitrate migrating into water sources where it could potentially be a hazard to humans or animals.

There are numerous (and widely published) management techniques available that promote greater N use efficiency, such as split or delayed applications, cover crops to take up residual N, nitrification inhibitors, etc. These should be part of a system of BMPs that integrates N management with other management aspects to lower unit cost of production to the point of highest net return for the existing soil and climatic conditions.

Many N practices have been proven over numerous years of research and farmer experience. Perhaps less appreciated are how other practices not directly related to N fertilizer itself can impact on its efficiency. Balanced fertilization which contributes to more yield than when N is applied alone is one example, as seen in Table 3 (8). Applying appropriate rates of NPK resulted in substantially more yield and no net nitrate addition to the soil profile; both N and P efficiencies were substantially improved. Where P or K was deficient, there was a net increase of residual N in the profile.

Table 3. Balancing nutrients benefits corn yield and nutrient efficiency.

Fertilizer rate			Grain yield	Efficiency		Unused N[1]
N	P_2O_5	K_2O		P_2O_5	N	
	lb/A		lb/A	lb grain/lb nutrient		lb/A
0	60	90	2,300	38	--	--
180	60	0	5,380	90	30	+55
180	0	90	6,220	--	34	+36
180	60	90	8,010	133	44	-6

Illinois

[1]Unused N is the amount of applied N not accounted for in the above ground portion of the crop, based on N uptake of 2.3 lb/cwt of grain.

Dr. Ardell Halvorson, USDA-ARS, Akron, Colorado, confirms the importance of nutrient balance (9): *"Adequate levels of soil P and /or K are needed to optimize the use of available N supplies by both dryland and irrigated crops. Therefore, maintaining adequate levels of available P or K will improve N use-efficiency by the growing crop and reduce the potential of NO_3-N loss by leaching, assuming good irrigation and N fertilization management practices are used."*

Nitrogen efficiency is also affected by management decisions or inputs not directly involving fertilizer materials. Variety selection, plant population, planting date, irrigation timing, pest control, and others have an important impact. In fact, anything that affects ultimate yield will affect N use efficiency. Response to N fertilization was more than doubled in a California study (Table 4) when the plant population was increased to 26,000 plants per acre or more (1). It can be assumed that the additional yield removed more N, thereby leaving less in the environment following harvest. Unfortunately, residual N was not evaluated in this study.

Table 4. Plant population, a "low cost" input, influences irrigated corn yield and fertilizer use efficiency.

Fertilizer N	Population, plants/ha		
	18,000	26,000	34,000
lb/A		Grain yield, lb/A	
0	9,370	9,340	10,170
200	11,520	14,040	15,190
Response	2,150	4,700	5,020

Sacramento Valley, California

A problem with at least some past soil fertility research is lack of detailed observations of all important parameters affecting crop yield and the environment. Many trials involved gathering yield data and little else. The attitude among policy makers in the US during the 1960's, 70's and early 80's was that food production was ample (even excessive) and therefore, research dollars should be spent elsewhere. The result was a lack of resources to thoroughly evaluate evolving production systems. Fortunately, the recent emphasis on MYR and on developing BMPs is resulting in much more in-depth studies of the entire production system, including long-range implications relative to environment and production sustainability.

The data in Table 4 also indicates that not all MYR innovations are exclusively for the wealthy, developed farmer. Many inputs add little or nothing to the cost of production. Timeliness of operations such as planting date, irrigation frequency, and scheduling of various field operations are "no cost inputs". Others, such as improved variety, splitting N applications, and increased plant population are "low cost" inputs in that they contribute little additional cost over the present system. These and other practices can be utilized by farmers of any economic or technological level to increase yield and production efficiency.

Summary

Why manage soil and water resources for maximum production efficiency? To feed a growing world population and to protect the more fragile ecologies.

Literature Cited

(1) Arjal, R.. D., J. D. Prato and M. L. Peterson. 1978. Response of corn to fertilizer, plant population, and planting date. Calif. Agriculture 32 (3):14-15.

(2) Borlaug, N. E. 1990. The challenge of feeding 8 billion people. Farm Chemicals International. Summer, 1990.

(3) Borlaug, N. E. and C. R. Dowswell. 1993. Fertilizer: To nourish infertile soil that feeds a fertile population that crowds a fragile world. Better Crops with Plant Food 77 (3):6-7.

(4) Cassman, K. G. 1990. The role of soil fertility research in developing sustainable food production systems. Better Crops with Plant Food 74 (4):16-19.

(5) Conservation Technology Information Center (CTIC). Undated. Crop residue management...Gaining ground in the '90s. Pamphlet. Conservation Technology Information Center, West Lafayette, IN.

(6) Cotton Physiology Today. 1993. Conservation Tillage. Newsletter. Vol. 4, No. 9 (October). National Cotton Council, Memphis, TN.

(7) Peterson, G. A., D. G. Westfall, and A. D. Halvorson. 1992. Economics of dryland crop rotations for efficient water and nitrogen use. In (J. L. Havlin, ed.) Proceedings Great Plains Soil Fertility Conference 4:47-53. March 3-4. Dept. of Agronomy, Kansas State Univ., Manhattan.

(8) Potash & Phosphate Institute (PPI). Undated a. Fertilizer management for today's tillage systems. Booklet. Potash & Phosphate Institute, Norcross, GA.

(9) Potash & Phosphate Institute (PPI), Undated b. Nitrogen management and the environment. Pamphlet (Reference #93009), Potash & Phosphate Institute, Norcross, GA.

(10) Potash & Phosphate Institute (PPI). 1990. Sustainable innovations -- A part of, not apart from conventional agriculture. Better Crops with Plant Food 74 (2):6-11.

(11) Reetz Jr., H. F., T. R. Peck, and M. G. Oldham. 1990. Long-term evidence for sound fertility management. Better Crops with Plant Food 74 (1): 18-20.

(12) Thompson, R. K., E. B. Jackson, and J. R. Gebert. 1976. Irrigated wheat production response to water and nitrogen fertilizer. Tech. Bull. 229. The Univ. of Arizona, Tucson.

(13) von Uexkull, H. R. 1992. Sustainable agriculture for China. p. 1-13. In Proceedings of the Third International Symposium on Maximum Yield Research, Sept. 6-8, 1992, Beijing, PRC. China Agricultural Scientech Press, Beijing.

(14) York, E. T. 1989. Research for a sustainable agriculture. Better Crops with Plant Food 73(3):8-11.

An Integrated Approach To Pesticide Regulation

James W. Wells, Director
Department of Pesticide Regulation
California Environmental Protection Agency

Introduction

After World War II, many new chemicals found their way into agriculture. The new products helped prompt the so-called "Green Revolution." Chemicals were substituted for higher-priced, labor-intensive weed and insect control methods and practices to reduce pest populations. This immediately reduced labor needs, provided more effective control, and increased yields as modern farming practices and cropping patterns evolved around chemical use.

However, the 1960's forever changed the way society viewed pesticides. Although some problems had been apparent for some time--most notably, concerns about possible chronic health effects and the increasing resistance of some pests to the new products--the seminal event was the publication in 1963 of *Silent Spring.* Its author, Rachel Carson, presented compelling arguments that pesticides, such as DDT, and other chemicals were being used excessively, with little regard for their impact on either human health or the environment. In the last three decades, it has become increasingly clear that the benefits of pesticides--like the benefits of everything else in life--have associated costs. Concerns have escalated about their impact on human health and the environment.

The Department of Pesticide Regulation (DPR) has a commitment to protect the environment and public health, while providing the tools agriculture requires as it moves toward reduced-risk pest control strategies. This mission is becoming more critical as regulatory action and market forces take away the chemical tools that made the Green Revolution possible and that farmers have come to rely on to produce their crops. Working with industry and public interest groups, our goal is to help accomplish this transition in the least disruptive manner possible such that we maximize environmental benefits and keep farming economically viable. It is not simply a matter of telling farmers that they must use less pesticides. We know that pest management takes place within an ecosystem. We realize that we must understand the net effect of removing a pesticide from the system. Substituting one chemical for another may only shift the problem from one area of concern to another. For example, the substitution may cause increased pest resistance, or harm to beneficial organisms, or result in more use of another compound with increased risk to human health or the environment. It is time for impacts from pesticide use to be integrated into considerations of the whole ecosystem.

We are also developing and implementing several initiatives with other government agencies so that we can accomplish mutual goals in a coordinated manner. When implemented, they will minimize inconsistent state policies, with respect to pesticides, between agencies. Some of these initiatives include coordination between DPR and the State Water Resources Control Board (SWRCB) and its associated regional boards on overlapping water quality issues, and a Departmental pest management strategy in which pesticides will be regulated in the context of the overall ecology of crop production, pest management, and pesticide use.

Integrating Pesticide Regulation at the Government Level

Since DPR's ground water program has been in place for some time and the number of active ingredients being detected (and verified) due to legal, agricultural use for the first time is small, attention is turning to nonpoint sources of pesticides in other media, such as surface water. Surface water issues will change the way farmers and regulators do business. If we look at any river or stream in California, we will probably find traces of chemicals that are used in that watershed, and often at levels that may impact fish or wildlife.

Currently, DPR's surface water program is limited to individual problems and implemented as resources allow. For example, beginning in 1984 DPR set up the rice herbicide project to reduce and control the discharges of pesticides from rice fields. Through a combination of voluntary management practices implemented by growers, and mandatory permit conditions enforced by the County Agricultural Commissioners, these measures have met with great success. Rice herbicide levels have been reduced 99.5 percent over the last nine years, making the reduction in pesticides in the Sacramento River one of the outstanding examples of pollution reduction in the country.

However, it is time to move beyond specific problems and overlapping government regulation. Since the advent of the California Environmental Protection Agency (Cal/EPA), pesticides and water quality issues reside in one umbrella agency even though they are derived from separate federal and state laws. This presents an excellent opportunity for coordination of regulating activities. DPR and the SWRCB and its associated regional boards signed a Memorandum of Understanding (MOU) two years ago to develop a comprehensive, integrated statewide water quality management program. When implemented, this MOU will eliminate inconsistent state policies between these two organizations. The implementation mechanism is called a "management agency agreement," or MAA. Implementation of both the ground and surface water programs will then be accomplished through this MAA, currently being developed by the Department and the SWRCB. The purpose of the MAA is to: (1) protect ground and surface water quality and beneficial uses while recognizing the need for pest control, and (2) use the authorities of DPR and the Water Board in a coordinated manner. Under the

MAA, ground and surface water detections will trigger more rapid response to, and resolution of, identified water quality problems by both agencies.

Let me give another example of a pesticide program which is a component of a larger state plan. New attention is being placed on reducing pesticide use because volatile organic compounds in pesticide formulations can promote air pollution. We are working closely with Cal/EPA's Air Resources Board (ARB) and with industry to develop a state plan that allows consideration of local conditions and will avoid unnecessarily severe federal regulations. The federal Clean Air Act Amendments of 1990 require states to develop State Implementation Plans (SIPs) for attaining and maintaining air quality standards for air pollutants such as ozone. In cooperation with local air districts, the ARB periodically publishes an emission inventory of all sources of air pollutants in each air basin and each county within that basin. Pesticide application has been identified as a source of VOCs in many California air basins. VOCs are precursors to tropospheric ozone formation which is harmful to both human health and vegetation. DPR has drafted a plan designed to reduce VOC emissions from agricultural and commercial structural pesticide applications. The draft plan includes developing VOC content data for each formulated pesticide, establishing target VOC reduction levels and dates, and identifying voluntary and mandatory measures to reduce VOCs. It is expected that most of the reductions will occur as a result of ongoing activities such as continued adoption of integrated pest management (IPM) programs, pesticide users switching to low VOC formulations, and registration of new products designed to be used at very low rates. If ongoing activities and voluntary measures do not meet the interim reduction goals, mandatory measures will be adopted. Mandatory measures would focus on pesticides with greater than average VOC emissions and possible VOC content. ARB staff have been working closely with local districts to ensure they understand DPR's proposal and claim the appropriate emission reductions in their plans.

DPR's pesticide control plan will be transmitted to U.S. EPA by the ARB as part of its 1994 SIP submittal. The final DPR regulations will be adopted and submitted within one year. This makes the pesticide control measure eligible for conditional approval under the federal Clean Air Act and U.S. EPA guidance. If U.S. EPA acts quickly and grants conditional approval, DPR's measure could replace the proposed Federal Implementation Plan rule immediately.

Integrating Pesticide Regulation at the Ecosystem Level

In the past, the emphasis in regulating pesticides has been on assuring that each pesticide can be used safely and that the requirements for safe use are strictly enforced. It has been a "chemical-by-chemical" approach. Pest management considerations must become part of the day-to-day processes and activities at DPR. They must be incorporated, for example, into the review and decision-making process for the registration of new chemicals.

In the future, we want to regulate pesticides in the context of the overall ecology of crop production, pest management, and pesticide use. To meet this future, we have been working on a Departmental strategic plan to enhance the regulation of pesticides in California. We want to use all of the wide range of our regulatory authority along with developing a series of private-public partnerships to expand mutual resources. These partnerships will allow us to work with industry to develop lower-impact pest management strategies that reduce the overall risk from the use of pesticides. Without compromising the vitality of California's agricultural economy this strategy is expected to reduce the reliance on and amount of pesticides used in the state.

It is our responsibility to assure that pesticides are distributed and used safely. In this context, safe means that there are no significant risks to the public, workers, or the environment. Of course, whether significant risks are present is a matter of science and judgment, and whether risks are acceptable will depend on who is making the judgment. For that reason, DPR believes that even though it judges the current risks to be acceptable, a continuous effort to minimize risk is still appropriate. That is why DPR has greatly expanded its commitment to helping the continuing movement of less chemically dependent agriculture into the farming mainstream.

The role of government should be to facilitate the ongoing revolution by farmers to use more environmentally benign tools. DPR is making regulatory changes, removing unnecessary bureaucratic obstacles to the registration of safer pest management products, and encouraging the use of reduced-risk practices to control pests in agriculture, schools, homes, and businesses. As a way to disseminate information on, and encourage use of, less chemical intensive methods of pest control, DPR has initiated a program to recognize California growers who are developing and using innovative ways of managing pests that reduce risks that may be associated with the use of traditional chemical pesticides. We call this program IPM Innovators. We have identified groups of growers who have found ways to work with trade associations, commodity groups, private organizations, and others to help develop and promote the use of these "pest management systems." Most of these groups are voluntary; they are not initiated by DPR or other government agencies. DPR wants to recognize as IPM Innovators groups that are providing this kind of leadership in carrying out economically sound reduced risk pest management systems, and to encourage others to carry out the systems and to form similar groups. DPR recently presented its first "IPM Innovator" awards to acknowledge the leadership and creativity of California farmers who have joined together to find new environmentally friendly ways to fight insects, weeds, and other pests. When the project is thoroughly developed, DPR will assist IPM Innovators to locate and apply for sources of funding, both private and public. DPR scientific staff may assist groups to find needed technical assistance in pest management, or to develop the kind of documentation necessary to define the system and promote it to others.

Conclusion

The reality is that changes are inevitable and potentially expensive, not only to California agriculture, but to our entire economy. New laws and regulations will come, a reflection of societal changes. The challenge is to identify the real risks, and then to work together to minimize them. Public and private interests must pool their resources to find solutions. At the same time, we must be willing to recognize and pursue great opportunities. Government can and should provide the forum we need for coordination and decision-making, in which reasonable interested and involved parties can craft strategies to accomplish mutual goals.

COMPLIANCE PLUS

Roger A. Yeary
Vice President
Health, Safety & Environment
ServiceMaster Consumer Services

ServiceMaster Consumer Services is the parent company of the two largest urban providers of pest management and lawn care services in the United States, Terminix International and TruGreen♦ChemLawn, having combined revenues of almost one billion dollars.

TruGreen♦ChemLawn provides lawn care and ornamental tree and shrub care service from approximately 190 company-owned locations in 39 states. We provide services to approximately 1,500,000 customers. Thus, we deal with divergent environmental concerns which are often converted to political activism and a complex patchwork of regulatory compliance. We vigorously promote preemption of local ordinances that regulate our business. Though it is unrealistic to have federal preemption, we have seen great progress in the last several years in initiatives for state level preemption.

Because The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) regulates the interstate commerce of pesticide products, the U. S. Environmental Protection Agency (EPA) dominates the regulation of pesticide products. However, states and, in some instances, municipalities, enact regulations that affect pesticide use via business licenses, recordkeeping requirements, building codes, and certification and licensing of employees, and collect fees from the industry to operate those regulatory programs.

The ServiceMaster Environmental Stewardship Principles state that we will strive for "compliance plus." That is, we will seek to exceed the standards of all applicable federal, state, and local regulations. Compliance plus is tough, especially in an era of political correctness, where traditional expressions in communications with customers and the public are challenged as false or misleading advertising and a whole new paradigm of risk communications has emerged.

The following regulatory issues are of immediate concern to us as they affect our operations by continuously increasing direct costs or reducing productivity:

Pesticide Storage

- fire codes
- community right-to-know; 40 CFR, part 370
- containment; 40 CFR, part 165

Pesticide Container Disposal; 40 CFR, part 156

- superfund paranoia
- rinse standards

Fill Systems; 40 CFR, part 165

Pesticide Labelling

- worker protection; 40 CFR, part 170
- eye protection
- mixing & loading vs. application
- irrigation requirements
- reentry intervals

Posting and Notification; EPA Memo August 23, 1994

Post-Application Exposures to Pesticides

- EPA Non-Occupational Pesticide Exposure Study

Advertising Guidelines; EPA Memo June 8, 1993

Risk Communication

Compliance plus is taking voluntary initiatives to improve worker safety and protect the environment because they seem to be the "right thing to do."

For example, we began installing systems for containment of recycling water to wash pesticide service vehicles in 1975. The same year, we began monitoring pesticide applicators for exposure to organophosphates by measuring cholinesterase. As of this date, this is not a regulatory requirement for the lawn care industry at any governmental level. However, one state—not California—has established an incident reporting system for pesticide illness and, with virtually no experience, has challenged our interpretation of the data. And the State of California has given us the run around for licensing our laboratory in California. Thus, operating in interstate commerce under federal licensing and inspection has not reduced duplication of state licensing and, of course, state fees. However, the EPA has visited our laboratory to learn from our experience, which has been published (J. Toxicol. Environ. Health 39:11-25, 1993).

The EPA is continuously challenged and criticized by activist groups such as The Environmental Defense Fund (EDF), The National Coalition Against the Misuse of Pesticides (NCAMP), National Resources Defense Council (NRDC), Greenpeace and others. Often, this takes the form of litigation against the Agency with the courts judging scientific issues.
The EPA NOPES study found residues of pesticides in homes where there was no known history of pesticide use in the home. The National Academy of Science report on "Pesticide Residues in the Diets of Infants and Children" elevated concerns about pesticide exposures to infants in the

home environment. Subsequently, the Agency sponsored two workshops on assessment of post-application exposure to pesticide in urban environments and the Agency indicated it would seek a data call-in. We have conducted and published studies on pesticide applicator and residential exposure of pesticides and are working with the Agency and an industry task force to benefit from our experience and to promote good science and practices in collection of the data.

The outcomes become important for the issue of reentry onto treated sites and the communication of risk. As participants in the workshop, we had an opportunity to review data from research sponsored by the Agency and found the lack of knowledge of pesticide procedures, including drift, resulted in a gross overestimate of dislodgeable residues and track-in of pesticides onto indoor carpeting.

As a pesticide user, we have to deal with the practical realities in the use of personal protective equipment by our pesticide applicators. Neither the EPA Registration Division nor the persons writing pesticide labels for manufacturers seem to be aware of the impracticality and, consequently, poor worker compliance for what seem to be logical instructions for protective equipment. We have particularly quarreled with the Agency over a requirement to wear chemical goggles when spraying diluted aqueous mixtures of pesticides where both common sense and animal test data indicate that dilution virtually eliminates the eye irritation of the formulated product. Unsupervised workers in hot, humid climates and, who with their own experience have an absence of irritation, will not comply with such directions. We have obtained our own test data and have lobbied the Agency to change label directions to specify "eye protection" allowing the option of safety glasses, goggles or a face shield and after almost a decade, have made progress.

Integrated Pest Management (IPM) is a politically correct term to which has been attached arbitrary goals on the reduction of pesticide use. Most activist groups and the EPA embrace IPM as a synonym for reduced pesticide use. In fact, the EPA has a Pesticide Use/Risk Reduction initiative which will set goals for percent of acres under IPM. However, to date, there has been a very fuzzy linkage of risk to pesticide use. In preambles to such initiatives, the Agency uses pesticide incident data, such as "300,000 poisoned farmworkers each year," which is based on use of multiple imprecise fudge factors and a meager data base. We participate in this public policy-making process and often agree with the Agency,but do not hesitate to challenge either "poor use of data" or "use of poor data." Because, if cited often enough, the myths become facts.

The two newest issues that have been laid at the feet of the EPA are 1) allegations of increased risk of breast cancer from environmental organochlorines, including a demand from Greenpeace that all uses of chlorine be discontinued and 2) multiple chemical sensitivity — an alleged disease of "victims" of pesticides. Banishing chlorine chemistry is unbelievably naive. The link to breast cancer and "future generations" is a strong political force. Multiple chemical sensitivity also has more emotional appeal than science, but has impacted urban pesticide use by posting and notification regulations.

To quote Lee Iacoca in today's regulatory climate we either "lead, follow, or get out of the way."

REDUCED HERBICIDE USAGE IN PERENNIAL CROPS, ROW CROPS, FALLOW LAND AND NON-AGRICULTURAL APPLICATIONS USING OPTOELECTRONIC DETECTION.

ABSTRACT

Regulation of the use of herbicide materials is an ever increasing problem for farmers. Every year a longer list of material types are banned from use. One result of public pressure and regulation has been increased cost of herbicide materials. In most crops today the cost of herbicide and its application is a major component in the cost of production.

Selectively spraying agricultural chemicals in a way that causes them to contact only foliage, sometimes referred to as "spot spraying" or "intermittent spraying", has been limited in the past to a person visually observing the plant to be treated and then manually directing a spraying device. Devices which attempt to automatically sense plants, either mechanically or through the use of electrical conductivity, sonar, light or infrared radiation have <u>not</u> been widely accepted. Previous attempts, without exception, have had serious performance or cost/performance disadvantages.

It is well known from the literature that growing plant tissue has a very unique spectral reflectance in the upper visible wavelengths and in the near infrared. Earlier inventors attempted to use reflected sunlight, passing through optical filters to separate various wavelengths in an attempt to distinguish between these objects. Shadows plus the sun's variable intensity and spectral distribution render a device using sunlight inconsistent at best.

Recently equipment has been developed which uses a unique and novel approach to this problem which allows the device to work equally well in bright sunlight, in shadows or in the middle of the night. The ***WeedSeeker***™ generates its own light from solid state light emitters which are modulated to isolate them from the sunlight. This design approach has eliminated all of the problems associated with earlier attempts to accurately detect the presence of small amounts of plant tissue using spectral reflectance.

Future ***WeedSeeker***™ products will differentiate between plant species based upon their unique spectral reflectance characteristics. This will make it possible for "selective sprayers" to identify certain crops and non-crop plants and treat them individually with applications of herbicides and other pesticides or nutrients.

Equipment for chemical free weed control in row crops is possible which will employ an optical sensing technique to determine the exact location of the foliage in the field of view. When weeds are detected the computer instructs a mechanical hoe to remove them leaving the crop plants undisturbed. In addition to the mechanical removal of weeds, considerable interest exists in integrating the ***WeedSeeker***™ sensing technology with currently available flame cultivation equipment.

We should expect to see significant advances in this area of technology development over the next several years. These advances will ultimately lead to dramatic reductions in the amount of agricultural chemicals used in the United States and around the world.

PATCHEN CALIFORNIA, INC.
22217 OLD SANTA CRUZ HWY
LOS GATOS, CA 95030
ph 408-353-1615 -- fax 408-353-1222

BACKGROUND

Regulation of the use of herbicide materials is an ever increasing problem for farmers. Every year a longer list of material types are banned from use. The materials which are still available are facing limitations in the ways they can be used and regulation enforcement is increasing, as are the penalties imposed upon violators.

Selectively spraying agricultural chemicals in a way that causes them to contact only foliage and not the bare ground or open air is not a new idea. Successful "selective application" of chemical materials, sometimes referred to as "spot spraying" or "intermittent spraying", has been limited in the past to a person visually observing the plant to be treated and then manually directing a spraying device. Devices which attempt to automatically sense plants, either mechanically or through the use of electrical conductivity, sonar, light or infrared radiation have not been widely accepted. Previous attempts, without exception, have had serious performance or cost/performance disadvantages. Some examples include a weed sprayer which uses a light beam to detect weeds which are taller than the crop plants. The limited usefulness of this approach is obvious. Other examples include orchard sprayers which use sonar to detect the presence of trees and attempt to avoid spraying spaces between trees. Mixed results have been reported with the sonar device, indicating that maintenance and cost effectiveness are issues left to be improved upon.

There has been for generations, a strong interest in using reflected optical images to control agricultural equipment. In fact, there exists considerable prior art in this country, in Great Britain and in the USSR dating back as far as 1947. Few of these innovations have ever been reduced to practice because the technology required was not practical until very recently.

At least one herbicide application device has become available which relies upon the unique spectral reflectance of living plant tissue to detect the presence of weeds. It uses optical filters and silicon photodetectors to separate two critical wavelengths, then compares the signals representing these wavelengths using electronic circuitry. The usefulness of this device is limited by the decision of the inventor to use naturally occurring ambient light as the radiation source. Relying upon sunlight presents the difficulty that the sun's spectral distribution changes dramatically as the sun sweeps across the sky. Spectral variations as well as intensity variations are relatively unnoticeable to human eyes but have dramatic implications to analytical radiometric sensing devices. This sunlight based equipment is able to compensate somewhat for large shadows by directing a second photodetector pair to the sky as a differential reference. Additionally, the unpredictable effects of changing sun angle and cloud cover can be compensated for by continual operator adjustments. However, the lack of tolerance for localized shadows combined with a somewhat large (8" X 24") field of view and high detection threshold, make this equipment totally ineffective in perennial crops or under the canopy of row crops.

MODERN OPTOELECTRONIC TECHNOLOGY

It is well known from the literature that growing plant tissue has a very unique spectral reflectance in the upper visible wavelengths and in the near infrared. Figure 1 shows reflectance comparisons between typical growing plant tissue, dead leaves, mineral soil and a certain parasitic weed. Earlier inventors attempted to use reflected sunlight, passing through optical filters to separate various wavelengths in an attempt to distinguish between these objects. Obviously the sun constantly varies in intensity and spectral distribution as it sweeps across the sky. In addition, shadows from trees, buildings or in fact the spray vehicle itself tend to render a device using sunlight inconsistent at best.

Recently equipment has been developed which uses a unique and novel approach to this problem which allows the device to work equally well in bright sunlight, in shadows or in the middle of the night. The ***WeedSeeker*™** generates its own light from solid state light emitters which are modulated to isolate them from the sunlight. In other words, the internally generated light is "coded" and the detector can only "see" reflected light that has the proper modulation "code".

High power and precise wavelength (color) Gallium Arsenide Phosphide and Gallium Aluminium Arsenide light emitters, are focused precisely on small spots on the ground. They are powered by an internal power source and modulated under control of a microcomputer which is also contained within the module. Phase shift and frequency modulation techniques have pronounced advantages for this application since virtually all potentially interfering noise sources are predominantly amplitude varying. The sun has no coherent phase or frequency noise which could interfere. Optical and infrared energy is selectively reflected back to the module depending upon the presence of undesirable foliage in the field of view.

Very sensitive Silicon photodetectors are mounted in the module; precisely aligned behind an optical system to efficiently capture the light energy. These detectors convert the photo energy into low level analog electrical signals which contain the color signature of the objects in the field of view. The low level analog signals are processed by way of patented circuit and system innovations and converted to digital signals which are recognized by the computer.

Each module contains its own microcomputer which takes into account the color signature of the objects in the field of view along with information about the background lighting and the speed of the tractor. Software stored in an Erasable Programmable Read Only Memory (EPROM) allows the computer to make a decision about the disposition of an object in the field of view and command the sprayer heads to take the appropriate action. When the computer decides that a weed is present, one or more of the selectively controlled spray heads emits a short burst of herbicide directly onto the foliage and specifically avoids spraying the surrounding area.

This design approach has eliminated all of the problems associated with earlier attempts to accurately detect the presence of small amounts of plant tissue using spectral reflectance. The ***WeedSeeker*™** products are totally insensitive to sunlight and shadows. Since the system "sees" only light which is generated inside the system itself, it works as well in total darkness as it does in the direct sunlight.

It was not possible until recent years to bring the various elements described above together in a cost effective way. The Gallium Aluminum Arsenide epitaxy has recently been pioneered for traffic lights and automobile tail lights; the valves used in the spray heads have been recently developed for ink jet printers; lower cost microcomputers and memory make it possible to integrate these things at affordable costs.

APPLICATION CONSIDERATIONS

It is tempting to establish a certain percentage of weed cover in any given situation and relate that to the amount of spray which could be saved using certain "selective spraying" technologies. What becomes immediately apparent is that the relationship cannot be quantified without considering related parameters including:

Individual weed size ("w" measured in inches)
- w_1 weed length in the direction of travel
- w_2 weed width perpendicular the direction of travel

Detector Field of View ("FOV" measured in inches)
- d_1 in the direction of travel
- d_2 perpendicular the direction of travel

Spray pattern ("s" measured in inches)
- s_1 in the direction of travel
- s_2 perpendicular the direction of travel

Detection threshold (D_{th} measured in %)
- minimum detectable area of FOV occupied by weeds

Weed cover (W measured in %)
- proportion of given field covered by weeds

Spray ratio (S measured in %)
- ratio of area sprayed to total area

Figure 2 shows a simple computer spread sheet model of a section of field with weeds. Virtually every dimensional parameter can be varied to simulate any given weed problem. The user is able to sketch a particular weed pattern on the screen and observe the effect on spray material saving with three simultaneous spray patterns. It is possible to alter critical parameters such as nozzle size and detect threshold and interactively compare various selective spraying approaches.

Figure 3 shows a series of results derived from the spread sheet of Figure 2. It is made up of a family of curves showing the relationship between weed cover (W) and spray ratio (S). It assumes that all weeds are rectangular and measure two inches on each side. It is strictly theoretical and conservative to the extent that it assumes that weeds are randomly scattered. Clearly, as the size of the spray pattern of each nozzle of a selective spray system decreases with respect to the weed size, the potential for saving increases. When the spray pattern is much smaller than the nominal weed size, the total area sprayed will approximate the actual weed cover. At the other extreme, where the spray pattern is much larger than individual weeds, more material is wasted than actually comes in contact with the weeds. There is a task appropriate field of view, spray pattern and detection threshold for every application and it is quite common that the correct one for a given weed/crop situation is not cost effective in another.

The detection threshold (D_{th}) is a variable of considerable importance. It sets the limit to which the system is able to discriminate between plant tissue and background. There are system limits imposed which relate to the noise floor, bandwidth and distortion properties of the optical and electronic systems. Given that these are held constant, the detection threshold (D_{th}) is a function of two primary ratios. The first is the relative difference in reflectance at the two reflected wavelengths and the other is the ratio of weed area to non-weed area in the field of view. The first is optimized by choosing the optimum wavelengths of energy to be reflected. This is done by choosing one wavelength at the peak of the chlorophyll absorption band and the other at a convenient place in the near infrared (NIR) where reflectance is relatively higher. The area ratio issue is addressed with an optical system design which has two primary goals. The first is a fixed field of view width (d_2) irrespective of the distance from detector to object. The other is a very small and fixed field of view length (d_1). As field of view length (d_1) approaches zero the area ratio $w_1 \times w_2 : d_1 \times d_2$ ceases to be a square law function and approaches the linear $w_2 : d_2$. This allows much smaller weeds to be detected than might otherwise be possible. This choice of course requires that the system bandwidth be proportionally higher as d_1 is restricted since information must be processed faster.

The current state of this technology is to make possible the detection of 1/8" diameter weeds using a field of view of 2" X 3/16". Widening the 2" dimension tends to degrade the detectable weed width proportionally in linear fashion. It is not affected in relation to weed area because the field of view is constrained in one axis as described earlier. The ***WeedSeeker***™ family of selective sprayers are each equipped with a sensitivity control which allows the operator to program the system to ignore weeds under a certain size.

With the above considerations taken into account, Figure 3 allows the observer to compare weed sizes (w) to spray pattern sizes (s) and predict a certain saving potential. The two inch rectangular weeds in this example can of course be replaced with weeds of any size and shape. Experience indicates that weed formations generally tend to not be random but rather are found in patches, being influenced by wind, rain, seed availability, etc.. This reality would tend to make the potential for savings greater than that indicated by Figure 3.

AVAILABLE PRODUCTS

The current ***WeedSeeker***™ products focus on minimizing or eliminating preemergence herbicide materials. Preemergence chemicals are more expensive and are often looked upon as being hazardous to the environment because of their persistence of activity in the soil.

<u>The PhD1620 NARROW STRIP SPRAYER</u> is directed primarily toward weed control in vineyards and certain orchard applications. Using the ***WeedSeeker***™, the winter pre-emergence treatment is done with a fraction of the herbicide used in the current method or eliminated entirely. The ***WeedSeeker***™ selective and precisely targeted application of herbicide is much more effective later in the growing season.

Unlike traditional farm practice, with this equipment, it is not necessary for the operator to physically view the area being sprayed, therefore allowing 24 hour operation. Spraying herbicide at night has some significant advantages. Cooler night temperatures allow longer and more efficient working hours at critical times during the season. The absence of sun prolongs effectivity of the herbicide material. The higher relative humidity at night aids foliage wetting and the absence of wind after sunset eliminates over-spray. All of these things result in greatly enhanced efficiency in the use of the herbicide material.

<u>The PhD600 VARIABLE STRIP WIDTH SPRAYER</u> addresses the use of chemical herbicide in orchards and groves where wider strips are common and trunk-to-trunk weed control has become popular in recent years. It is especially useful along freeways, railroad rights-of-way, etc., in addition to row crops and fallow land.

The principle of operation is basically the same as used in the original ***WeedSeeker***™ model PhD1620. The optical system, the fluid handling, and the heart of the electronic system are unchanged. The differences lie in the dimensional resolution of the viewing area and spray patterns, and the mechanical system configuration. These configuration differences allow more flexibility of use and offer a lower overall system cost. Various product offerings with corresponding spray patterns are shown in Figure 4.

FUTURE PRODUCTS USING OPTOELECTRONIC TECHNOLOGY

Generically Specific Sprayers

Future ***WeedSeeker***™ products will differentiate between plant species based upon their unique spectral reflectance characteristics. This will make it possible for "selective sprayers" to identify certain crops and non-crop plants and treat them individually with applications of herbicides and other pesticides or nutrients. Examples include discriminating between rice seedlings and watergrass or between dodder and safflower, alfalfa, or tomatoes.

Vehicle/Implement Guidance

Automatically guiding a vehicle or implement accurately through the field requires that the location of the row of crop plants be precisely sensed. Equipment using mechanical means, ultrasonic sonar and infrared detectors have been tried with little or no success.

The computer within the ***WeedSeeker***™ with the aid of software composed for this purpose, compares the current data being gathered from the detectors to data stored in memory. Knowing which plants are the crops and which are weeds, allows the computer to plot a line which represents the centerline of the crop row.

Selective Orchard Sprayers

In recent years, orchard sprayers have been developed which employ sonar as a means of detecting the proximity of trees. When a tree is sensed to be in close proximity of the sprayer, the sprayer is energized. These sprayers are expensive and they demonstrate the fundamental limitations of the sonar technology. They are not able to discriminate between trees, buildings, power poles and people, leading to the distinct possibility of spraying non-tree objects, including workers.

An orchard sprayer equipped with ***WeedSeeker***™ technology will not spray non-tree objects, including people. This approach constitutes a significant advance in the precision with which it is possible to apply pesticides in orchards, groves and ornamentals. The Patchen system has the additional advantage that the technology is far less costly than the sonar system making it cost effective in even small to medium sized orchards.

Chemical Free Weed Control

Equipment for chemical free weed control in row crops is possible which will employ an optical sensing technique to determine the exact location of the foliage in the field of view. When weeds are detected the computer instructs a mechanical hoe to remove them leaving the crop plants undisturbed. This equipment eliminates costly hand labor and uses no chemical herbicide. In addition to the mechanical removal of weeds, considerable interest exists in integrating the ***WeedSeeker***™ sensing technology with currently available flame cultivation equipment.

SUMMARY

A new technology has been described which addresses a need which has existed since the advent of agricultural chemicals. It brings elements of modern optoelectronic technology to bear on one or the most important problems facing agriculture today; how to maintain profitability in the face of ever increasing costs and government regulation.

We should expect to see significant advances in this area of technology development over the next several years. These advances will ultimately lead to dramatic reductions in the amount of agricultural chemicals used in the United States and around the world.

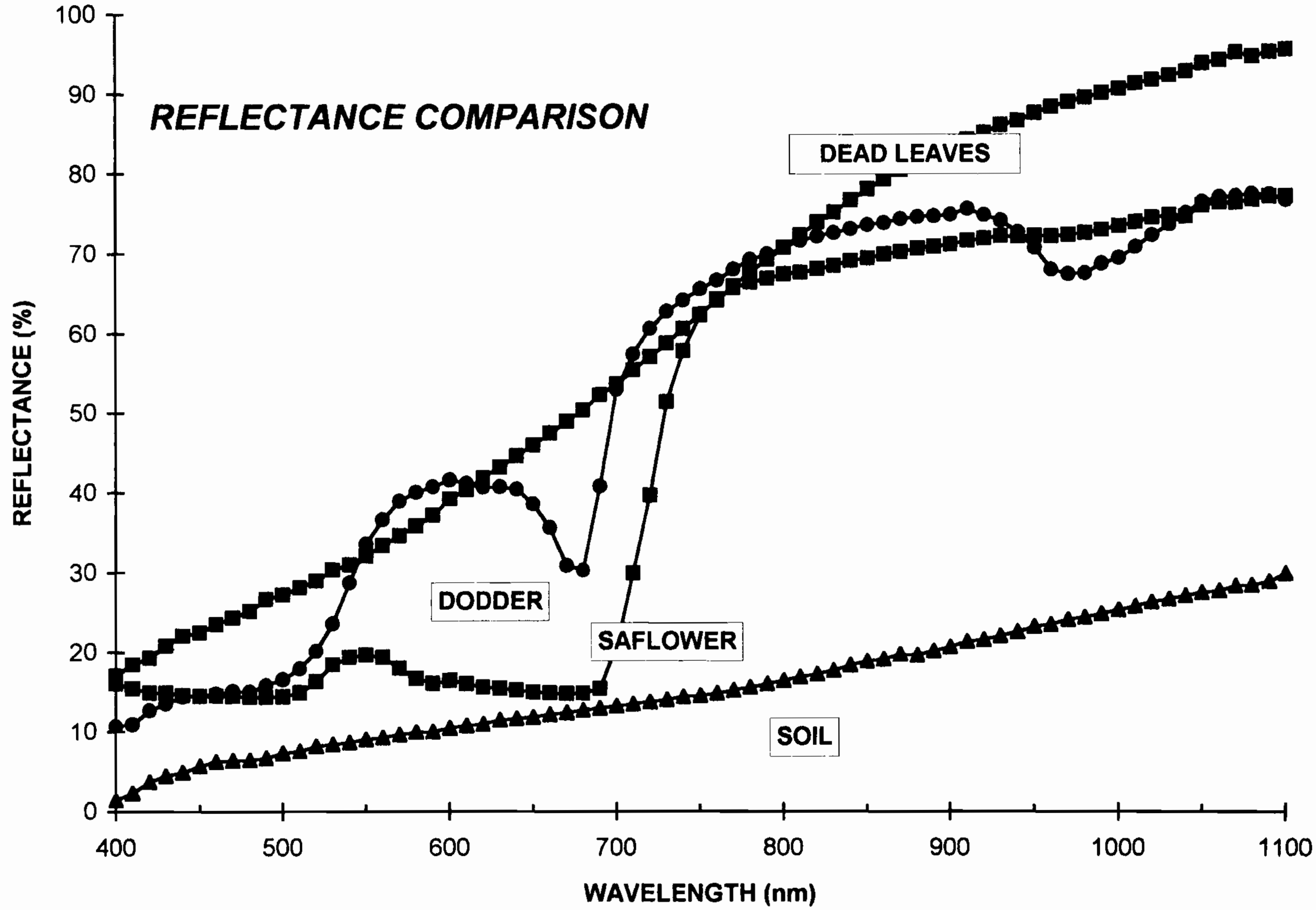
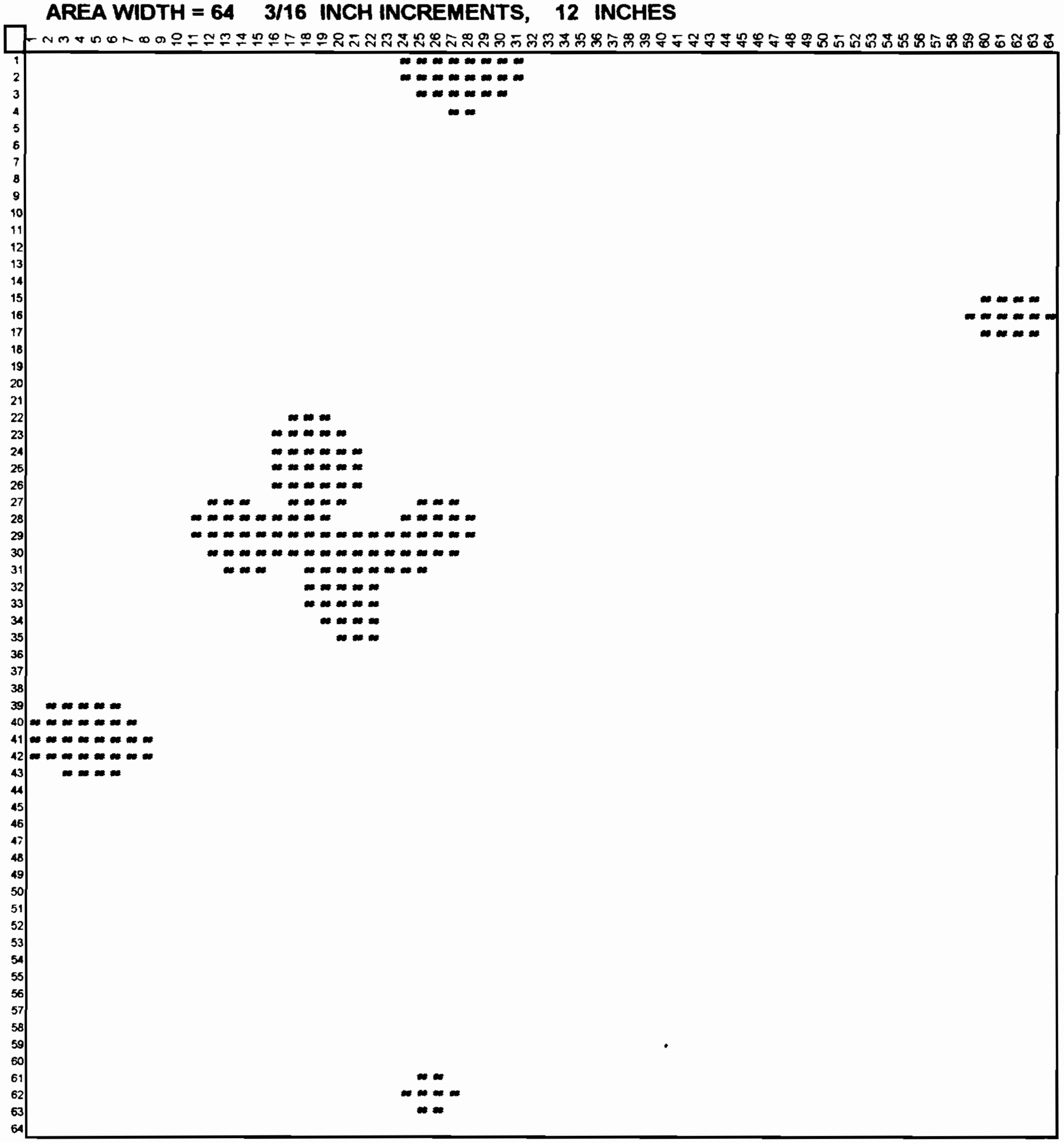


FIGURE 1, *SPECREF5.XLS*

WEED DISTRIBUTION vs SPRAY PATTERN MODEL

AREA WIDTH = 64 3/16 INCH INCREMENTS, 12 INCHES

AREA LENGTH 64 3/16 INCH INCREMENTS 12 INCHES



3	4	5	5	5	5	3	2	0	0	2	4	5	5	4	7	9	12	13	12	10	7	3	7	11	10	9	6	3	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	3	3	3	1

TOTAL WEED SITES	190	OF	4096

WEED COVER RATIO (W)	5%		
AREA WIDTH INCREMENTS	3/16		
AREA LENGTH INCREMENTS	3/16		
NUMBER OF SPRAY PATTERNS	4	2	1
WIDTH OF SPRAY PATTERNS (s)	3 IN	6 IN	12 IN
DETECT THRESHOLD (WEED SITE	1	2	4
DETECT RATIO	17%	27%	22%
SPRAY RATIO (S)	34%	50%	88%

RANDOM NUMBER	B7
RANGE	.530
ROUND	.010

FIGURE 2, *WEEDDIS5.XLS*

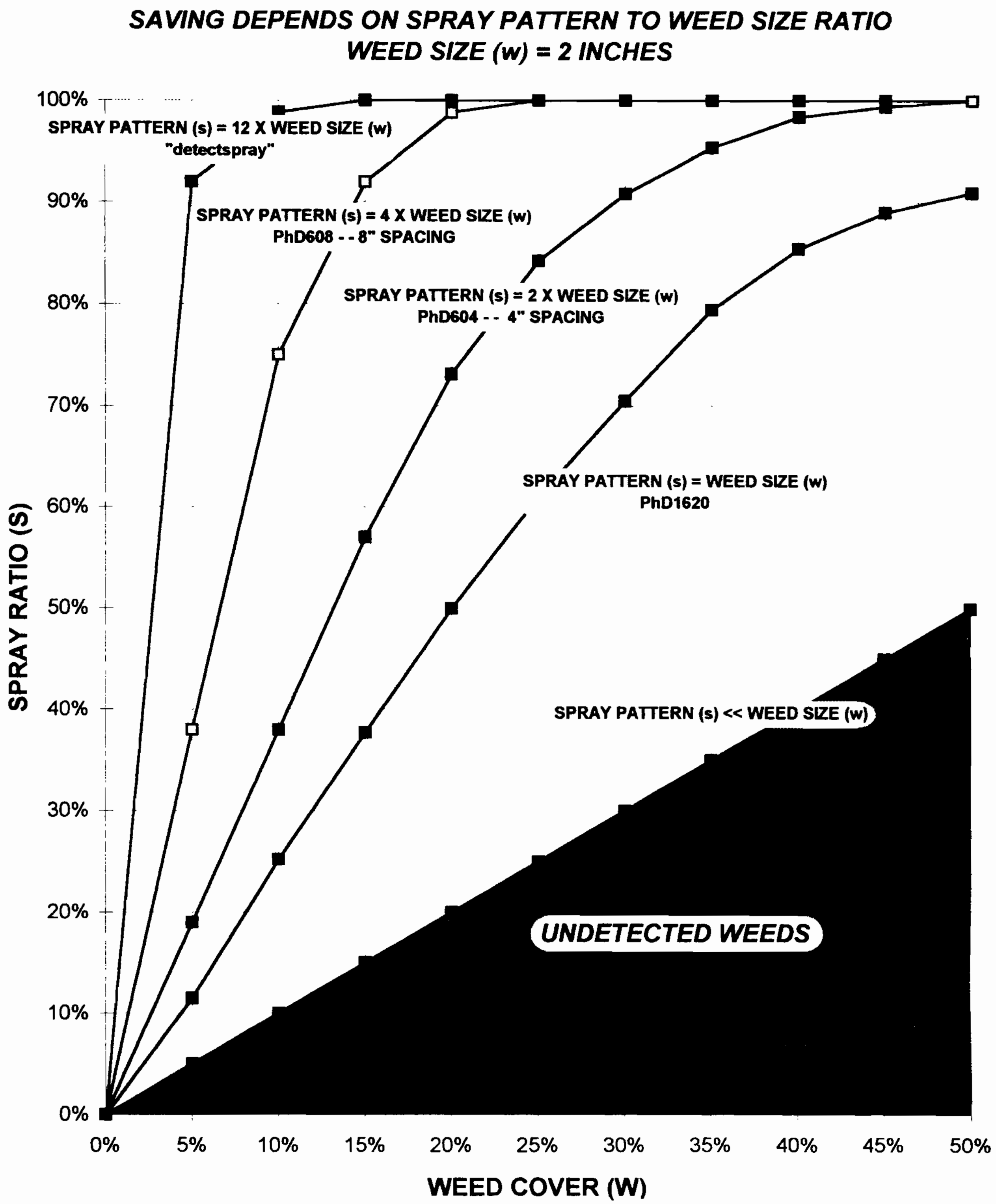


FIGURE 3 *WEEDSIZ5.XLC*

WeedSeeker™ PRODUCT SELECTION GUIDE

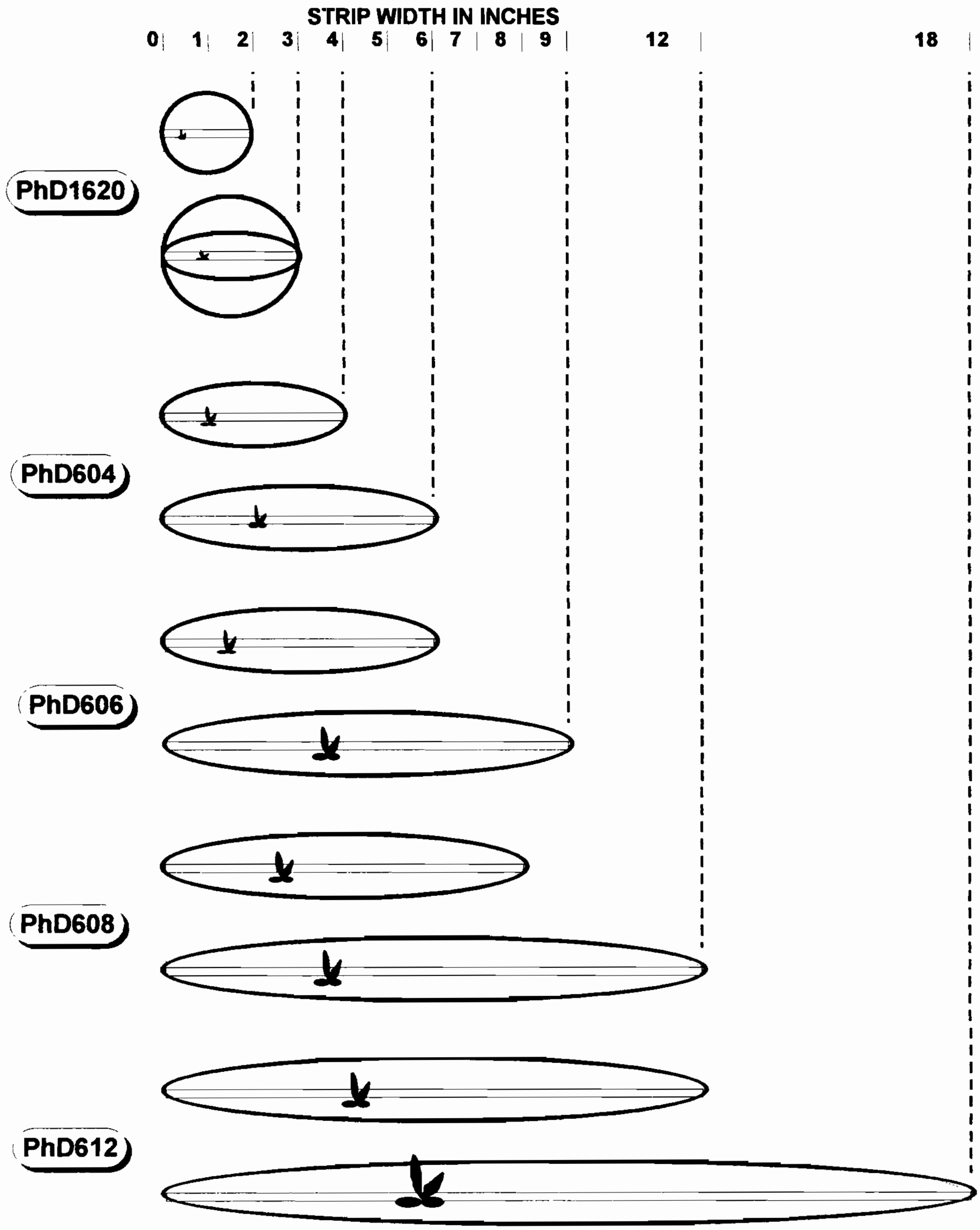


FIGURE 4 *WEEDFLX5.XLS*

Layby Weed Control in Tomatoes using Variable Herbicide Rates

W. Thomas Lanini, E. M. Miyao, and B. Correiar

Department of Vegetable Crops

University of California, Davis

Herbicides represent over 75% of the pesticides used in tomatoes (Campbell Soup survey, 1990 - unpublished). In the Campbell Soup survey covering over 500 California processing tomato growers, it was found that over 90% used layby herbicide applications to help control weeds; trifluralin (Treflan) was most commonly used. Layby treatments are soil incorporated, placing the herbicide into the upper soil layers, with the incorporation process removing any weeds which may have emerged prior to the treatment.

Only six weeks of weed free conditions were needed to a avoid tomato yield losses from field bindweed (Lanini and Miyao 1988). Although yield losses do not appear to occur from weeds emerging 6 to 8 weeks after tomatoes, weeds can produce seed and in some instances, interfere with harvest (Lanini et al. 1991). Reduced rates of herbicide, sufficient to prevent or slow weed growth and prevent seed set prior to crop harvest, presents a potential option. A variable rate treatment, would use increasingly lower rates going from the furrow to the crop, preventing weed growth for a short period until the crop canopy developed into that area. The crop canopy would then provide sufficient competition to prevent any further weed growth.

To evaluate this concept, five studies were established in 1994 to determine the effects of variable rate layby herbicide treatments on tomato yield, quality, and weed cover and seed production.

Materials and Methods:

Five Herbicide lay trials were established in cooperation with growers in the Davis area of California. Tomato planting dates varied from mid-February to late April. When tomatoes were approximately 8 inches tall, layby treatments were applied. Plots were 3 beds wide by 100 feet long and replicated 3 or 4 times. Standard rate layby (Treflan) treatments were applied and compared to untreated or variable rate treatment plots. The standard rate was the rate the individual grower used and ranged from 0.8 lb/a to 0.9 lb/a.

Varying rate plots were applied using a 5 nozzle boom, with each nozzle varying in size and covering approximately 10 inches (Figure 1). The center nozzle (nozzle 3) centered on the furrow applied full rate (equal to the growers standard rate), nozzle 2 and 4 applied 0.67 or 0.5 of the standard rate, and nozzle 1 and 5, 0 or 0.33 of the standard rate. The nozzle arrangement for these three treatments is:

Nozzle position	1	2	3	4	5
Standard	8006E	8006E	8006E	8006E	8006E
Varying rate #1	8002E	8004E	8006E	8004E	8002E
Varying rate #2	blank	8003E	8006E	8003E	blank

In addition to the constant rate treatment, an untreated control was also included for comparison.

Weed density, % cover, and seed production were measured at 4 week intervals until crop harvest. Percent weed cover and density by weed species will be measured using a 15 X 50 inch quadrat (3 samples per plot), divided into sections representing the areas covered by each nozzle. Plots were machine harvested for yield determination and subsamples taken for determination of maturity (reds, greens, rots) and quality (brix). Weed seed production was estimated for all species.

Results: Emerged weeds were practically non-existent prior to layby due to cultivation and hand weeding practices prior to layby. Regardless of treatment, weed populations remained low through harvest. The most common escape weed was nightshade (*Solanum* sp.) which was not controlled by Treflan. Tomato yields in the two fields harvested to date did not differ among treatments (Table 1). The Rominger field averaged over 50 tons/acre yields. This field was planted early (Feb. 15) with 2 rows per bed. The average yield in the Turkovich field was less than 30 tons/acre. This field was harvested 2 to 3 weeks past prime harvest time, due to over-production in earlier harvested fields and no market for the extra tomatoes. Many of the tomatoes fell off the vines during the pickup process of the machine harvest, and thus a lower yield was observed. Additionally in the Turkovich field, the variable rate and untreated plot did not receive a side-dress fertilizer application and thus a slight difference in yield may have occurred. Soluble solids did not differ among treatments. Weed pressure was low in both of these fields with very few weeds going to seed in untreated plots.

One field just harvested has extreme weed pressure, primarily from barnyardgrass. Untreated plots observationally appeared to have much lower yields. Data on this and another plot will be finalized and presented at the meeting.

Conclusions: Variable rate treatments have the potential to reduce herbicide use 40 to 60%. In fields where weed pressure is low, this appears to be a viable option. Variable rate application requires only to change the nozzles in a standard layby herbicide application setup as outlined in Figure 1. Differences in weed cover or weed seed production were not evident between the standard layby treatment and variable rate treatments. Further studies are planned to evaluate variable rate layby treatments in earlier planted tomatoes as well as in other crops which also receive layby herbicide treatments.

Reference:

Lanini, W.T. and E.M. Miyao. 1988. Field bindweed competition studies in processing tomatoes. In: J.P. Orr Ed., 1988 Progress report - Nightshade, dodder and bindweed control in tomatoes. California Tomato Research Institute. p.45-47.

Lanini, W.T., G. Miyao, B. Fischer, H. Kempen, J. Orr, H. Agamalian, A. Lange, L. Clement, and B. Mullen. 1991. "Weeds", in Tomato Pest Management Guidelines, B. Ohlendorf and M.L. Flint, Eds. pp.26-35.

Figure 1. Diagram of variable rate treatment showing rate at each location between the crop rows and nozzles used to achieve this rate.

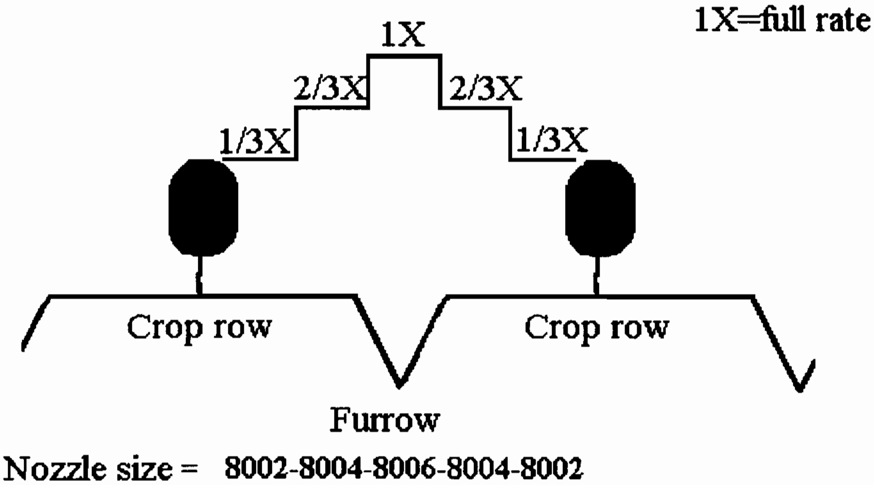


Table 1. Tomato Yields as affected by layby herbicide treatments.

	Rominger	Turkovich	
Treatment	Yield	Yield	Soluble Solids
	(tons/acre)	(tons/acre)	%
Variable 1*	54.16	26.68	5.7
Variable 2**	53.62	25.52	5.9
Standard	53.44	27.42	5.8
Untreated	53.17	26.83	6.0
LSD.05	NS***	NS	NS

* Variable rate 1 = 1/3X, 2/3X, 1X, 2/3X, 1/3X across the spray pattern with X equaling the standard rate used by the grower.

** Variable rate 2 = 0, 1/2X, 1X, 1/2X, 0 across the spray pattern with X equaling the standard rate used by the grower.

*** NS = not significant.

New Technology to Reduce Pesticide Use on Turf and Ornamentals

John T. Law Jr.
Regional Technical Manager
TruGreen-ChemLawn

TruGreen♦ChemLawn is a service provider to the Turf and Ornamentals industry. These services are primarily fertilizer applications, pesticide applications, turf aerations and overseeding from approximately 190 company-owned locations in 39 states. We provide services to approximately 1,500,000 residential customers, and many commercial customers.

This paper discusses ways that TruGreen♦ChemLawn is reducing pesticide use. These include using:

- A new spray technology — called Dual-Line Injection — allowing "on-demand" pesticide use when making liquid turf applications.
- On-truck computers with specialized data bases for easier and better use of customer's pest history, easy access to pest control information, and an easier way to deliver information on proper cultural practices to customers.

This new technology is discussed in more detail below. To help understand how this technology can reduce pesticide use I will first discuss pesticide issues unique to the TruGreen♦ChemLawn landscape service. This service business is different from agriculture or even landscape maintenance. It is a marketing driven service business. What customers want, and what they will buy drives the business. Residential lawn customers typically want very few weeds and a thick green lawn. Tree and shrub customers typically want very little insect and disease activity. To achieve these goals, the service is designed as a year round program with regularly scheduled service visits. The materials applied during these service visits varies with pest cycles and plant growth and development. Meeting the customer demands can create pressure to make many pesticide applications. One balance to this pressure is the fact that the customer does not pay for pesticide use — the charge is the same regardless of the pesticide and amount applied. The less pesticide we use the more profit we make on that service visit. So aside from the standard pressures to reduce pesticide use — government regulation, liability concerns, and social pressures — there is a direct bottom line benefit. Of course we must always satisfy the customer if we want to keep them.

Dual-Line Injection

Part of keeping customers on our service is achieving excellent pest control results, particularly turf weed control. Let me describe how we get good pest control results and how the new dual-line technology reduces pesticide use while producing the same level of pest control. Dual-Line is a further development in our liquid fertilizer and pesticide application technology.

Pesticide applications to trees and shrubs has to be liquid to get coverage of a complex three dimensional shape. Many turf applications can be liquid or dry since turf is usually a relatively flat smooth surface. However we try to make as many liquid applications as possible. Liquid applications are more precise and accurate, especially on the small irregular shaped turf areas around many homes and businesses in California.[1] Liquid postemergent broadleaf herbicide applications are also more effective than granular applications, and broadleaf weeds are our major turf pest target. The draw back to liquid turf applications is that there is no soluble or suspendable slow release nitrogen fertilizer. Frequently irrigated, quality turf requires continuously available nitrogen fertilizer to maintain good color.[2] For this reason, turf programs based on liquid applications require more applications per year to maintain color. More applications are also required for some difficult to control weeds such as oxalis, nutsedge and dallisgrass.

For quality control and environmental reasons we fill pesticides at the operations facility.[3] This procedure in the past has reduced options for an applicator in the field. For example, during times of the year when preemergent herbicide is scheduled the spray tank is filled with fertilizer and preemergent herbicide. If preemergent herbicide is not desired — such as on a thick lawn that is mowed and watered properly, with a corresponding reduced risk of crabgrass — the applicator has to make a granular application to get the required fertilizer down. However, as discussed above granular applications are not as desirable.

The Dual-Line injection system allows an applicator to apply pesticides to a zone of a lawn, on demand, while fertilizing. Therefor the preemergent part of the

---

[1] Irregular and small turf areas are a maintenance problem as well as an application problem. However turf has so many advantages over other ground covers that homeowners and professional landscape architects alike keep installing turf. Turfgrasses are the most widely adapted perennial ground cover. Turf can be managed with a relatively low skill work force. Turf is more tolerant of the common poorly structured urban soils than most plants.

[2] Nitrogen requirements are higher in the coastal west than in areas with a continental climate because: turf growth rates are high, frequent irrigation causes some nitrogen to volatilize, and the common practice of removing clippings takes a lot of nitrogen away.

[3] All mixing and truck filling operations are completed inside the operations facility in a containment area that has been designed to prevent inadvertent spills escaping in to the environment. If any materials are accidentally spilled in the mixing or truck filling process, they are collected by the branch water recycle system. The water recycling system is a contained system consisting of a series of drains leading into a sump that collects water used to wash trucks and other water generated in the truck filling process. The recycle system allows this washwater to be recycled back through the fill system, reducing the fresh water consumed and allowing beneficial reuse of the materials involved.

application can be added (injected) as needed. This represents a significant reduction in pesticide use. There are many other situations where Dual-Line can reduce pesticide use. First let me describe the Dual-Line technology.

Instead of a single hose from the spray truck to the applicator's spray gun there is a twin hose (where the name Dual-Line come from). The spray gun has a two stage trigger. Pulling the trigger to the first stop sprays what is in the main tank through one hose, pulling the trigger the rest of the way adds what is in a smaller tank through the other hose. The smaller tank typically has a diluted pesticide solution that will not be needed on all lawns[4]. Since there are two hoses, no purging is needed, such as when switching between different spray tanks

Most of the time the injection system has broadleaf herbicide in the injection tank. Fertilizer and water are filled in the main tank for lawn spraying, with herbicide injected only on turf areas with broadleaf weeds. Other uses include: avoiding spraying preemergent on newly seeded lawns or lawns that will be overseeded, applying MSMA on turf areas with crabgrass, or applying insecticides for lawn infested with armyworm.

In-Truck Computer

Another new technology we will be implementing this year is a computer that goes in the spray truck. An important part of reducing pesticide use is pest history. The computer has a touch screen making it easy to both access and enter pest and host information. For example, if a lawn has no history of summer annuals such as crabgrass spurge, and cultural practices have been good, that customer probably does not need a preemergent herbicide application. Or another example would be grubs. If the customer has a history of grubs it would then be a good use of time to check for grubs.

Good cultural practices are of course the best way to reduce pesticide use. Unfortunately we have little direct control over cultural practices. Our customers are responsible for mowing, watering and pruning. We provide aeration service and sometimes overseeding but we have to convince the customer to buy these services when they are needed. The computer has a printer attached so the applicator can print out various notes (including graphics) on cultural practices keyed to the customers specific problem. Thatch control is a good example. Thatch buildup in lawns causes many problems including poor water penetration leading to thin turf leading to summer annual weeds. Thatch also is home to certain harmful turf insects such as fiery skipper or armyworm. Thatch is best controlled with aeration which supports a microbial

---

[4] Using dilute pesticide is important for reducing the risk of pesticide use. When concentrated pesticides (as formulated by the manufacturers) are diluted for end use the toxicity is greatly reduced. Many TruGreen♦ChemLawn tankmixes have been tested for toxicity. They all received the lowest acute toxicity rating — practically non-toxic. Using diluted pesticides in the Dual-Line system also makes gives more precise applications. Small differences in metering concentrated pesticides results in a much greater error than metering diluted pesticides.

process that breaks down the thatch. Leaving a customer with a note — at the time of the service visit keyed to the specific turf area and problem — is more likely to result in the customer taking action than trying to explain the problem later on the phone.

Applicators can also access information to help them identify plants and pests. The computer is "docked" with a central computer in the main facility every night. Information is then uploaded and downloaded so that applicator will have access to timely information and not have "wade" through pests and problems unlikely to occur at that time of the year, or not in the area they will be servicing the next day.

A note keyed to the customers property may also satisfy a customer who demands a pesticide application. Once a customer identifies a problem they typically want a pesticide application. Many customers believe there is a spray for every problem just as many people believe there is a pill for every ache. The computer can print a much nicer more valuable looking note that an applicator can write.

INTELLIGENT SPRAY SYSTEM FOR REDUCED HERBICIDE CONTROL OF VEGETATION

C.J. Tauzer
D.C. Slaughter
D.K. Giles

Biological & Agricultural Engineering Department
University Of California, Davis
Davis, CA 95616

Written for the

1995 Plant And Soil Conference

of the

California Chapter
Of
American Society Of Agronomy

INTRODUCTION

The California Department of Transportation (Caltrans) expends a considerable amount of human and financial resources in its highway maintenance program for the control of vegetation along the shoulders of roadways. Effective weed control has multiple benefits including increased visibility and safety for drivers, reduced loss of natural resources (e.g., water) to unwanted vegetation and a reduction in alternative hosts for insect pests and diseases. Application of herbicides is one of the most effective methods for weed control.

However, due to environmental concerns and the ever rising cost of herbicide application, there is a need to develop improved means of weed control in a reduced herbicide environment. One possible solution is to develop new chemical spray technology that could be intelligently controlled. If a system could be developed to apply herbicides only to the targeted plant material the energy and material costs involved in weed control could be reduced.

Researchers with the Biological And Agricultural Engineering Department, working in conjunction with Caltrans, have recently developed a prototype Intelligent Spraying System (ISS). The research was performed as part of the Advanced Highway Maintenance and Construction Program (AHMCT). The prototype has been designed to operate under the current Caltrans herbicide application conditions while reducing the amount of amount of herbicide required to effectively treat an area. The technical objective of this research was to determine the feasibility of an intelligent "offset" spray system where the spray vehicle is driven along the edge of the roadway and a computer vision system determines the presence of plant material in real-time. Upon command from the computer control system, spray material is delivered horizontally to the region adjacent to the vehicle in which the plant lies and not to the surrounding soil which is void of plants.

This system uses a real-time computer vision system to detect live (green) plant material growing along the roadside. This vision system is coupled to a set of rapid-response spray control valves and nozzles to permit selective application of herbicides to the detected plant material. The implementation of this technology should allow the California Department of Transportation to reduce the amount of resources required to maintain an effective weed control program using herbicides while at the same time reducing the amount of chemicals unnecessarily released into the environment.

INTELLIGENT SPRAY SYSTEM HARDWARE

A photograph of the ISS is shown in Figure 1.

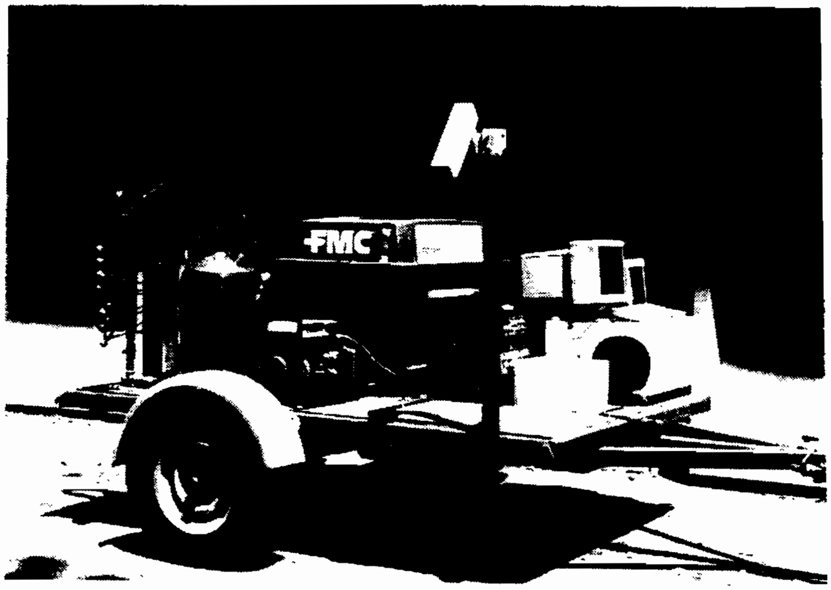


Figure 1. Photograph of the Intelligent Spray System.

The prototype ISS combined two fundamental elements: 1) a computer vision system, and 2) a rapid-response intermittent spray system. The system components and configuration are described below.

Computer Vision System

A color computer vision system was developed to demonstrate the feasibility of detecting green plant material growing next to the roadway. This system consisted of a solid-state color video camera (Sony, model XC-711), a computer video interface circuit board (RasterOps frame grabber, model 24 XLTV), and a computer (Apple, model Macintosh IIfx). The frame grabber was capable of digitizing true-color video images at a rate of fifteen frames per second. The resolution of the digitized color images was 640 columns by 480 rows. Once a video image was digitized it was stored in the memory of the frame grabber and could be accessed directly by the computer.

A color reference table was developed which could be used by the computer in real-time to determine if the color of a picture element (pixel) corresponded to one of several shades of green commonly observed in live plant material. The color reference table was stored in computer memory as a color look-up-table (CLUT) and was used by the computer to determine if any plant material was present in the field of view.

Each image was subdivided into eight regions of interest (ROI) where each ROI corresponded to a region of soil perpendicular to the right edge of the vehicle carrying the intelligent spray system (ISS) as shown in Figure 2. The ISS was equipped with eight spray nozzles and each of the eight image ROI's corresponded to one of the eight spray nozzles. Each image ROI was defined as that portion of the computer image which contained the view of the soil which could be sprayed by its corresponding nozzle. For example, the left most ROI viewed the area of soil closest to the vehicle and this area of soil could be sprayed by the bottom spray nozzle. The resolution of the digitized image allowed the computer to identify plants as small as 80 square millimeters under ideal conditions.

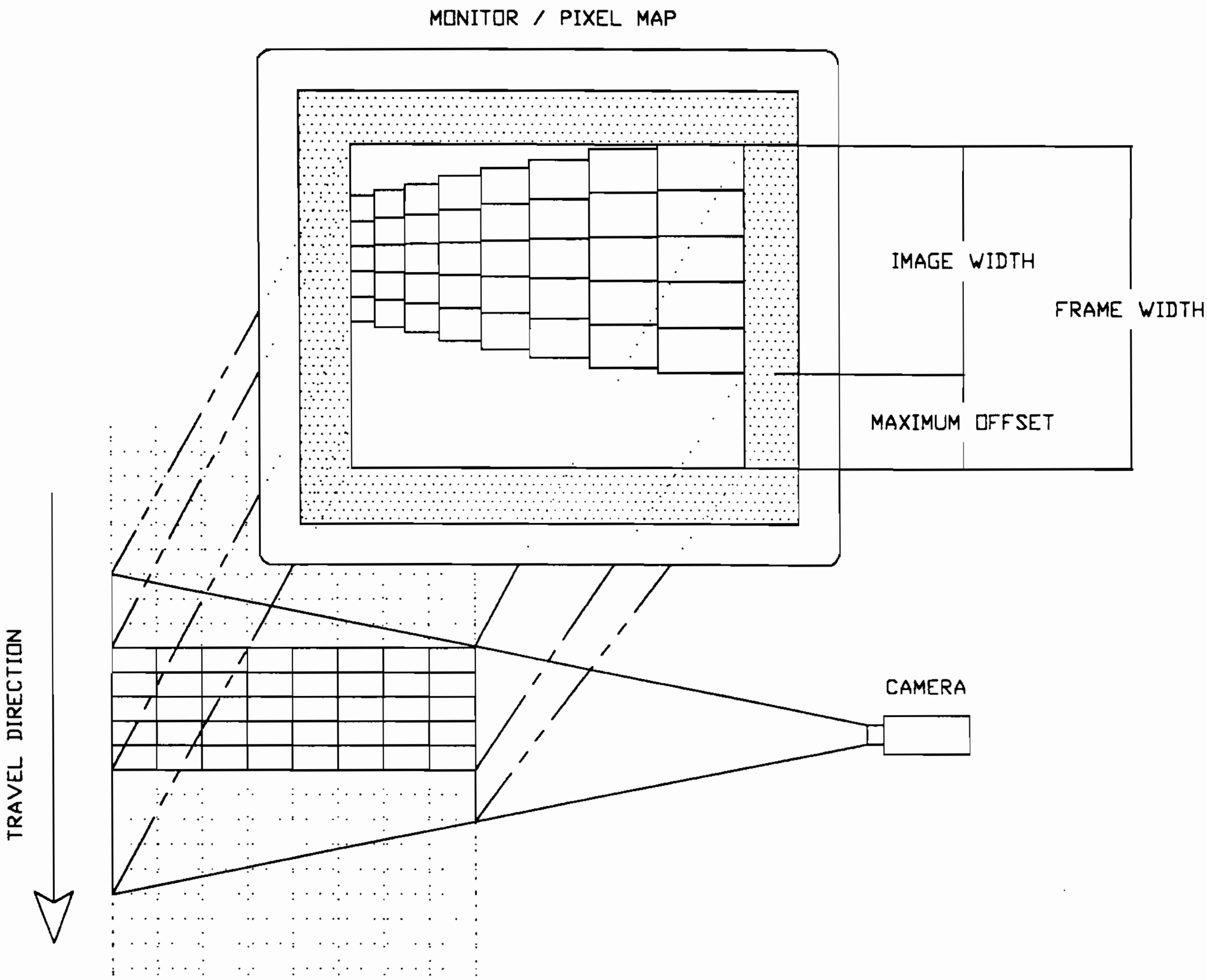


Figure 2. Schematic diagram showing the camera field of view and individual regions of interest.

In operation, the computer would examine each of the eight ROI's and determine which regions contained green plant material. If a region contained green plant material, a computer memory flag was turned on to indicate that the appropriate valve should be turned on in time to spray the plant detected in that region. The computer maintained a series of memory flags for each spray valve in a circular memory buffer and turned each spray valve on and off independently as needed to spray plant material in each region.

Rapid-Response Intermittent Spray System

A schematic diagram of the rapid-response intermittent spray system is shown in Figure 3. The system consisted of a pump, filter, pressure regulator, pressure relief valve, manifold, eight solenoid valves, and eight spray nozzles. A manifold pressure of 517.1 kPa (75 psi) was required to provide a 63.1 ml/s (1 gpm) flowrate through the spray nozzles. Each valve was controlled by the computer through a series of electronic relays which allowed the computer to open or close each of the eight valves independently.

INTELLIGENT SPRAY SYSTEM OPERATION

A schematic diagram of the overall layout of the ISS is shown in Figure 4 and a flowchart showing the general sequence of events for operating the ISS is shown in Figure 5. The sequence begins with a test to determine if the width of a spray region has been traveled by the system. The ISS used a radar displacement sensor (Raven Industries) to determine the distance traveled. The sensor emitted 130 electronic pulses per meter traveled and was capable of operating at travel speeds from 1.5 km/hr (0.9 mph) to 110 km/hr (68 mph). Once the vehicle arrived at the new region to be analyzed, the computer would begin the process of acquiring a new computer image of the new region. The acquisition of an image was conducted by the frame grabber as an independent task allowing the computer to monitor the travel of the vehicle and to control any of the eight valves as needed. Once the image was digitized and stored in the computer's memory analysis of the eight individual ROI's in the image was conducted. If any of the eight ROI's contained a weed a flag was set in computer memory marking that ROI to be sprayed when the spray nozzle was positioned above the region of soil containing the weed. The computer used displacement information from the radar sensor to determine when the correct time to open each valve had occurred.

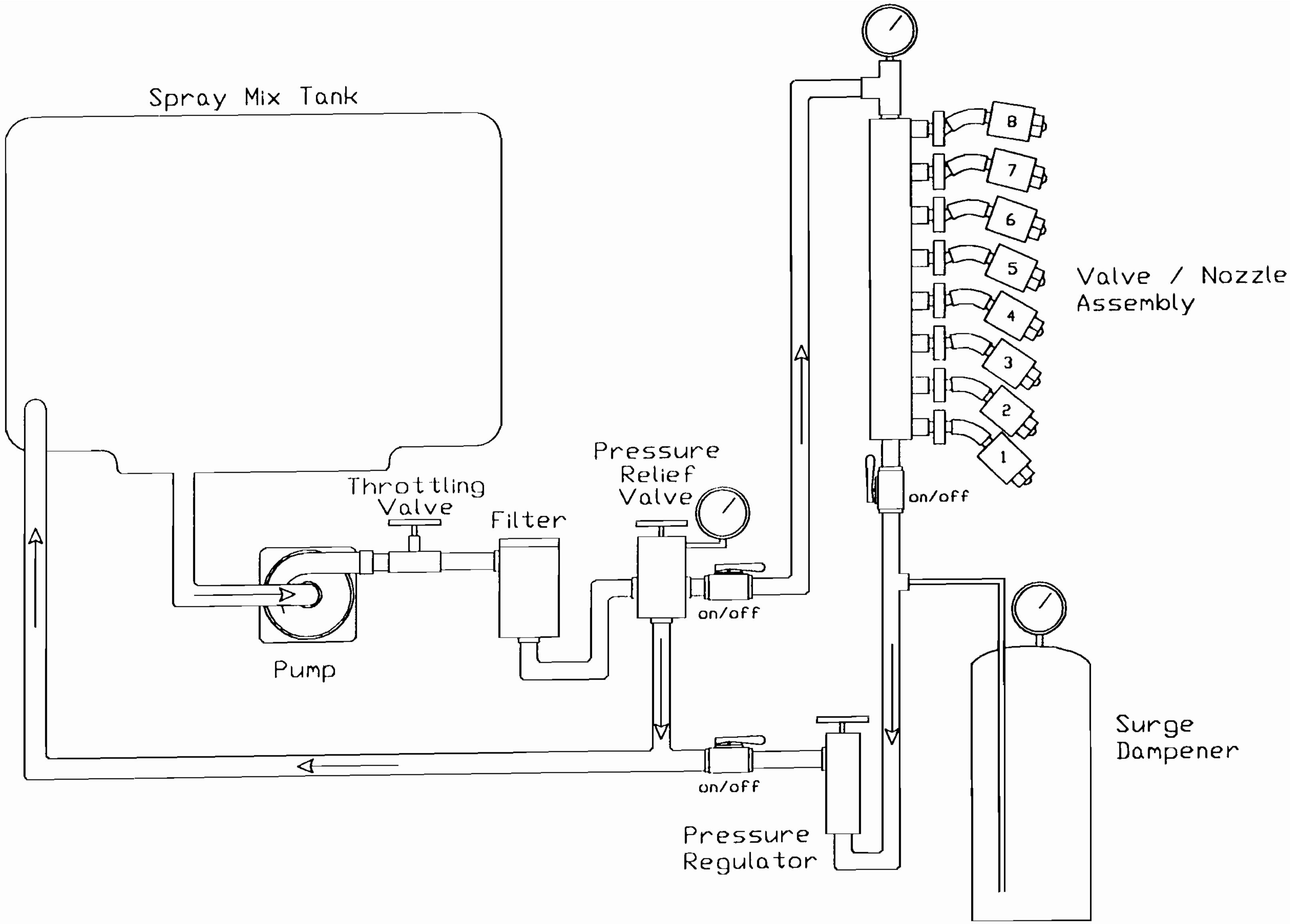


Figure 3. Schematic diagram of the rapid-response intermittent spray system.

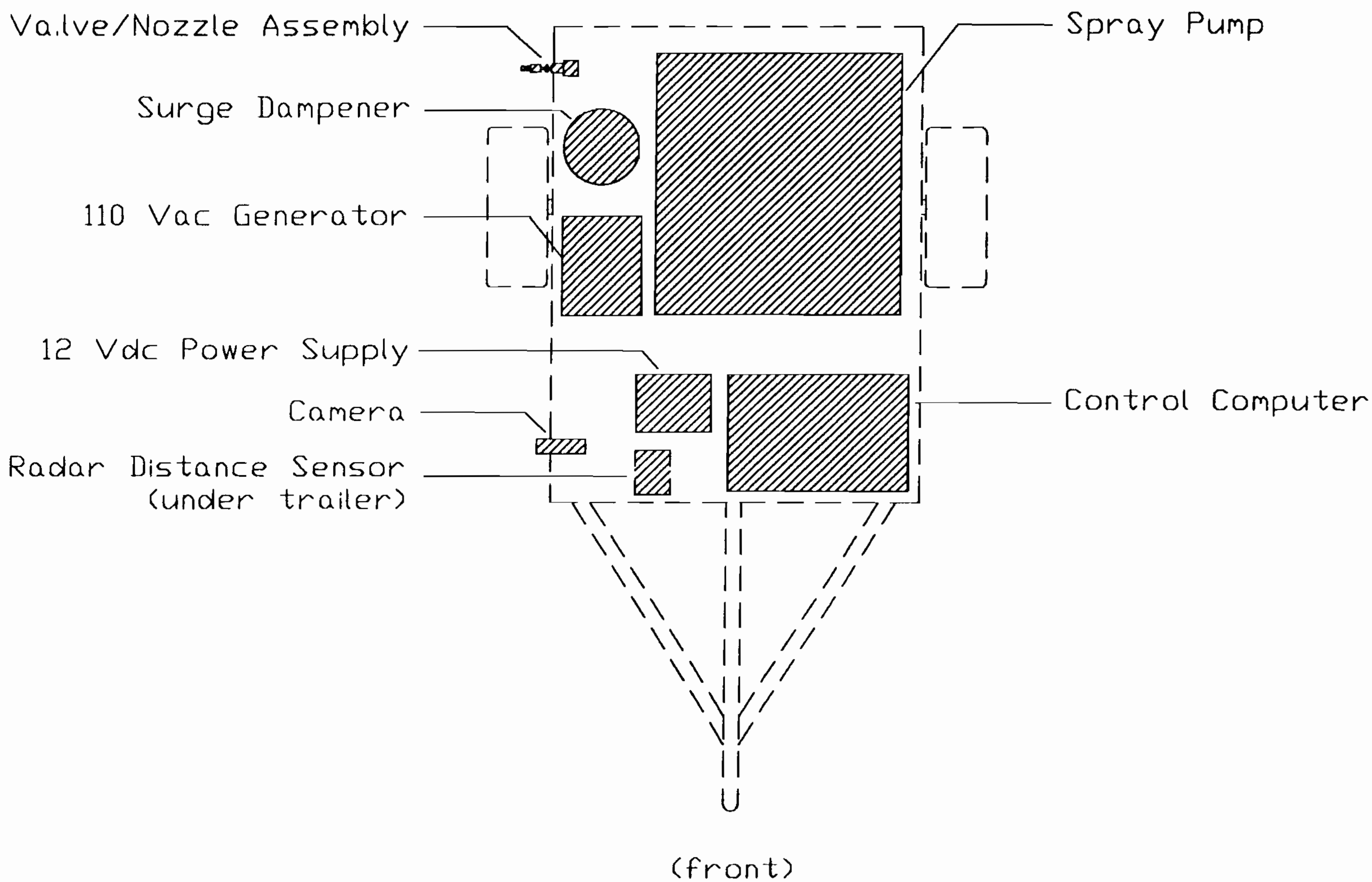


Figure 4. Schematic diagram (top view) of the prototype Intelligent Spray System.

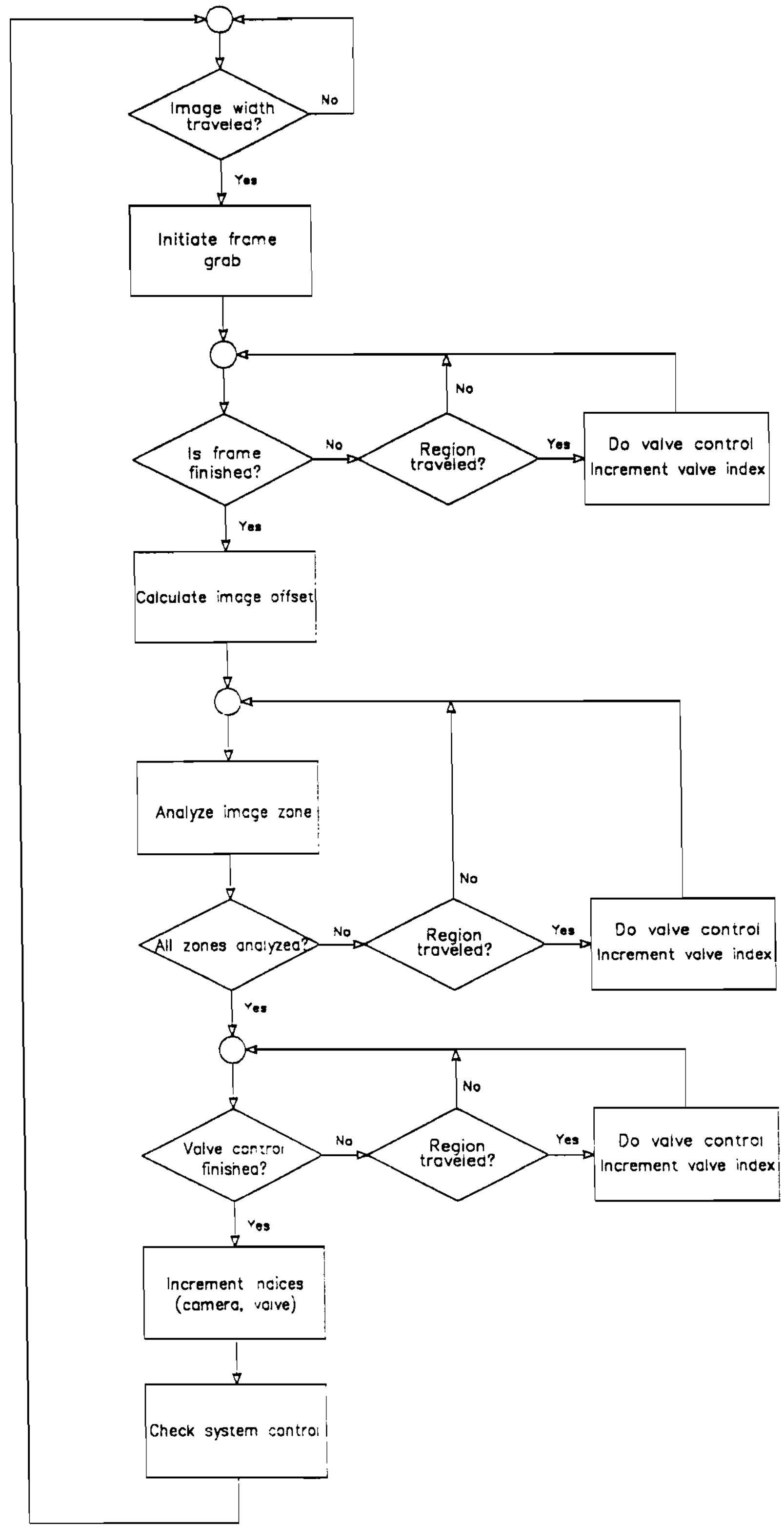


Figure 5. Flowchart showing the operating sequence of the Intelligent Spray System.

PERFORMANCE RESULTS AND DISCUSSION

Computer vision resolution tests were conducted from a moving vehicle at three travel speeds (3.2 km/hr (2.0 mph), 8.0 km/hr (5.0 mph), and 12.9 km/hr (8.0 mph)). The theoretical minimum resolution under ideal conditions with a stationary camera would be 80 mm^2 (0.124 in^2). At all three travel speeds the system was able to detect a 50 mm x 50 mm (2 in. x 2 in.) target 100% of the time. The system was able to detect a 25 mm x 25 mm (1 in. x 1 in.) target at 3.2 km/hr (2.0 mph) and 8.0 km/hr (5.0 mph) 81% of the time on the average, and 67% of the time at 12.9 km/hr (8.0 mph). The system was able to detect the 12.5 mm x 12.5 cm (0.5 in. x 0.5 in.) sample between 17% and 33% of the time depending upon speed. This indicates that, with the equipment used in this test, the minimum resolution from a moving vehicle under natural outdoor illumination was approximately five times greater than the theoretical minimum. The minimum resolution might be improved by using a camera with higher resolution, more light sensitivity with less noise and by optimizing the shutter speed for different vehicle speeds.

The results of tests used to measure the performance of the target image mapping are summarized in Table 3. There were a total of seventy-five target sites recorded in this series of tests. A target site may be in two ROI's if the target lies across the border between the regions. Eight target detection conditions occurred in the analysis. These conditions consisted of targets which were in one or two ROI's, targets which were detected in one or two ROI's, and the level of offset between the actual target site and the detection site which varied from zero to two ROI's. The most accurate spray targeting is represented by conditions which have no offset between target site and detection site. When an offset occurs the level of weed control can be improved by extending the time the valve is open for a number of ROI's before and after the detected region. For example, if the valve control is set to spray two ROI's before the target and two ROI's after, the total coverage would be five ROI's rather than one ROI. This would ensure that the target is sprayed even when an offset condition occurs. The target was accurately detected with no offset condition 31% of the time in this test. Eight percent of the time the system sprayed two adjacent ROI's when only one contained a target. When the target was located in two adjacent ROI's the system correctly sprayed both ROI's 34% of the time and only sprayed one of the two ROI's 56% of the time. If the ISS was set to spray $^{+}$/-1 ROI (in the direction of travel) then the target would be sprayed 97% of the time. Spraying additional ROI's would further improve the coverage at the cost of decreased efficiency. For example, tests indicate that if the ISS was set to spray +/-2 ROI's then the target would be sprayed 100% of the time.

Table 3. Performance Results for the Intelligent Spray System (75 total targets)

CONDITION	OCCURRENCE
1 target region, 1 detected region, no offset	2
1 target region, 1 detected region, 1 region offset	4
1 target region, 1 detected region, 2 region offset	1
1 target region, 2 detected regions, no offset	6
2 target regions, 1 detected region, no offset	35
2 target regions, 1 detected region, 1 region offset	1
2 target regions, 2 detected regions, no offset	21
2 target regions, 2 detected regions, 1 region offset	5

Spray deposition tests were conducted by spraying a random pattern of plants using weed activated application (normal ISS operation). The tests were repeated using identical plant patterns using conventional application (full coverage). The results from the spray depositions test are shown in Table 4. Lower spray deposition was achieved when the ISS used weed activated spray control rather than conventional spray control. The only exception was in region 8 at 8.0 km/hr (5.0 mph). On the average the spray deposition with the ISS operated in the weed activated mode was 57% of the conventional continuous spray system. The higher deposition achieved with the conventional spray control is likely to be the result of spray overlap between adjacent regions. Since all regions are being sprayed with the conventional method, a target in a specific region would be sprayed by the nozzle set for that region, plus the over spray from nozzles targeting adjacent regions. The deposition would also be increased by fall-out from the spray streams targeting ROI's further out. An additional factor which could result in lower deposition when using the weed activated control is the variance in the spray stream path due to wind influences. It was observed during the testing that a light wind of 1 to 3 km/hr (0.6 to 2 mph) was enough to shift the spray stream into an adjacent ROI. Wind would have less of an impact with the conventional spraying method since all of the spray streams would shift, so that a region would be sprayed by the spray stream originally targeting the adjacent region. The deposition could be increased by spraying +/-1 ROI (in the direction of the spray stream) or by using nozzles with a higher flowrate.

Table 4. Percent Of Conventional Spray Deposition Achieved Using Weed Activated Control

SPRAY ROI	DISTANCE	DEPOSITION (% of Full Coverage) 3.2 km/hr (2.0 mph)	8.0 km/hr (5.0 mph)	12.9 km/hr (8.0 mph)
1	0.3 m (1 ft)	90%	89%	73%
2	0.6 m (2 ft)	51%	61%	58%
3	0.9 m (3 ft)	45%	47%	44%
4	1.2 m (4 ft)	67%	64%	15%
5	1.5 m (5 ft)	60%	61%	41%
6	1.8 m (6 ft)	54%	64%	26%
7	2.1 m (7 ft)	40%	40%	33%
8	2.4 m (8 ft)	97%	101%	48%

The advantage offered by the ISS for spray application is clear when the amount of spray material used by the ISS system operating in the weed activated mode is compared to the amount used in the conventional mode. The amounts were estimated by comparing the total time that the spray valves were on for each mode. The test results showed that the ISS system uses substantially lower amounts of spray material compared with a conventional spray system when the weed population is sparse. In the tests conducted here the ISS achieved an average spray deposition 57% of that applied by a conventional spray system while using less than 4% of the spray material used by the conventional system. If adjacent ROI's (both perpendicular to and parallel to the direction of travel) were also sprayed by the ISS the average spray deposition should be equivalent to that of a conventional spray system while still using less than 10% of the spray material used by the conventional system.

CONCLUSIONS

The technical feasibility of developing an intelligent spray system (ISS) for use by the California Department of Transportation (Caltrans) in the control of vegetation along the shoulders of roadways was established by developing a prototype. The prototype ISS consisted of two fundamental elements: 1) a computer vision system, and 2) a rapid-response intermittent spray system. This study indicates that it is feasible to use a computer vision system to automatically detect the presence of green plant material and to use a rapid-response intermittent spray system to efficiently apply chemical herbicides only to the targeted plant material. Results indicate that by using the ISS a substantial reduction in herbicide applied to non-plant material could be achieved. Implementation of this technology should allow the Caltrans to reduce the financial resources spent on chemical herbicides and to reduce the amount of chemical herbicides released into the environment. Tests have verified that a ten to 20-fold reduction in the amount of applied herbicide may be possible.

Yield Monitoring: The New Agronomic Challenge

T. Macy

(Paper not submitted in time for inclusion in Proceedings.)

Development of Innovative Agronomic and IPM Management for Success in the California Melon Industry

John B. LeBoeuf, CPAg
Certified Professional Agronomist
Fordel, Inc., Mendota, CA

INTRODUCTION

With economic hardships being felt by many California melon growers in recent years, efforts have been made by managers of melon production to acquire useful information for help in surviving rough economic times. Reduced water deliveries to growers due to drought may have reduced planted acreage of some crops in the San Joaquin Valley but melon plantings have not been reduced overall. Suppliers of perishable vegetables try to get their crops into certain marketing windows of opportunity. A production problem in one agricultural region may bring good fortune to individuals able to supply a commodity to the marketplace. But a problem due to overproduction of a crop, such as cantaloupe, can result in economic losses to many growers, packers, and shippers.

Revenues from vegetable production typically follow a roller coaster pattern of many ups and downs with weekly changes in price quite common. Growers strive for maximum yields with the hope that their crop goes to market when prices are favorable. Production managers are becoming more receptive to field specific information as an aid in decision making when it is provided in a timely manner.

RECENT ECONOMIC HARDSHIPS

Salmonella Scare

The California melon industry has encountered some severe economic hardships in recent years. During the summer of 1991, news headlines linked salmonella with cantaloupes. An outbreak of salmonella poisonings had the media focusing attention on cantaloupe production during the peak harvest of melons in the San Joaquin Valley. Orders for cantaloupes were cancelled by produce buyers on the east coast of the United States. California melon production was never identified as being involved with the few improperly chilled cut melons that supposedly caused the problems at a few salad bars. Nevertheless, thousands of acres of high quality melons were disced under due to the sudden collapse of demand in the market.

Silverleaf Whitefly

Less than two months after the salmonella hysteria, another event put the cantaloupe industry in the news. The silverleaf whitefly, Bemisia tabaci, inflicted tremendous losses on growers in the Imperial Valley. A pest out of control took thousands of planted acreage to an untimely demise. A sudden loss of the melon crop was devastating to the local economy of the Imperial Valley at the same time that prices soared to record highs for melon producers in other growing regions. With melons being identified as the silverleaf whitefly's primary choice for a host, many growers are reluctant to get involved with producing a crop that may or may not make it into harvest unless they get sound advice.

Virus Diseases

Numerous virus diseases spread by aphids have reduced yields of both cantaloupe and honeydew fields. The last several growing seasons have been impacted by watermelon mosaic virus(WMV, formerly referred to as Race 2), cucumber mosaic virus(CMV), zucchini yellow mosaic virus(ZYMV), papaya ringspot virus(PRV, formerly referred to as WMV Race 1), and cucurbit aphid-borne yellows virus(CABYV). Virus transmission by low levels of aphids can inflict severe losses. Fall melon production is usually the time when virus related losses are the greatest.

Serpentine Leafminer

During the summer of 1993, economic losses in cantaloupe, honeydew, watermelon, and mixed melons were being reported due to a species of serpentine leafminer known as Liriomyza trifolii. The pest was not being controlled by any of the insecticides registered for use on melons. A request for a Section 18 Crisis Exemption for the use of Avermectin (trade name Avid) was submitted to the Department of Pesticide Regulation in Sacramento, CA. The request was approved during the first week in September of 1993 but this proved to be inadequate for immediate help as irrigation water was running in many fields and the exemption was specific for ground applications only.

Overproduction

Overproduction of a fresh market vegetable almost always leads to a fall in prices as the supply and demand situation falls out of balance. Melon production in California usually sees its share of overproduction every year when prices fall below packing charges. As peak production saturates the limited market for the perishable commodity, many fields are not harvested to their potential or may be abandoned and disced under.

INNOVATIVE AGRONOMIC PRODUCTION PRACTICES

Attempts are being made to do a better job in managing row crops such as cantaloupe and honeydew by adapting agronomic practices that are more common in cotton production.

Soil Temperatures

Soil temperature readings in early spring are used to help in timing of plantings. A soil temperature of 60 degrees Fahrenheit, with a forecast of five days of good weather, is considered optimum for both cotton and melons. Planting into cold and wet soils usually brings germination problems associated with the damping off complex of fungal pathogens (*Pythium*, *Phytophthora*, *Rhizoctonia*, and several others) and insect pressure from wireworms(*Limonius* spp.) and seedcorn maggots(*Delia platura*). Soil temperature differences have been noted in fields on the same ranch that may differ in soil types, moisture content, or just row direction. Managers are watching daily soil temperatures as planting into fields which are warmer increases their chances of success.

Plant Populations

Estimates are being used to determine stand establishment, spacing of plants in the row for management of desired fruit size, and to check on the effectiveness of thinning crews. Just as field personnel working in cotton would use field sampling procedures to estimate plant populations, squares, green bolls, and open bolls, melon personnel can use sampling techniques to estimate the quantity of marketable fruit per acre. Information based on reliable field sampling can help in marketing of the produce. Knowing the quantity of fruit, and the estimated percentages of the five different sizes, helps in planning advance sales.

Phenology Models and Degree Days

Phenology models are being used for help in spacing out acreage across a 19 week planting season. Field information collected across several seasons has been used to make predictions on seed emergence, two true leaves, bloom, and harvest dates based on a particular plant date. A properly spaced planting allows for optimum use of manpower, machinery, and cooling and storage facilities. Degree day information is being looked at to see if harvest dates can be predicted based on the weather.

IMPLEMENTING IPM PROGRAMS

A lack of economic incentives facing chemical companies trying to re-register or develop new pesticides for minor crop usage is a major concern of growers. As recently as five years ago, many melon growers strived for bug free fields. Faced with the shrinking arsenal of registered pesticides(such as the loss of Ethion and Mevinphos), some growers have openly embraced IPM alternatives. No longer are fields sprayed on a regular basis for leafhoppers, spider mites, thrips, cabbage loopers, and armyworms. Augmentation of natural enemies for biological control of pests has been used with limited success. Release of beneficial insects and mites, under the supervision of a qualified professional such as a Pest Control Adviser(PCA),can reduce pesticide usage and minimize the risk of pesticide residues.

Pheromone traps for monitoring of cabbage looper, Trichoplusia ni, has been used to help in the timing of releases of Trichogramma parasitic wasps. When male moths are caught in the pheromone traps, an order can be placed with an insectary for delivery of the wasps. Waiting to find looper eggs in the melon canopy would not allow ample time to order, receive, and release the eggs containing the beneficial wasps.

The release of green lacewing, Chrysoperla sp., for biological control of the melon aphid, Aphis gossypii, can be effective when aphid levels are low to medium. Once aphid colonies start flaring up, their reproduction rate quickly reaches the point where beneficial species can't keep up. Crops can be damaged by sticky honeydew secretions and the accompanying black sooty mold.

Yellow sticky cards are very effective in monitoring flying insect species. During windy conditions dust can quickly cover the surfaces and the cards would have to be replaced. The prevailing winds blow bugs into a field and yellow sticky cards are an effective monitoring tool. Cantaloupe and honeydew flowers are yellow and the yellow sticky cards are attractive to many species of insects that would never be observed by an individual scouting the field during routine checks. Intensive field monitoring of insects and mites and data collection of population levels of both pest and beneficial species has brought about an understanding of relationships in the environment.

NEW TECHNOLOGY

An airborne crop monitoring service offered through the Space Remote Sensing Center at the Stennis Space Center in Mississippi has been used on cantaloupe and honeydew fields. Information gathered from remote sensing cameras mounted in a fixed wing aircraft flying at 6,500 feet above the fields has been very useful in crop management, especially in irrigation. Processing of the computer enhanced FARMVIEW images is being done at the Geo Information Technology Center in Fresno, CA. The images are delivered 24 hours after the flight. The green vegetation index, with a biomass histogram showing 16 categories, displays differences in the field which many times is not visible to an observer in the field. The technology detects energy outside of the visible range of the electromagnetic spectrum utilized by the human eye.

SUMMARY

By developing innovative agronomic production practices, implementing integrated pest management(IPM) programs, and utilizing technological advances, growers are striving to gain an advantage over others in the highly competitive California melon industry.

A CASE FOR RETAINING PESTICIDES: MICROBIAL DEGRADATION OF HERBICIDES

John D. Helm and Thomas T. Yamashita
California State University, Fresno

INTRODUCTION

With heightened concerns for environmental safety and the vulnerable position of agriculture, many farmer practices have been exaggeratedly blamed for our country's pollution. The scare from Big Green has sent a wave of controversy across the nation. However opinions may fall, it is clear that the consensus has taken the position that the great majority of farm chemicals must be phased out and replaced with "Safe, Sustainable Systems". Most agriculturalists who have grown up on the farm and/or have learned in depth the necessities of farming life will categorically admit that "We Cannot Afford To Lose Many Of Our Chemicals In Agriculture".

For the past many years the PI has examined a highly viable technology that may possibly appease environmentalists, chemical companies and growers, alike. That technology encompasses the use of indigenous microbial flora to accelerate the mineralization of various pesticides. A pesticide that is known to have potentially hazardous persistence in the environment can be targeted and its mineralization achieved with highly grower-compatible programs. The system essentially makes the statement: "Using safe procedures, continue to use selective, approved and necessary chemicals in your farming regime, but at the end of the season, institute a CLEAN-UP PROGRAM to assure safety and appease the public and regulatory agencies". Such a scheme presents a highly viable solution which avoids "extreme reactions" such as across-the-board banning that will gravely affect our agriculture and national economy.

While the loss of many groups of chemicals would be devastating, farmers would, perhaps, feel the greatest loss in the banning of "Herbicides". For these reasons, the PI has invested energies examining mineralizing schemes for key, model herbicides. For example, we have examined the problems with

Atrazine persistence. Through various mathematical formulae, such as the Piston-Displacement Models, the PI has developed models to elucidate the apparent nature of Atrazine persistence. All previous models had been developed considering only the soil medium. We incorporated: a) root harvesting, tissue concentration factors and b) tissue persistence/tissue degradation factors. In so doing, a predictive model was established whereby, based on estimated biomass (corn stubble remaining in the field) and indigenous microbial activity levels in relation to the rate of tissue decomposition, the extent of subsequent damage to a rotation crop could be estimated. More importantly, it established a tangible scheme to minimize Atrazine carryover, thereby allowing its use in corn in an economically compatible rotation program. Related studies have been conducted with trifluralin, imazamethabenz-methyl, simazine, oryzalin and others.

Such systems need to be brought to the attention of regulatory agencies such that the pressures on the banning of these important herbicides would be mollified. For, the instituting of "Soil Activation Programs" is not superfluous to a normal, farmer-friendly practice. Further, many of the proposed systems are designed to reestablish optimum fertility and soil aggregation characteristics reminiscent of productive lands and are coincident with the goals of the USDA Soil Conservation Service.

With the fast pace of modern agriculture and our formidable task of feeding the world, we cannot suddenly shift to subsistence, sustainable systems overnight. A much needed mobilization to search for "Safe Alternatives" has been set in motion. However, in the interim, it is the feeling of our research team that the most efficient and viable solution to environmental concerns for pesticide use resides in demonstrating its mineralization. That is, by instituting a relatively simple, soil activation program at the season's end, it would be possible to insure:

1] Freedom from damaging herbicide persistence to subsequent rotational and/or existing permanent crops

2] A dispelling of fears regarding pesticide use in general

3] An indirect instituting of soil-building programs

4] Mollifying of fears surrounding pesticide persistence and build-up in the environment

5] Positive demonstrations, data and precedence for chemical companies, regulatory agencies and farmers to defend continued use of selected, necessary pesticides

CLOSING NOTES

A formalized remediation/testing scheme is being initiated with emphasis on developing grower-friendly, clean-up protocols. Initial results will be presented at the annual meetings in Visalia, January 10-11, 1995.

Challenges and Opportunities for Mixed, Conventional, and Organic Production

T. O'Neal

(Paper not submitted in time for inclusion in Proceedings.)

Agronomic and Economic Potential of Alternative Production Systems

S.Temple

(Paper not submitted in time for inclusion in Proceedings.)

Interactions Between Plant or Soil Conditions and Insect Pests and Natural Enemies Can Combine for Improved IPM

K.M. Daane[1], L.E. Williams[2], R.S. Johnson[3] & J.W. Dlott[1]
[1]Laboratory of Biological Control, UC Berkeley; [2]Dept. of Enology and Viticulture, UC Davis; [3]Dept. of Pomology, UC Davis

A common goal of Integrated Pest Management (IPM) and sustainable agriculture is to reduce chemical inputs, such as pesticides, without decreasing product quality or economic profits. For insect control in particular, the replacement of insecticides is typically sought through improved biological controls. Such focus often leads researchers to overlook the effects of cultural controls, such as insect/plant interactions. For example, one facet of biological control is the conservation of beneficial insects, most commonly through the addition of cover crops. Cover crops can increase beneficial insect numbers by providing shelters or alternative hosts or enhance beneficial insect longevity and fecundity by providing extra floral nectaries. The literature is replete with evidence of cover cropped agricultural systems containing fewer numbers of insect pests and greater numbers of beneficial insects as compared with clean-cultivated systems. However, while insect pest densities are often lower in cover cropped systems, there is less direct evidence that such reduction is due solely to an increase in biotic mortality caused by natural enemies. While often overlooked, cover cropping can also affect plant characteristics which, in turn, can affect pest densities through an increase in abiotic mortality (e.g. physical factors). Here we present two case studies in which the manipulation of plant characteristics caused a reduction in insect pests, and propose that such changes could have resulted from the addition of cover crops. First, we review studies on the reduction of leafhopper pests in grape vineyards through changes in applied irrigation (Daane et al. 1995a). Second, we present data on the reduction of two lepidopteran pests of nectarines through changes in applied nitrogen (Daane et al. 1995b).

Applied Irrigation. The variegated grape leafhopper, *Erythroneura variabilis*, is the most serious insect pest of grapevines in California's San Joaquin Valley. At high densities, this leafhopper can cause chlorotic spotting and defoliation, reducing leaf photosynthesis, and its excretions of honeydew act as a substrate for sooty molds, resulting in cosmetic damage to fruit. Adult leafhoppers, flying at harvest-time, are a hindrance to workers which can limit their productivity. Insecticides have been the mainstay deterrent against this pest; however, their use is in jeopardy due to increasing pesticide resistance, secondary pest outbreaks, and regulatory restrictions. Improved IPM methods are needed. Previous work has correlated vigorously growing vines to higher leafhopper densities. One important cultural practice that will have a profound effect on vine vigor is the amount of applied water. To determine mechanisms by which irrigation amounts affect leafhoppers, a study was initiated in 1990 in a 4 acre (1.6 ha) vineyard at the Kearney Agricultural Center (KAC), the vineyard was part of a long-term irrigation study, directed by L.E. Williams.

Thompson Seedless vines used in this study were planted in April 1987 as cuttings. Two cuttings were planted in a weighing lysimeter located close to the center of the vineyard. The weighing lysimeter rested upon a sensitive scale, which had an overall system resolution of less than 1.0 lb (400 g or 0.05 mm of water). The weight of the lysimeter was measured hourly each day throughout the growing season. The loss of weight by the lysimeter each hour was assumed to be due to the loss of water by grapevines via transpiration and from the soil by evaporation. The two vines in the weighing lysimeter were automatically irrigated whenever the vines used 0.08 inches (2 mm) of water. Individual rows within the 4 acre vineyard, surrounding the lysimeter, were irrigated (via drip) at various fractions of the amount of water used by the vines in the lysimeter. Irrigation treatments ranged from 0.0 to 1.4 (0.2 increments) times the water amounts given to the vines in the lysimeter. Irrigation treatments were laid out in a line-source configuration, with eight replicates of each treatment block.

In 1992 and 1993, when leafhopper data were collected, vines irrigated at amounts equal to or greater than water applied to the vines in the lysimeter were never under stress at any time during the growing season, based on plant measures of vine water status (e.g. photosynthesis, stomatal conductance and leaf water potential, and canopy temperature). However, these same measurements were much lower for vines irrigated at less than full vine evapotranspiration. Measurements of vegetative growth (fresh pruning weights) were a linear function of applied water over the range of treatments imposed. Therefore, leaf area per vine was almost 3 to 5 times greater for non-deficit irrigated vines compared to those receiving no water (0.0 treatment). Yields over the course of the study have been maximized at irrigation amounts between the 0.6 and 1.0 treatments.

Leafhopper densities were measured in the 0.0, 0.4, 0.8, and 1.2 irrigation treatments and showed that vine condition, resulting from the differential effect of irrigation treatments, significantly affected leafhopper densities. As the season progressed, the differences among treatments increased; results from peak leafhopper counts in the third brood showed a strongly positive correlation between leafhopper numbers and irrigation levels. The progressive and widening differences in leafhopper densities paralleled increasing differences in vine water stress among irrigation treatments.

Other studies suggest that differences in leafhopper densities can be attributed to host plant condition effects on leafhopper nymphal size and mortality and adult dispersal and fecundity. From each irrigation treatment, individual 5^{th} instar nymphs were weighed. Results showed a significant and positive correlation between leafhopper weight and irrigation levels. In cage studies, significantly greater nymph mortality was recorded in the 0.0 and 0.4 irrigation treatment than in the 0.8 or 1.2 treatments, as measured by the number of leafhopper nymphs developing to the adult stage. It should be noted here that this study tested the mortality of 2^{nd} to 5^{th} instars. There may be a greater effect from host plant condition on leafhopper egg and 1^{st} instar stages. Of the nymphs that reached the adult stage, their development was ≈2 to 3 days faster in the 0.0 and 0.4 irrigation treatments. We believe this difference can largely be explained by differences in vine temperature between the irrigation treatments. Grapevines that were irrigated at full evapotranspiration had canopy temperatures less than ambient and were up to 18°F (10°C) cooler than the deficit irrigated vines.

The preference of adult leafhoppers to disperse to well-irrigated vines was studied in mark, release, and recapture experiments. Results show that significantly more marked and recaptured adults and total adult leafhoppers were collected in the highest irrigation treatments levels. The results imply that either the adult leafhoppers were more attracted to vines in the higher irrigation treatments or that the leafhoppers randomly dispersed but were better arrested at the higher irrigation treatments. More important, irrigation treatments also affected leafhopper fecundity. Two experiments were conducted. In the first experiment, the tested adults were reared from nymphs in the 1.0 treatment and isolated in the 0.0, 0.6, and 1.2 irrigation treatments. In the second experiment, nymphs were reared in the 0.0, 0.6 and 1.2 treatments and isolated as adults in the 1.0 irrigation treatment. After 4 weeks, the numbers of leafhopper eggs deposited by the isolated adults were counted in all treatments in both experiments. Results showed that significantly more eggs were deposited on leaves in the higher irrigation treatments, indicating that leaves in the lower irrigation treatments were either a poorer adult food source (resulting in lower fecundity) or created a less favorable environment (resulting in shorter longevity). There were no significant differences in egg production in the cross experiment in which leafhopper adults reared in the 0.0, 0.6, and 1.2 irrigation treatments were isolated in the 1.0 irrigation level. This implies that the adult leafhoppers compensated for the poor quality food source during the nymphal development.

Applied Nitrogen. The oriental fruit moth (OFM), *Grapholita molesta*, and the peach twig borer (PTB), *Anarsia lineatella*, are the primary moth pests in California's nectarine and peach orchards. Mating disruption for OFM, using moth sex pheromones, has proved to be a viable control option and well-timed applications of *Bacillus thuringiensis* can provide control of PTB. Both offer a 'least-toxic' alternative to organophosphate insecticides. However, fruit harvested mid- to late-season require a second application of pheromones and repeated applications of *B. thuringiensis*, increasing pest control costs and often resulting in incomplete pest control. Therefore, it is important to combine these chemical control strategies with orchard management practices that either decrease pest abundance or increase natural enemy abundance. In studies conducted on commercial-farms, we observed that high moth pest densities occurred in trees which had excessive new shoot growth and that shoot growth was related to nitrogen (N) input. We tested this relationship in an experimental orchard at KAC, that was part of a long-term nitrogen study under the direction of R.S. Johnson.

The test plot was a 2 acre (0.8 ha) block of 'Fantasia' nectarines. Five N fertilization treatments were organized in a randomized block design, treatments were: an unfertilized control and 100, 175, 250, and 325 lbs N/acre/year. The four N treatments all received 100 lbs N as ammonium nitrate broadcast in early September. The latter three treatments then received supplements of ammonium nitrate or calcium nitrate in the spring. All fertilization events were followed immediately with furrow irrigation (about 30 lbs N/acre/year was added by the irrigation water). The trees were planted in 1975, the fertilizer treatments were initiated in 1983 and have been maintained since that date.

In 1991 and 1992, when data on OFM and PTB were collected, the trees produced very well; yields and fruit weights were comparable to peak years of production, from 1984 to 1986. Fertilization rates between 100 and 325 lbs N/acre/year resulted in no differences in either yield or fruit weights; whereas, in the unfertilized treatment both yields and fruit weights were significantly reduced, as compared to the other N treatments. Although total yield was not affected by the fertilization treatments above 100 lbs N/acre/year, the time of fruit maturity was influenced. The higher N rates significantly delayed commercial maturity by an average of 4-5 days. Also, vegetative growth, as measured by topping weights above 10 ft, correlated well with N rate. Leaf N levels from samples collected in July increased proportionately to the amount of N applied. Even though the levels varied some between the two years, the results suggest that leaf levels higher than 3.0% indicate excess N fertilization for 'Fantasia' nectarine.

To determine the effect of N fertilization on fruit damage by insect pests, over 50,000 (1991) and 40,000 (1992) fruit were examined at harvest for damage from PTB, OFM, and the omnivorous leafroller, *Platynota stultana*. Results show that fruit damage by moth pests was significantly and positively correlated to N fertilization in both 1991 and 1992. Because the plot size was small and the moths could easily fly between plots, there are only a few possible explanations for the increase in fruit infestation in the higher N treatments. First, fruit in the high N treatments takes a longer time to reach maturity and the delay in fruit ripening resulted in a greater period of exposure to pests; this may become extremely important if cultivar fruit maturity closely follows either PTB or OFM egg hatch. A second possibility is that the different fruit infestation levels observed reflect a preferential egg deposition by adult moths on trees and fruit in the higher N treatments. Finally, characteristic of the tree, such as increased shoot growth resulting from excess n fertilization, led to an increase in moth pest abundance in the higher N treatments. The latter hypothesis was further tested.

While fruit infestation is the primary economic loss from moth pests, PTB and OFM can not sustain populations in the orchard without feeding on foliage. To determine the effect of foliage condition on PTB larvae, 30 new growing shoots and 30 older shoots were collected, each shoot then received a single, 1st instar PTB larva. The success or failure of the larvae to infest each shoot was determined. Results showed over 90% successful entry of the PTB larvae on new shoots, whereas less than 10% survived on the older shoots. The data indicate that new shoots provide excellent larval feeding sites, however, as those shoots harden off they are less suitable and finally unsuitable for PTB feeding.

To determine if N fertilization could affect the number of available host sites (e.g. new shoots), the total number of new and infested shoots was determined in the 'Fantasia' nectarine block. Results showed that N fertilization affects the relationship between the tree and the moth pests by increasing the amount of vegetative growth. While there was no significant difference between N treatments in the number of available or infested shoots early in the season, after harvest the differential effect of N on vegetative growth became apparent and resulted in significantly greater numbers of available host sites and infested shoots in the higher N treatments.

Summary. We have provided two examples where plant growth, as affected by irrigation and N applications, significantly changed insect pest status. In vineyards, deficit irrigation amounts had an effect on leafhopper nymphal mortality and size. More important, results showed that dispersing adults were collected in greater numbers and deposited more eggs on well-irrigated vines. Differences in adult dispersal fecundity between vineyards can be important in determining the increase or decrease in leafhopper densities, particularly because the primary leafhopper natural enemy is the egg parasite. In stone fruits, increased N fertilization was correlated with greater PTB and OFM pest problems. We believe that differences in pest densities can be primarily attributed to changes in the number of available host sites, especially late in the growing season. The increase in PTB and OFM survival in August and September represents an increase in the overwintering population and potential damage to next season's crop.

Changes in both irrigation and N fertilization can be manipulated by cover crops. Cover crops compete with vines for water and nutrients and, therefore, can reduce vine vigor; for this reason cover crops can have a duplicitous role in the management of leafhoppers both by supporting a more diverse beneficial insect fauna and increasing abiotic leafhopper mortality. Growers using cover cropping systems to increase the number of beneficial insects are also reducing the leafhopper numbers by reducing irrigation to the vines, without reducing crop yield. Cover crops can also directly affect the levels of N available to the tree. In the 'Fantasia' block studied, the 100 lbs N/acre/year rate of fertilization produced sufficient vegetative growth to maintain yields and fruit weights equivalent to higher fertilization rates. Applying higher rates of N fertilization produced no beneficial effects and would only reduce fruit red color and increase the possibility of leaching nitrates into the ground water. Growers are often encouraged to lower the input of synthetic nitrogen (N) fertilizers or to use compost or leguminous cover crops to provide the essential N needed for crop production. In organic orchards, we have observed both low and high N levels resulting from the addition of different cover crop species combined with compost.

Literature Cited

Daane, K.M., R.S. Johnson, T.J. Michailides, C.H. Crisosto, J.W. Dlott, H.T. Ramirez, G.Y. Yokota & D.P. Morgan. (in press). Nitrogen fertilization affects nectarine fruit yield, storage qualities, and suceptibility to brown rot and insect damage. Calif. Agricul.

Daane, K.M., L.E. Williams, G.Y. Yokota & S.A. Steffan. (in press). Irrigation amounts affect variegated grape leafhopper in a Thompson Seedless vineyard. Calif. Agricul.

Biologically Integrated Orchard Systems (BIOS): a voluntary approach to pesticide reduction

Robert L. Bugg, Ph.D. Cover Crop Analyst, University of California Sustainable Agriculture Research and Education Program; Jill Klein, Program Coordinator, Community Alliance with Family Farmers Foundation; Glenn Anderson, Farmer, Anderson Almonds; Ray Eck, Farmer, Almondeck Farm; Lonnie Hendricks, Farm Advisor, University of California Cooperative Extension, Merced County; Cynthia Lashbrook, Pest Control Advisor, Four Seasons Ag. Consulting, Inc.

Introduction

A new project has been developed to provide technical and financial support to Merced and Stanislaus County almond growers and Yolo and Solano County walnut growers who are willing to experiment with reducing chemical fertilizers and pesticides. This project is coordinated and supported financially by the Community Alliance with Family Farmers (CAFF) Foundation. To carry out this project, CAFF Foundation has formed a management team in each region of two farmers, the county farm advisor, a pest control advisor, and a UC extension researcher with experience in Biologically Integrated Orchard Systems (BIOS).

BIOS relies more on biological processes than agri-chemicals for cost-effective fertility and pest management. For example, an ongoing comparison of organic and conventional almond orchards has confirmed that cover crops can be an important tool in managing almond pests and their natural enemies (Hendricks, 1991). Under BIOS management, agri-chemicals are selectively used so they do not interfere with desirable natural processes, and in some cases, to enhance or fine-tune biological subsystems.

This approach is on the cutting edge of agricultural technology and growers can use these techniques to reduce chemical inputs while maintaining high productivity (Vereijken, 1989). As with most forms of ecological agriculture, there is no unique "right way" to farm with BIOS; rather, there are guiding principles, sets of options, and trade-offs to consider.

The BIOS Model

The Community Alliance with Family Farmers (CAFF) Foundation, a non-profit corporation, in collaboration with the University of California Cooperative Extension, the USDA Agricultural Stabilization and Conservation Service, the USDA Soil Conservation Service, private sector farmers, private businesses and pest control advisors have joined together to transfer farmer-proven methods to reduce chemical use from farm to farm.

In 1993, these collaborating entities, coordinated by CAFF Foundation, established the first in a series of model demonstration programs, called BIOS, for Biologically Integrated Orchard Systems. The first BIOS project provided a select set of almond growers with a the following package of technical support and financial incentives to help them reduce their farm chemical use:

Technical Support

- A customized plan for each transitional parcel developed by a team of experienced BIOS farmers, a U.C. Cooperative Extension Farm Advisor, a researcher, the farmer and his or her pest control advisor (PCA).
- A program of pest monitoring for each parcel.
- A newsletter summarizing the results of the monitoring and current field conditions sent regularly to participating farmers and PCAs.

- Consulting services throughout the season to answer questions concerning the transitional process.
- Monthly problem-solving meetings or on-farm workshops, seminars, and facilitated focus sessions. Topics include pest and disease identification, cover crop management for beneficial insects, orchard floor management, bird management, etc.

Financial Incentives

- Subsidies of $20 per acre available through the ASCS SP-53 program.
- Cost-sharing available through corporate sponsors for cover crop seed, beneficial insects and mites, insectary shrubs and trees, equipment, lab services and pheromone traps.

BIOS Program Results

The first BIOS program in Merced County enrolled 26 almond growers, each of whom committed 30 acres on average to a three-year transition. Total acreage of individual participants' farms ranged from under 100 acres to over 5,000. In a single season under BIOS management, all participants eliminated their use of specific organophosphate pesticides and pre-emergent herbicides; soluble nitrogen fertilizers were reduced by at least 20% as well. Many members of these chemical families have been identified as contributing to pollution of ground and surface waters.

One of CAFF Foundation's goals in establishing BIOS was to help the $500 million California almond industry, currently the state's second-largest user of agricultural pesticides, reduce its reliance on these chemicals. This goal has been endorsed by the Almond Board of California, which recently agreed to work with CAFF Foundation to publicize BIOS to almond growers throughout the Central Valley. Two additional BIOS projects were established in July, 1994 and are underway in Stanislaus County (22 growers, almonds) and in Yolo and Solano Counties (19 growers, walnuts).

BIOS Management Overview

Understory Management

Understory cover crops are key components of ecological orchard management because they are useful in maintaining soil fertility and in controlling pests. There is a rich array of cover-cropping options and associated management issues. In general, we suggest cover cropping during the cool season with a mixture of both seeded and resident plant species.

Mowing is an important tool in orchard cover crop management. Mowing can be used to:
1) reduce frost problems; 2) increase air movement and thereby reduce humidity and possible problems with plant diseases; 3) reduce weed competition with cover crops; 4) postpone maturation of cover crops; 5) rejuvenate cover crops; 6) provide food for earthworms and other decomposers; 7) provide mulch for beneficial arthropod habitat, weed control, and reduce evaporative loss of soil moisture; 8) kill cover crops; 9) force beneficial arthropods to move into trees by reducing the amount of understory habitat; and 10) provide "habitat edges" for beneficial arthropods at the interface between mowed and unmowed cover crops. Edges are especially rich habitats for many beneficial arthropods.

Either rotary or flail mowers may be used to mow cover crops. Rotary mowers are believed to be gentler on beneficial insects and spiders (Bugg & Ellis, 1990), and have a greater range of height adjustment. Tillage usually destroys cover crops, but leaving remnant bands can allow reseeding and provide habitat for arthropods (Bugg & Waddington, 1994). In BIOS for almonds, we usually restrict tillage to disking or shallow rototilling when preparing the orchard floor for harvest.

Plant Materials

Proper cover crop species selection and management will lead to good tree nutrition (Russell Lester, 1993, personal communication), improved biological and cultural control of pests (Altieri and Schmidt, 1986a,b; Barnett et al., 1989; Meagher & Meyer, 1990b; Bugg et al. 1991c;Ouyang et al., 1992; Bugg & Waddington, 1994), and breakdown of plant residues in time for harvest (Ruz Jerez et al., 1988). Cover crops may include domestic forms, wild, resident plants, or combinations. Seeded cover crops may include various legumes (clovers, medics, and vetches), as well as certain grasses, such as cereal grains. Different orchards may require different mixes of cover crops. Components to consider in choosing a suitable cover crop mixture include soil type, irigation system, spatial niches (i.e. orchard middles, tree rows, and berms), and manager preferences.

Benefits of Cover Cropping

The breakdown of cover crop residues provides a more gradual release of nitrogen than that obtained with synthetic fertilizers (Smith et al., 1987). This moderate nitrogen supply may lead to less foliar growth by almond trees during the summer. Cover cropping can lead to greatly improved water penetration by opening the soil and increasing organic matter and thus water retention (Williams, 1966). This may improve irrigation efficiency. Use of mown cover crop residue as mulch can help retain soil moisture and encourage earthworms.

Seeded and resident plants provide habitat for beneficial insects and mites that aid in pest control. Various plants can provide important alternative foods that beneficial insects rely on when they are not attacking pests. Several plants in the pea family harbor aphids and the lady beetles and lacewings that attack them. Bigflower vetch, common vetch, and 'Cahaba White' vetch (a hybrid) have extrafloral nectaries on their stipules (Bugg, personal observation; Duke, 1981).

Many types of insects are susceptible to generalist predators. The predatory mite *Euseius tularensis* attacks spider mites and scale crawlers. It also feeds on windblown pollens of trees and grasses in the winter and spring. This predator can reproduce (for at least one generation) on a diet of grass pollen alone and thus be well established before pest spider mites become abundant. Cool-season annual grasses that provide usable pollens include annual ryegrass, barley, cereal rye, and soft chess.

Various types of spiders move into almond trees from cover crops when the latter die or are mown. The most important kinds of spiders appear to be in the families Aegelenidae (funnel-web spiders), Clubionidae (sac spiders), Linyphiidae (line-weavers), Salticidae (jumping spiders), and Theridiidae (comb-footed spiders).

Formica aerata (commonly called the gray field ant, California gray ant, or crazy ant) and a close relative, *Formica moki*, are generalist predators that appear to be important natural enemies of peach twig borer, a major pest of almonds (Dlott et al., 1994). The gray field ant often feeds on at the extrafloral nectaries of common vetch and 'Cahaba White' vetch, and also tends cowpea aphid colonies on these two plants.

Commercial Insectary Cover Crops

Several commercial fall-sown and spring-sown "insectary crops" are now available in California. Several of these plants attract beneficial arthropods (Bugg & Waddington, 1994).

Perennial Insectary Plants

Some beneficial insects associated with almonds show more affinity for various shrubs and trees than they do for cover crops. For example, comanche lacewing (*Chrysoperla comanche*) is a generalist predator seldom found in cover crops but often seen at night taking nectar from flowering trees, such as soapbark tree, which flowers from mid-May through mid-June (Bugg, 1987), and bottle tree, which flowers from mid-May through mid-October (Bugg, personal observation). Brown lacewings and lady beetles also occur on soapbark trees (Bugg, 1987). Other flowering trees and shrubs that attract large numbers of beneficial insects include the following natives: blue elderberry, coyote brush, California coffeeberry, California lilacs, California wild buckwheat, holly-leaved cherry, mule fat, toyon, and various native willow (Bugg & Heidler, 1981)

The Roles Of Decomposers

Decomposers are important in BIOS because they break down plant litter (liberating nitrogen and other plant nutrients) and assist in the development of humus. Categories of decomposers include earthworms, various insects, certain mites, beneficial nematodes, fungi, protozoa, actinomycetes, and bacteria. As an orchard is gradually converted to BIOS management, decomposer abundance and diversity appear to increase. BIOS orchardists have observed that as decomposers become more abundant, plant litter is broken down increasingly rapidly. These observations are supported by some scientific studies (El Titi & Ipach, 1989; Luftenegger & Foissner, 1989; Kelly & Scott, 1990; Foissner, 1992) showing that farms with high inputs of organic matter have higher levels of some kinds of soil life and more rapid decomposition of cellulose.

Compost

A compost is formed during a biological process that converts organic materials such as manures, leaves, brush chippings, sludge, leaves, paper and food wastes into soil-like material through the action of microorganisms. Composts also differ from the raw materials in having higher concentrations of humic and fulvic acids (Hammond & Adams, 1987). These acids are complex organic chemicals derived from the breakdown of lignin in plant residues and from phenolic substances synthesized by microbes. Both humic and fulvic acids are essential in building cation exchange capacities (CEC) of soils; thus, compost may be an *indirect* source of nutrients. Research by Thompson et al. (1989) suggested that soil organic matter contribution to CEC ranges from 14-56%, depending on the parent materials, clay content, and method of determining CEC. Compost can also improve soil physical conditions (Tester, 1990).

The severity of phytopthora and other root rots may be lessened by compost, as has been suggested by studies in avocado orchards (see review by Chung et al., 1988). The mechanisms for this suppression are unclear. Composts contain microorganisms, such as fungi, algae, actinomycetes and bacteria that are mainly aerobic. These organisms may improve the decomposition of raw organic matter on the orchard floor.

Conclusion

A survey conducted after the first full year of BIOS generally indicates that growers have reduced synthetic pesticide and fertilizer applications and plan to increase their BIOS managed acreage. Most growers reported that they better understand the biology of the entire system and feel that with the cover crop, they are encouraging beneficial insects, mites and soil organisms. Many are reluctant to apply sprays which might disrupt the increased biological activity. We believe BIOS provides a successful model of a voluntary pesticide reduction program which uses an incentive-based strategy rather than regulation for pesticide reduction. With the passage of A.B. 3383, we will be seeing additional BIOS-type projects which will use this approach.

References

Altieri, M.A., and L.L. Schmidt. 1986a. Cover crop manipulation in northern California orchards and vineyards: Effects on arthropod communities. Biol. Agric. Hort. 3:1-24.

Altieri, M.A., and L.L. Schmidt. 1986b. Cover crops affect insect and spider populations in apple orchards. Calif. Agric. 40(1,2):15-17.

Barnett, W.W., L.C. Hendricks, W.K. Asai, R.B. Elkins, D. Boquist, and C.L. Elmore. 1989. Management of navel orangeworm and ants. Calif. Agric. 43(4):21-22.

Bugg, R.L. 1987. Observations on insects associated with a nectar-bearing Chilean tree, *Quillaja saponaria.* Pan-Pacific Entomologist 63:60-64.

Bugg, R.L., and R.T. Ellis. 1990. Insects associated with cover crops in Massachusetts. Biol. Agric. Hort. 7:47-68.

Bugg, R.L. and Heidler, N.F. 1981. Pest management with California native landscape plants. UC Appropriate Technology Program, Research Leaflet Series #8-78-28.

Bugg, R.L., M. Sarrantonio, J.D. Dutcher, and S.C. Phatak. 1991c. Understory cover crops in pecan orchards: Possible management options. Amer. J. Altern. Agric. 6(2):50-62.

Bugg, R.L., and C. Waddington. 1994. Managing cover crops to manage arthropod pests of orchards. Agric. Ecosyst. Environ. 50:11-28.

Chung, Y.R., H.A.H. Hoitink, and P.E. Lipps. 1988. Interactions between organic-matter decomposition level and soilborne disease severity. Agric. Ecosyst. Environ. 24:183-193.

Dlott, J.W., K.M. Daane, M.P. Jones, and I.M. Peterson. 1994. Participatory research in pest management: the impact of generalist predators on the peach twig borer in peaches. Plant Protection Quarterly 4(3):1-5.

Duke, J.A. 1981. Handbook of legumes of world economic importance. Plenum Press, New York. 345 pp.

El Titi, A. and U. Ipach. 1989. Soil fauna in sustainable agriculture: results of an integrated farming system at Lautenbach, F.R.G. Agric. Ecosyst. Environ., 27: 561-572.

Foissner, W. 1992. Comaprative studies on the soil life in ecofarmed and conventionally farmed fields and grasslands of Austria. Agric. Ecosyst. Environ. 40:207-218.

Hammoud, G.H.H., and W.A. Adams. 1987. The decomposition, humification and fate of nitrogen during the composting of some plant residues. p. 245-253. *In* M. De Bertoldi, M.P. Ferrranti, P. L'Hermite, and F. Zocconi (ed.) Compost: Production, Quality and Use. Elsevier Applied Science, New York.

Hendricks, L.C. 1991. Comparing organic to conventional culture methods in commercial almond production in Central California. Final Report to the University of California Sustainable Agriculture Research and Education Program.

Kelly, K.M., and R.R. Scott. 1990. A comparison of the winter soil surface fauna in organically managed and conventionally managed areas. *In* Proceedings of the 43rd New Zealand Weed and Pest Control Conference. p. 104-108.

Luftenegger, G. and W. Foissner. 1989. Investigations on the soil fauna of ecofarmed and conventionally farmed vineyards. Landwirtschaftliche Forschung 42: 105-113.

Meagher, R.L. Jr., and J.R. Meyer. 1990b. Influence of ground cover and herbicide treatments on *Tetranychus urticae* populations in peach orchards. Experimental and Applied Acarology 9:149-158.

Ouyang, Y., E.E. Grafton Cardwell, and R.L. Bugg. 1992. Effects of various pollens on development, survivorship, and reproduction of *Euseius tularensis* (Acari: Phytoseiidae). Environ. Entomol. 21:1371-1376.

Ruz Jerez, B.E., P.R. Ball, and R.W. Tillman. 1988. The role of earthworms in nitrogen release from herbage residues. p. 355-370. *In* Jenkinson, D.S., and K.A. Smith (ed.) Nitrogen Efficiency in Agricultural Soils. Elsevier Applied Science, London and New York.

Smith, M.S., Frye, W.W. & Vacro, J.J. (1987). Legume winter cover crops. Adv. Soil Sci. 33, 141-163.

Tester, C.F. 1990. Organic amendment effects on physical and chemical properties of a sandy soil. Soil Sci. Soc. Amer. J. 54:827-831.

Thompson, M.L., H. Zhang, M. Kazemi, and J.A. Sandor. 1989. Contribution of organic matter to cation exchange capacity and specific surface area of fractionated soil materials. Soil Sci. 148:250-257.

Vereijken, P. 1989. From integrated control to integrated farming, an experimental approach. Agric. Ecosyst. Environ. 26:37-43.

Williams, W. 1966. Management of nonleguminous green manures and crop residues to improve the infiltration rate of an irrigated soil. Soil Sci. Soc. Amer. Proceedings. 30:631-634.

Can the Total N Needs of a Peach Tree be Applied by Foliar Urea?

R. Scott Johnson, Extension Pomologist
Department of Pomology
Davis @ Kearney Agricultural
Center

Harry L. Andris, Farm Advisor
U. C. Cooperative Extension
Fresno County

Supplying the total nitrogen needs of a peach tree through foliar fertilization is an intriguing idea that could have tremendous environmental implications. With minimum inputs of N to the soil, leaching of nitrates to the groundwater would be eliminated or at least greatly reduced. Even if foliar fertilization only supplemented the amount of soil N applied, it would still help minimize the problem of groundwater degradation.

The idea of foliar feeding with urea and other N containing compounds is not new (Swietlik & Faust, 1984). There is voluminous literature spanning the last 50 years on this subject. Many different plants including fruit and nut crops have been tested. In general, these studies have shown that N from foliar urea sprays is taken up rapidly and efficiently. Many reports indicate >80% of the applied N is taken up within 24 to 48 hours. However, currently within commercial orchards, foliar fertilization is not widely practiced.

There are probably several reasons why fruit growers have not accepted this practice as a viable option for nitrogen fertilization. First, nitrogen is needed in such large quantities in the plant that many separate applications would be required. At concentrations which do not cause leaf phytotoxicity it has been estimated that 10-20 individual sprays would be needed to meet the full N requirements of a fruit tree. This is simply impractical for most fruit growers. Second, the practice of soil fertilization has been so simple and effective that growers have not been motivated to change it. It has not been until very recently that this practice has been considered an environmental problem.

Because of the potential for soil applied nitrogen to contaminate groundwater supplies, we are pursuing a new approach to foliar fertilization which could be practical for growers and just as easy to implement as soil fertilization. The idea was first proposed by Oland (1960) and Titus (1972) on apple trees. This approach is to apply high rates of low biuret urea in the fall when leaffall is imminent so phytotoxicity and defoliation are not major concerns. The rates are high enough to supply about 50 to 100 lbs N/acre so only one or two sprays should be necessary. It might even be possible to combine at least one of these applications with other standard sprays, requiring no extra work for the grower.

As we started to investigate this idea, a number of questions came to mind. We felt it was important to start with the most basic questions first and build from there so we could confidently recommend this practice to growers.

The questions we have concentrated on are as follows:

1) Besides damaging the leaves, do high rates of urea cause any economical damage such as bud mortality, shoot dieback, or fruit quality problems?

2) Is urea taken up by peach leaves?

3) If urea is taken up by peach leaves, is it quickly moved out into the rest of the tree before spray-induced or natural leaffall occurs?

4) Is N from urea stored in the roots and other tissues and made available for growth in the subsequent year?

5) Can the long-term productivity of a peach tree be maintained by foliar urea alone?

To answer these questions, we have conducted a series of experiments over the past few years. The results have generally been very positive and encouraging. Herewith are our current answers to these questions.

<u>Do high rates of urea damage peach trees or fruit?</u>

We felt it was important to start with this question because one prominent fertilizer salesman in the area has claimed foliar urea will increase the incidence of double fruit formation. Therefore, we set up an experiment on Queencrest peach testing 6 different combinations of rate and timing. This was a well replicated trial (6 reps) in a uniform field so reliable statistics could be obtained. Over a two year period (1992-93) the foliar urea sprays caused no reduction in fruit set and no problems with fruit doubling or fruit quality. In this and a subsequent trial, some urea treatments have reduced flower density by about 20% compared to the control. However, if anything, this is a positive effect because extensive fruitlet thinning always needs to be carried out. In all of these trials, no shoot dieback or bud mortality has been observed. Therefore, we conclude that foliar urea does not damage the tree or fruit quality.

Is urea taken up by peach leaves?

This is an important question to answer because early studies on peach claim foliar urea is not effective (Norton & Childers, 1954, Weinberger, et al. 1949). These references are widely cited in current literature. To answer this question we used several different approaches. First, we applied a technique of rinsing leaves at specific intervals after application and analyzing the rinse solution for urea. We have repeated this experiment several times and consistently see a pattern of rapid uptake by the leaves (Fig. 1). Within 24 hours, 80% of the applied urea has disappeared from the leaf surface. This is consistent with the pattern reported for many other fruit species.

As a second approach to this question, we also analyzed the same leaves for total nitrogen content. The pattern of N increase within 24 hours after application parallels the disappearance of urea from the leaf surface (Fig. 1). This is further evidence of urea uptake by peach leaves.

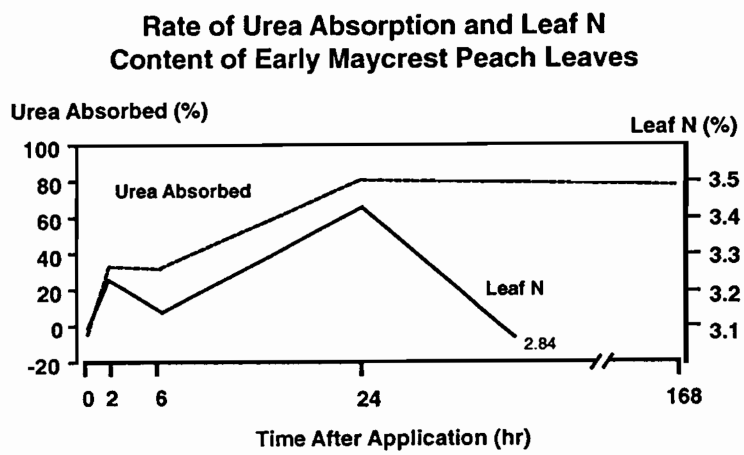


Figure 1.

Finally, we have recently conducted some preliminary studies using N^{15} labelled urea. The results support the conclusion that more than 90% of the applied urea is taken up by peach leaves within 1 week of application. Therefore, results from several studies offer strong evidence that urea is taken up quickly and efficiently by peach leaves.

Is the N from urea translocated out of the leaf before leaffall?

The answer to this question depends somewhat on the concentration of urea applied since higher rates cause more rapid defoliation. Based on several studies, we have concluded that rates of 4% (w/w, i.e. 4 lbs. urea (46% N) in 100 lbs. solution) to 8% do not promote too rapid defoliation. Therefore, this is generally the range we have been working within. When sprayed at 300 gals/acre, a 4% solution applies ~50 lbs N/acre.

The evidence for translocation of N out of the leaf comes mostly from data on leaf N changes over time. Figure 1 shows a rapid decrease in leaf N between 24 hrs and 1 week after application. Likewise, in a second experiment comparing 4.3% and 6.5% urea solutions, leaf N increased quickly after 24 hours but dropped back down within 1 week (Fig. 2). At 1 week there was no difference between the 4.3% urea spray and the unsprayed control. Since very little defoliation occurs within the first week at these concentrations, the conclusion can be drawn that the applied N is largely translocated out of the leaf before it falls.

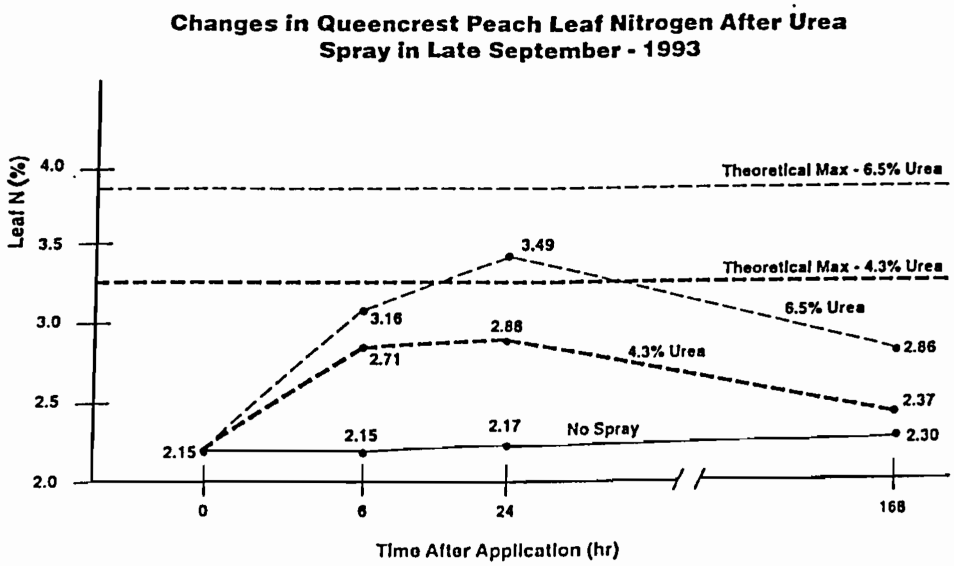


Figure 2.

<u>Is the N from urea sprays stored in the tree and available for growth the following year?</u>

This is another important question to ask because of early reports that foliar applied urea does not supply N to the roots very effectively (Forshey, 1963). To help answer this question, an experiment was initiated in the fall of 1993 in a block of Early Maycrest peaches that was quite N deficient. Two foliar urea treatments were imposed, both applying a total of 150 lbs. N/acre. The first treatment comprised 3 applications of a 4.3% (w/w) urea solution sprayed in 300 gals/acre solution. Applications were made at 2 week intervals between late September and late October. The second treatment was a single application in late October of a 13.0% (w/w) urea solution. These were compared to an unfertilized control and a soil fertilized treatment (100 lbs. N/acre as calcium nitrate in mid September) with each replicated 4 times.

Root and shoot samples taken during dormancy showed increased levels of N by all 3 fertilized treatments compared to the control (Table 1). Root levels were about double the unfertilized control with no significant differences among the 3 fertilized treatments. This provides strong evidence that foliar urea can supply N to help build root reserves. In the spring of 1994, all three fertilized treatments were noticeably different from the unfertilized control in leaf color and shoot growth.

Table 1. The effect of low biuret foliar urea sprays on Early Maycrest peach.

	Dormant Shoot N (%)	Dormant Root N (%)	May 1994 Harvest Yield (kg/tree)	Average Fruit Weight (g)
Unfertilized Control	1.31 b	.78 b	39.7	102.7 c
Soil Applied 100 lb N/acre in Sept. 1993	1.76 a	1.61 a	36.5	117.5 a
Foliar Urea 4.3% - 3 sprays in Sept., Oct. 1993	1.76 a	1.58 a	37.7	110.2 b
Foliar Urea 13% - 1 spray in Oct. 1993	1.63 a	1.39 a	40.1	110.2 b
Significance	.0001	.0002	NS	.0009

To continue addressing this question, plans are underway to use N^{15} labelled urea so more definitive data can be obtained.

<u>Can the long-term productivity of a peach tree be maintained by foliar urea alone?</u>

We won't have the final answer to this question for several more years but preliminary results are giving some indications. Yield data from the experiment mentioned above bring up some concerns with foliar urea. Total yield among the 4 treatments was no different but average fruit weight was (Table 1). The soil fertilized treatment had the largest fruit weight, the control had the smallest and the 2 foliar treatments were half way between. The cause of these differences is still unknown but it raises questions about the possibility of foliar urea leading to nutrient imbalances, lack of root growth or some other physiological problem. More information will need to be collected before firm conclusions can be drawn.

Conclusions

At this time we are cautiously optimistic about the possibilities of foliarly feeding peach trees with low biuret urea. It appears to be an efficient and environmentally sound way of supplying N to the tree without causing damage. We are not ready to recommend it as a complete substitution for soil fertilization but it definitely can supplement this practice. With one or two fall sprays of urea, soil applications can probably be cut in half. Currently, we are pursuing the idea of combining urea with zinc sulfate sprays which growers normally apply in October or early November. The preliminary results of this study are very encouraging.

Literature Cited

Forshey, C. G. 1963b. A comparison of soil nitrogen fertilization and urea sprays as sources of nitrogen for apple trees in sand culture. Proc. Amer. Soc. Hort. Sci. 83:32-45.

Norton, R. A. and N. F. Childers. 1954. Experiments with urea sprays on the peach. Proc. Amer. Soc. Hort. Sci. 63:23-31.

Oland, K. 1960. Nitrogen feeding of apple trees by postharvest urea sprays. Nature 185:857.

Swietlik, D. and M. Faust. 1984. Foliar nutrition of fruit crops. Horticultural Reviews 6:287-355.

Titus, J. S. 1972. Post-harvest urea sprays can supply nitrogen to the apple. Trans. Ill. State Hort. Soc. and Ill. Fruit Council 106:52-53.

Weinberger, J. H., V. E. Prince, and L. Havis. 1949. Tests on foliar fertilization of peach trees with urea. Proc. Amer. Soc. Hort. Sci. 53:26-28.

Plant Potassium Availability in California Soils

Robert O. Miller[1]

Introduction

Potassium nutrition continues to be an extremely important to agricultural productivity in California. In 1993 161,650 tons of K_2O fertilizer materials were applied to agricultural crops in California an increase of 170 % since 1990. The dynamics of available soil K are to a large degree driven by plant uptake and accumulation. Generally, uptake of potassium by annual crops can be separated into three phases: (1) period of slow steady uptake occurring during seedling vegetative growth; (2) period of rapid accumulation coinciding with rapid canopy expansion; and (3) period or slow uptake and retranslocation occurring during reproductive growth (Figure 1). Potassium accumulation and rate of uptake varies greatly across annual crops in California (Table 1). Maximum accumulation rates range from 4-12 pounds per acre per day for cereal, vegetable, forage and fiber crops. Potassium removal, that removed with harvested biomass, is greatest for vegetable and forage production systems. Removal of K by successive crops over time has led to a depletion of soil potassium on specific soils (Cassman, 1991).

The dynamics of soil potassium availability is determined by dissolution and desorption of K from soil minerals and soil nutrient transport mechanisms. Although soils may contain 2 % K by weight a majority of this not available to plants and is associated with mineral structures and/or in nonavailable forms. Specifically the amount and type of soil minerals (ie. feldspars micas, vermiculite) determine the labile K pool and the amount phytoavailable. Micaceous minerals may contain 6-8 % K by weight and readily release large quantities over time. Vermiculitic minerals may contain 1 % K by weight and reabsorb potassium from labile pools and fertilizer materials.

Soil nutrient transport is classified into three primary mechanisms: (1) root interception; (2) mass flow; and (3) diffusion. Root interception is that fraction of K absorbed via direct root contact and accounts for approximately 2% of uptake. Mass flow is the movement of K transported via the convective flow of water associated with evapotranspiration and can be estimated by multiplying the quantity of water transpired by the K concentration found in the soil solution. Generally mass flow only accounts for 20 % of the total accumulated during periods of maximum plant uptake. Therefore by default diffusion is the primary soil transport mechanism in soils (Table 2). Diffusion is described as the process by which a solute moves along a concentration gradient from a zone of

[1] Department of Land Air and Water Resources, University California Davis

high concentration in the bulk soil to one of low concentration at the root-soil interface. Because diffusion is affected by several factors such as soil water content, it cannot be easily estimated in soil. Although several researchers have successfully described mechanistic nutrient accumulation models based on solving equations of nutrient transport mechanisms (Barber, 1985), these have been of limited use due to their complexity and large number of variables.

Currently phytoavailable potassium is best evaluated through the use of chemical extractants which have been developed intuitively through plant nutrition and soil chemistry research. Several of these extractants (ie. soil tests) have been described in the literature all which have shown correlation with plant response (growth, uptake, or yield). However, only 2-3 have shown to be widely adopted due to feasibility and/or the availability of a correlation database. In the last 15 years funding support for continued development of existing soil extractants and that of new ones has declined in the presence of other agriculture research priorities and the relative low cost of fertilizer materials relative to the commodity revenue. Generally these existing methods, although lacking refinement do approximate K phytoavailability. With new crop cultivars, cultural management practices, increasing commodity yields, and the affects of decades of crop K removal, the question of soil phytoavailable potassium is now being revisited in California agriculture.

Cotton K Research

Cotton in Califorina has been shown to have a high potassium requirement and in 1992 a research project was initiated to update cotton fertility guidelines in California. A major component of this project was to evaluate existing and new methods of cotton K phytoavailability. In 1993 and 1994, sixteen locations were selected across six counties of the San Joaquin valley of California where K fertilizer field trials were established using the Acala cotton cultivar maxia. Treatments consisted of deep banding of 0 and 400 lbs of K_2O per acre using a replicated experimental design. Soils were sampled at three depths per location and were evaluated for K phytoavailability using ten existing chemical extraction methods. Crop tissue analysis was conducted through the season and yield components were determined at harvest.

For 1992 there wre significant cotton lint yield responses to K fertilizer at 6 of 16 locations. Results of this research have shown lint yield response is best described using subsoil samples of the 5-15 inch depth (Figure 2), independent of the soil extraction method utilized. Higher correlation of yield response to extractable K in subsurface samples is attributed to higher root density found at these depths relative to the surface samples. Of the ten methods evaluated, 1.0 N ammonium acetate, Mehlich 3 and 0.5 N ammonium bicarbonate - DTPA (AB-DTPA) extractants were all correlated with lint yield response. Soil solution K, nitric acid K, resin extractable K and the Unocal-K extractions were not correlated with lint yield responsesto K fertilizer. Based on Cate-Nelson statistical analysis of the 1993 data the soil critical value for K at the 5-15 inch depth is 90 mg kg^{-1} using the 1.0 N ammonium acetate or the Mehlich 3 extractants.

Although all locations had cotton petiole concentrations in excess of 4 % at the onset of bloom subsequent sampling indicated dramatic shifts in petiole K concentrations which was location dependent. Cotton petiole concentrations less than 2.75 % K at peak bloom were indicative of lint yield responses to K fertilizer (Figure 3). Cotton petiole concentrations at peak bloom were highly correlated with ammonium acetate, Mehlich 3 and AB-DTPA and were best described by quadratic functions. Petiole concentrations prior to defoliation, (four weeks post initiation of bloom) indicated that concentrations less than 1.3 % were indicative of lint yield responses. Although sampling at this date is too late for use in fertilizer management in the current year, it can be used as tool for subsequent year nutrient management. Using a modification of the K-fixation technique described by Cassman et al (1989), soils were evaluated for K-fixation potential. Results indicate subsoils that were capable of fixing greater than 60 % of applied K, were highly responsive to K fertilizers. In developing a potassium fertilizer management program for cotton in California this research strongly supports an intergrated soil-plant analysis program which evaluates both soil potassium availability and K fixation potential in conjunction with in season petiole analysis. This research project will continue in 1995 and 1996 with emphasis on calibration research.

Literature

Barber, S. A. 1985. pp. 90-102. Soil nutrient bioavailability a mechanistic approach. John Wiley and Sons. New York.

Cassman, K G., T.A. Kerby, B.A. Roberts, D.C. Bryant and S.L. Higashi. 1990. Cotton response to Potassium nutition effects on lint yield and fiber quality of Acala cotton. Crop Sci. 30:672-677.

Cassman, K.G. 1986. Soil crop management and plant factors which influence cotton potassium nutrition on vermiculitic soils of the San Joaquin Valley. J. Fert. Issues 3:38-45.

Roberts, Bruce Thomas Kerby and Bill Weir 1993. Foliar fertilization of cotton in California. Symposium: Foliar fertilization of Soybeans and Cotton. Proceedings if SSSA Cincinnati Ohio, November 8, 1993.

Figure 1. Potassium accumulation and partitioning by wheat, Yolo County California 1989

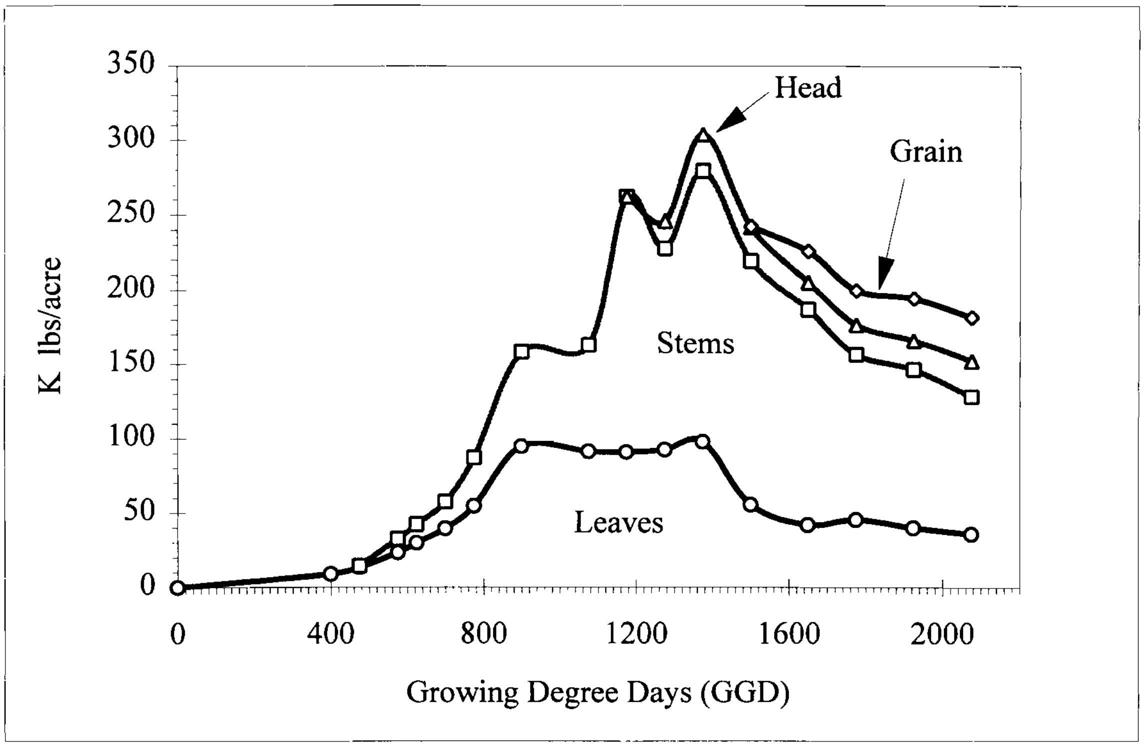


Table 1. Potassium accumulation, rate of maximum uptake and harvested with yield for six major crops in California.

Crop	Total K Uptake lbs/ac	Maximum K Uptake Rate lbs/ac/day	K Removed with Harvest lbs/ac
Wheat	300	4 - 8	30
Cotton	180	5 - 7	60
Alfalfa	400	4 - 8	400
Tomato	300	5 - 10	240
Pepper	300	4 - 9	180
Celery	400	6 - 12	250

Figure 2. Relative cotton lint yield response versus ammonium acetate soil extractable K 5-15 inch depth, 1993.

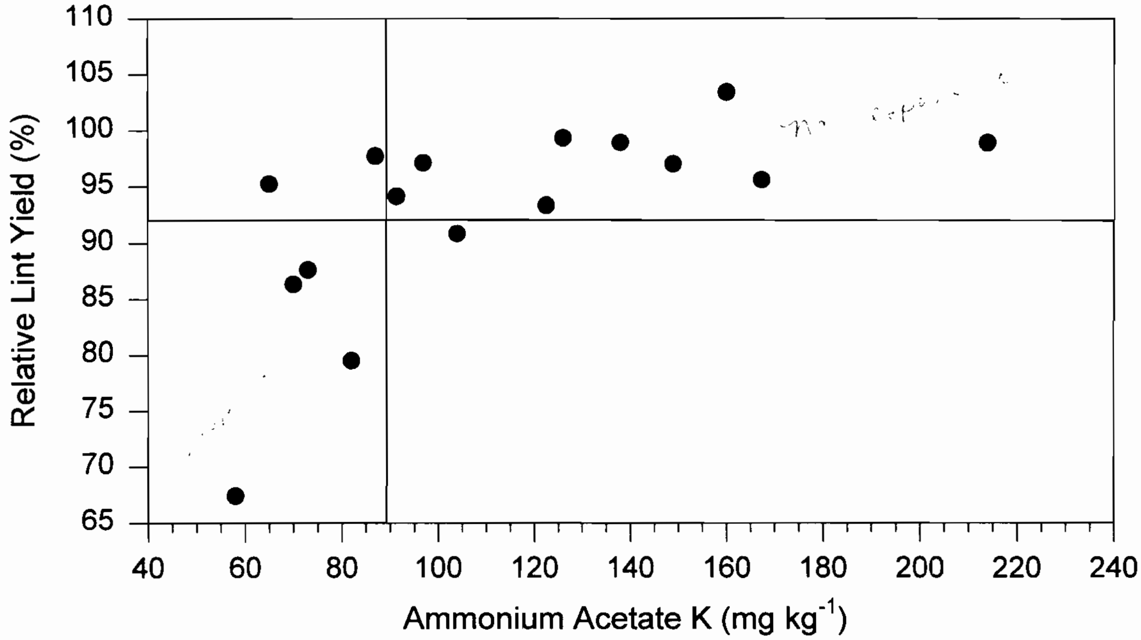
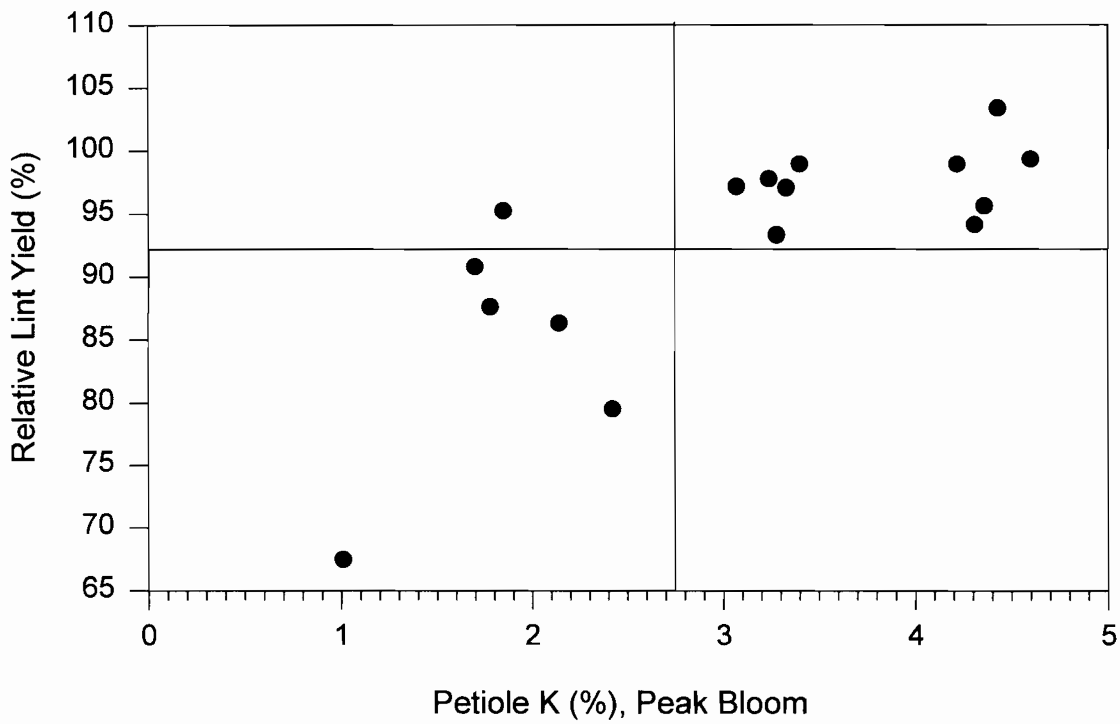


Figure 3. Relative cotton lint yield response versus control treatment cotton petiole potassium at peak bloom, 1993.



Spatially Distributed Nitrogen Recomendations

C. A. Redulla, J. L. Havlin, G. J. Kluitenberg, M. D. Schrock, N. Zhang

INTRODUCTION

National concern for groundwater quality has generated numerous studies documenting agriculture's role in groundwater contamination by pesticides and fertilizers (1,2,3). Although nitrate (NO_3^-) contamination of groundwater has been reported in almost every state, the areas of greatest concern occur in heavily populated states and in semi-arid states with intensive irrigated agriculture (1). Over 5 million ha are irrigated in Nebraska, Colorado, and Kansas (4). Recent studies have documented considerable groundwater nitrate contamination under center-pivot irrigation, especially on coarse-textured soils (5,6). The major factors contributing to groundwater NO_3^- under center-pivots include (1) irrigation /fertilizer nitrogen (N) rates above that required for optimum production, (2) shallow depth to groundwater, (3) irrigation during non-crop periods to leach soluble salts, and (4) NO_3^- in the irrigation water not considered as plant available N (4).

Reducing the potential for NO_3^- contamination of groundwater under irrigated soils primarily depends on reducing the quantity of fertilizer N remaining in the soil after harvest. Many studies have reported as much as 100 kg NO_3^- ha $^{-1}$ yr^{-1} in the soil profile after harvest (4,6). Fertilizer nitrogen (N) application timing, method of application, nitrification inhibitors, and N credits for manure and legume mineralizable N and for N in the irrigation water are important management practices for reducing NO_3^- leaching potential; however, the most important factor in reducing the quantity of N remaining in the soil after harvest is to apply the 'correct' fertilizer N rate (7,4).

Fertilizer N rates are determined by models generally represented by:

N recommendation = a(yield goal) - b(soil test N) - c(factors)

The 'factors' term include adjustments or corrections for previous crops. Soil test N represents extractable inorganic N determined prior to planting. Soil profile NO_3^- is highly correlated to yield response to fertilizer N and is routinely used in making N recommendations in the Great Plains. In the above model, 'yield goal' influences the quantity of fertilizer N recommended more than any other term.

Quantifying the spatial distribution in yield and soil test N will enable development of spatially distributed yield goals and soil N, which can be subsequently used to provide spatially variable N recommendations. Variable application of N, based on spatially variable yield goals and soil N, should reduce over-application of N and the quantity of leachable N left in the soil after harvest, which should reduce non-point source pollution hazard.

PROCEDURES

Two center pivot-irrigated cornfields in south central Kansas, Phillips and Rice, were chosen for this study. The Phillips and Rice fields averaged 84 and 91% sand and 9 and 6% clay content, respectively.

The 1993 yield map was obtained using a flow-sensor equipped combine. Yield goals were adjusted based on the last 5 years' average yields. Grid sampling on 60 by 60 m grids was done in March 1994 to get the soil nitrate for the 0-60 cm soil layer. These data were then used in the N recommendation model for each 60 by 60 m cell. The equation used was:

$$N_{rec} = (0.0241 \times YG \times 1.1) - (0.9375 \times NO_3)$$

where

N_{rec} = N fertilizer rate (kg N ha^{-1})
YG = cell yield goal (kg ha^{-1})
1.1 = textural factor for sandy soil
NO_3 = nitrate content for the 0-60 cm soil layer (kg ha^{-1})

The following procedure was done to test the relative importance of the soil nitrate map and the yield goal map in predicting N_{rec} on these fields:

1. Delete one-half of the soil nitrate data, deleting every other cell datum.
2. Use geostatistical tools, namely the semivariogram and kriging, on the remaining half to estimate the other half of the data.
3. Use this new set of data (½ original data and ½ kriged data) in the N_{rec} equation.
4. Apply some statistical tests to compare the original N_{rec} map with the new N_{rec} map.
5. Repeat from Step 1 using the other half of the data. This is also done on the yield goal data.

RESULTS

Figures 1 and 2 show the soil nitrate and yield maps for Phillips' field.

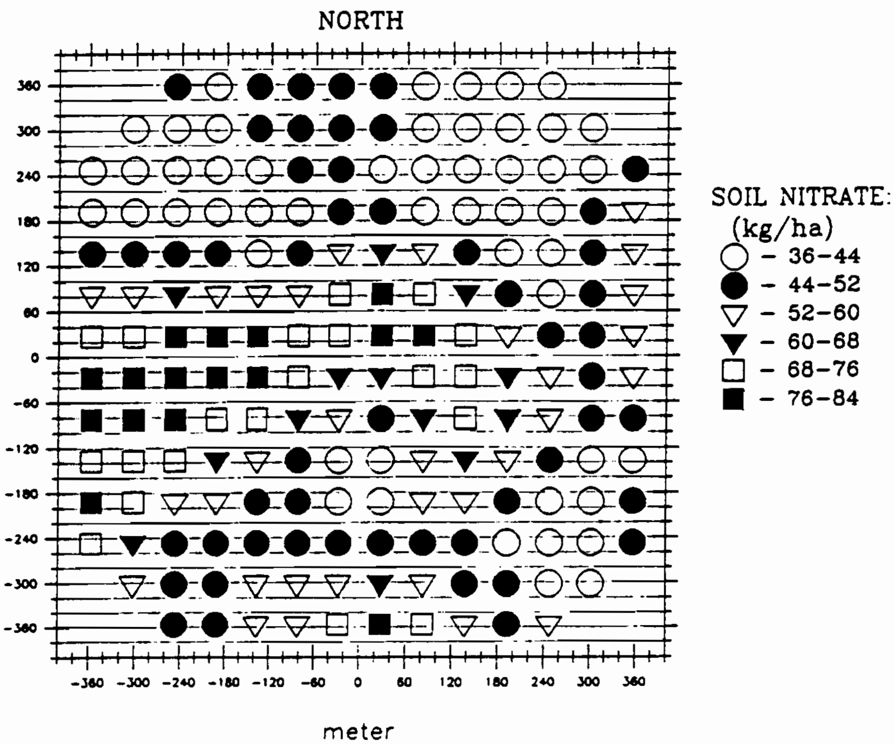


Fig. 1. Soil nitrate (0-60 cm layer) map of Phillips' field, 1994 Spring sampling.

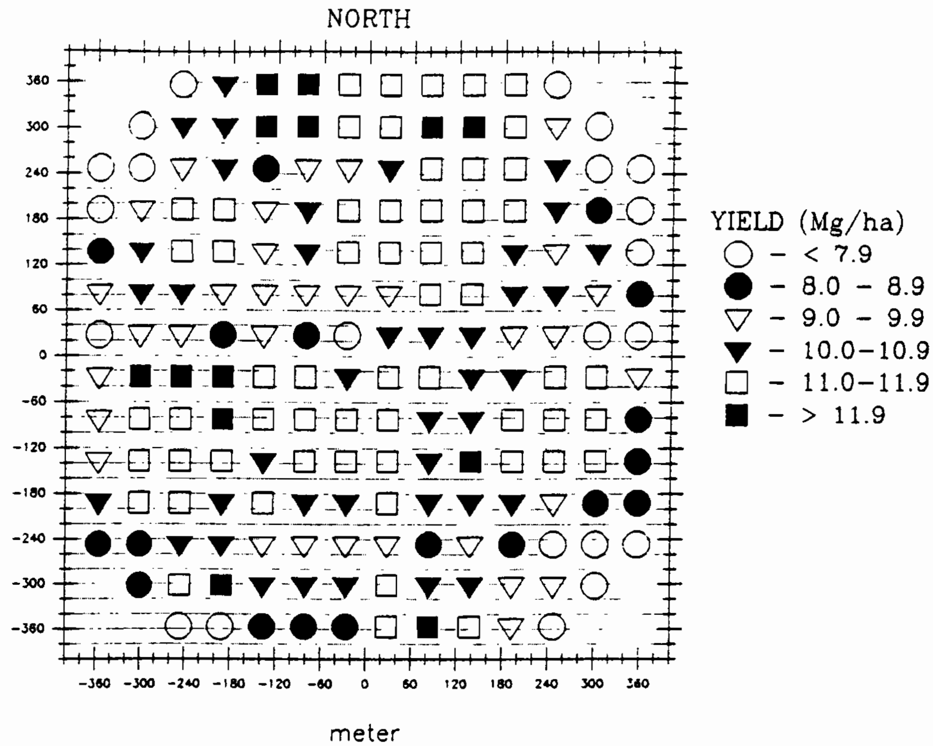


Fig. 2. 1993 corn yield map in Phillips' field.

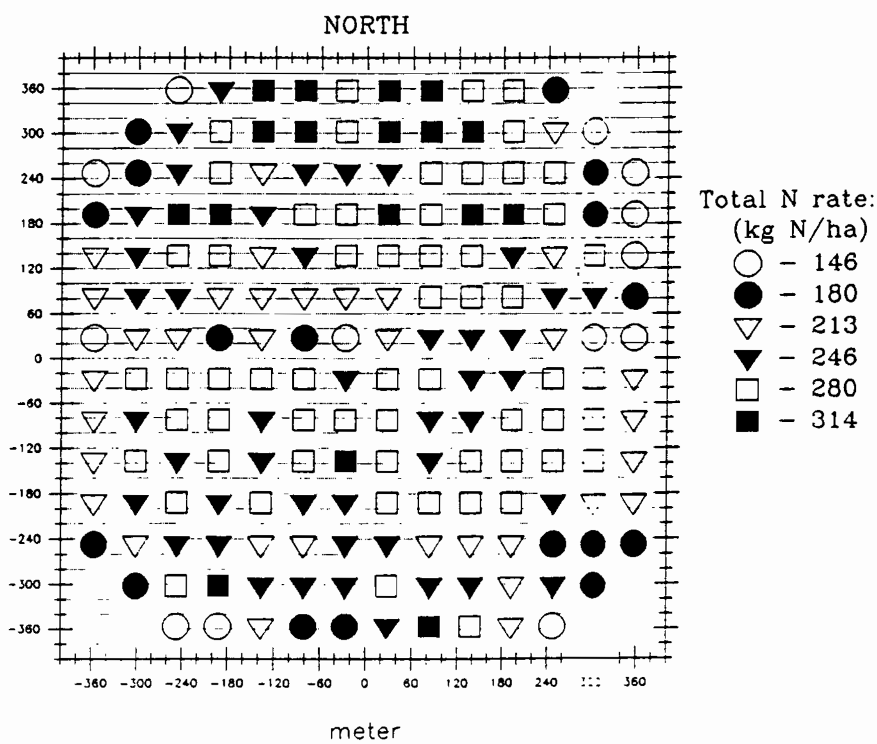


Fig. 3. The N_{rec} map of Phillips' field for 1994 Spring.

Table 1. Some descriptive statistics of the original N_{rec} maps of the two fields which was based on the equation:

$$N_{rec} = \underbrace{(0.0241 \times YG \times 1.1)}_{A} - \underbrace{(0.9375 \times NO_3)}_{B}$$

	Field							
	Phillips				Rice			
	ave.	min.	max.	S.D.	ave.	min.	max.	S.D.
N_{rec}	243	99	316	48	227	96	341	57
YG	11066	6283	13837	1803	10661	5245	15573	2395
NO_3	54	36	84	13	59	33	81	13
A	293	167	367	48	283	139	413	64
B	51	34	79	12	55	31	76	12

From Table 1, it is clear that the relative contribution of yield goal (*A*) to the N recommendation is almost six times greater than the contribution of soil nitrate (*B*).

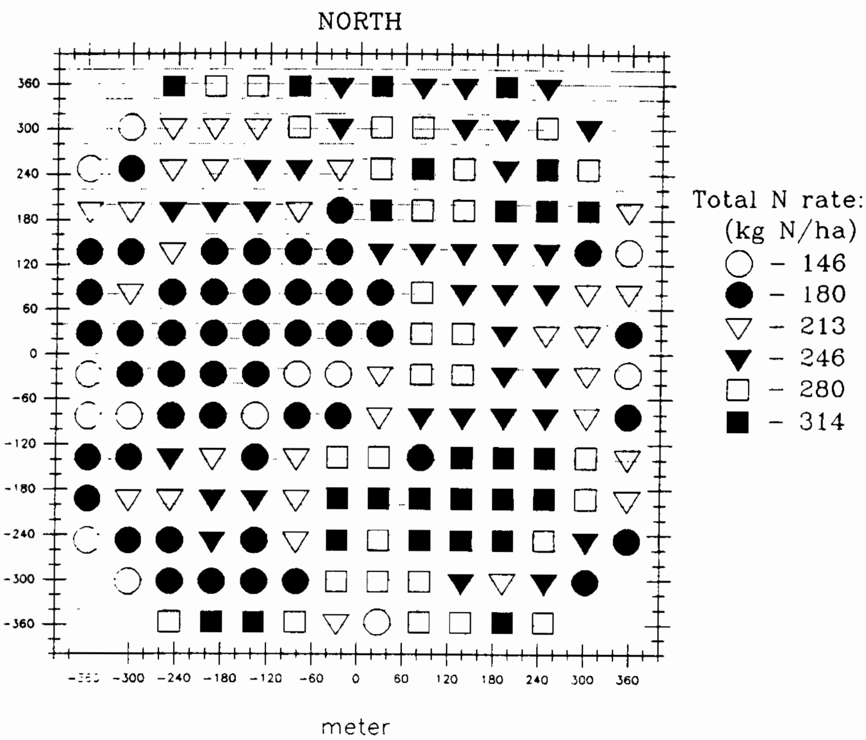


Fig. 4. The N_{rec} map of Rice's field for 1994 Spring.

Note that in Rice's field, the N_{rec} increases in the west-east direction. This was due to the the same trend observed in the yield map for this field.
To compare the modified N_{rec} maps to the N_{rec} maps in Fig. 3 and 4, a simple statistical test was done. For each cell, the difference of the two N_{rec} values were calculated and then squared. The sum of the squares for all the cells is presented in Table 2.

Table 2. Sum of the squared difference for the modified N_{rec} maps (1/2 of either soil nitrate or yield goal data is estimated) when compared to the original N_{rec} map (x = cell value of the original N_{rec} map, x_i = cell value of the modified N_{rec} map) using the six levels to total N rate.

Field	$\sum(x - x_i)^2$			
	Soil nitrate		Yield goal	
	(a)	(b)	(a)	(b)
Phillips	4557	4557	95912	107063
Rice	4356	5579	104891	95911

Again, it is shown that yield mapping is essential in obtaining the variable-rate N_{rec} map. However, the Wilcoxon matched pair signed-rank test showed that for all the modified N_{rec} maps, H_0 ($\mu = 0$) or the null hypothesis can not be rejected. Basically, all the modified N_{rec} maps have the same average nitrogen rate recommendation as the original N_{rec} map.

SUMMARY

Variable application of N is being compared to traditional or uniform N management to irrigated corn grown on sandy soils. Based on spatially variable yield goal and preplant soil profile NO_3^- concentration, spatially distributed N recommendations were developed using the Kansas State University N recommendation model. Although yield response data have not been summarized at this printing, several conclusions/observations can be made. First, yield goal as determined by combine monitoring grain yield in the previous year, influences the distribution of N recommendations more than preplant profile NO_3^- concentration. In fact, drastically reducing the number profile soil samples used to establish the spatial distribution of profile NO_3^- had little effect the spatial distribution of N recommendations. Second, fertilizer N was applied on 60 m by 60 m, which may not be small enough to reflect the variability in these fields. Within some of the individual grids, elevation can change by 8 to 10 m, which can influence yield goal and other parameters that may influence optimum N rate. Analysis of the yield monitored data will answer this question. Using the same grid structure, profile NO_3^- concentration after harvest and total N uptake by the crop are being quantified to assess the effect of variable and uniform N application on fertilizer N recovery. The hypothesis of the experiment is that variable application of N, based on spatially variable yield goal and profile NO_3^-, should reduce over-application of N and the quantity of leachable N left in the soil after harvest. The frequency of under-application of fertilizer N also should be reduced, which should enhance productivity. As soon as the analysis of the 1994 crop response data is completed, we can provide a copy of the provide. Please contact J.L. Havlin, Dept. of Agronomy, Kansas State University, Manhattan, KS, 66506.

REFERENCES

1. Madison, R. J. and J. O. Brunett. 1985. Overview of the occurences of nitrates in groundwater of the US. US Geol. Survey Water Supply Paper 2275. pp. 93-105.

2. Steichen, J., J. Koelliker, D. Grosh, A. Heiman, R. Yearout, and V. Robbins. 1988. Contamination of farmstead wells by pesticides, volatile organics, and inorganic chemicals in Kansas. Ground Water Monitoring Review. 8:153-160.

3. Exner, M. E., and R. F. Spalding. 1990. Occurence of pesticides and nitrate in Nebraska's Ground Water. Publication WC1, Water Center, Univ. of Nebraska.

4. Power, J. F., and J. S. Schepers. 1989. Nitrate contamination of groundwater in North America. Agriculture, Ecosystems and Environment. 26:165-187.

5. Schepers, J. S., and L. N. Mielke. 1983. Nitrogen fertilization, mineralization, and leaching under irrigation in the midwest. pp. 325-334. *In* R. Lowrence, R. Todd, L. Asmussen, and R. Leonard (Eds) Nutrient Cycling in Agricultural Ecosystems. Univ. GA Coll. Agric. Spec. Pub. No. 23, Athens, GA.

6. Hergert, G. W. 1986. Nitrate leaching through sandy soils as affected by sprinkler irrigation method. J. Environ. Qual. 15:272-278.

7. Jackson, G., D. Keeney, D. Curwen, and B. Webendorfer. 1987. Agricultural management practices to minimize groundwater contamination. p. 114. Environ. Resources Center, Univ. of Wis., Wis. Dept. Nat. Resources, Madison, WI.

Software Developed / the Process of Development

Software GIS Geographic Information System

FIS - Field Information System

Long Term Research on Agricultural Systems (LTRAS):

A 100-year Experiment Begins at U.C. Davis

R. Ford Denison, Associate Professor

Agronomy and Range Science, University of California, Davis

Low Input Sustainable Agriculture -- Tautology or Oxymoron?

Questions of sustainability and environmental impact often dominate the public debate on agriculture in California. The future availability of irrigation water and other inputs will depend in part on a public perception that agriculture is using water and nonrenewable resources efficiently and in a way that does not threaten wildlife or human health. It has been suggested that cropping systems that rely heavily on irrigation or synthetic inputs may be unsustainable. Various environmental and consumer groups are advocating a decrease in the use of agricultural inputs such as water, fertilizers, and pesticides. To some extent, criticism of current agricultural practices reflects an irrational fear of technology, but there may also be legitimate concerns about the long-term effects of these practices on soils, groundwater, and wildlife. In many cases, there are gaps in the objective scientific information base needed to make sound agronomic and policy decisions. This is particularly true for problems or potential problems that might develop, if at all, only over a period of decades.

In 1990, the University of California at Davis responded to public and industry concerns by establishing a new 300-acre field facility near campus for research on the long-term sustainability and environmental impact of agriculture. The first experiment at this Long Term Research on Agricultural Systems (LTRAS) facility examines the relationship between the sustainability of annual field crop systems and two key inputs -- water and nitrogen. This experiment occupies about 80 acres and has a planned duration of 100 years, reflecting the long time constants typically found for changes in some critical soil properties.

Experimental Design and Expected Results

The ten cropping systems at LTRAS include fully irrigated rotations based on corn and processing tomato, rainfed systems based on winter wheat, and winter wheat systems with supplemental irrigation. Within each irrigation treatment, we are comparing systems relying on nitrogen fertilizer with systems which use winter legume cover crops as a possible alternative source of nitrogen. The experimental design also includes unfertilized controls (with and without irrigation), and a corn/tomato rotation managed according to organic guidelines. Each two-year rotation is represented by both starting points, with three replicate one-acre plots.

Sustainability of each cropping system will be assessed from long-term trends in agricultural productivity, profitability, resource-use efficiency, and environmental impact. Underlying changes in measurable aspects of "soil quality", including pH, organic matter, weed seed banks, salinity, etc. will also be measured and analyzed.

In addition to characterizing and comparing the sustainability of ten specific cropping systems, research at LTRAS is expected to uncover more general principles. These principles will then be used to design cropping systems with improved performance. A secondary goal is the development of new analytical tools, including computer models, to predict long-term sustainability from farm records or short-term experiments.

"Time Zero" Site Characterization and Archival Sampling

A thorough characterization of initial conditions at the LTRAS site was considered essential to the success of this long-term experiment. These "time zero" data will be used to characterize the transition from previously uniform management (four years of commercial alfalfa production, followed by two years of sudangrass) to cropping systems differing in reliance on external inputs of water and nitrogen. Knowledge of initial conditions will improve our ability to resolve short- and long-term treatment effects.

We began by visiting the oldest long-term experiment in the world, the Rothamsted Experimental Station, in England. Researchers there emphasized the importance of collecting and saving archival soil and plant samples; theirs date back to 1843.

As part of our characterization of initial conditions, we collected over 1000 soil samples, composited by depth to 6 ft. Other archival samples include 288 intact soil cores to 6 ft and five cores from surface to groundwater (50 ft). We anticipate that these samples will be analyzed by future generations of scientists to answer questions we haven't even thought of yet, possibly using methods not yet invented.

Biological archival samples include weed seeds, preserved at -80 C, that were collected from temporary "weed preserves" in which weeds were permitted to set seed in 1994. Hundreds of soil samples collected with a flame-sterilized sampling device were freeze-dried aseptically to preserve microorganisms and DNA. These billogical samples will allow scientists working at LTRAS to study gradual genetic changes in populations of weeds and soil microorganisms in response to management practices, including pesticides, cover crops, fertilization, and irrigation.

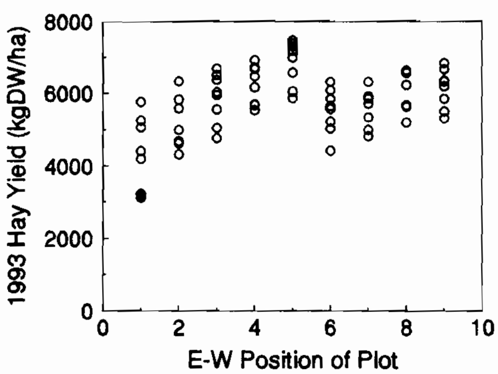


Figure 1. Yields by plot of a uniformly managed "time-zero" sudan hay crop, as a function of E-W position within the field.

Our time-zero data set also includes hay yields by plot from a uniformly managed sudan hay crop grown in 1993. Initial differences in productivity may be used as a covariate in subsequent statistical analyses. Spatial patterns seen in infrared aerial photos were consistent with the hay yield data (Figure 1) and apparently resulted from patterns of topsoil removal during laser leveling. Computer enhancement and analysis of these images also revealed some nonuniformity within individual plots. For example, the former locations of old water channels are still visible. These patterns persist, especially in our low-fertility treatments. This information is being used in the design of sampling protocols.

Some Results from Year One

The first experimental treatments at LTRAS were initiated with planting of wheat and legume cover crops in the fall of 1993. The first fully irrigated crops (corn and processing tomato) followed in the summer of 1994.

No conclusions about sustainability or environmental impact can be drawn yet, but differences in crop productivity with inputs of water and nitrogen were apparent in this first cropping year. Average wheat grain yields ranged from 3138 lb/acre with neither supplemental irrigation nor nitrogen fertilizer to 7860 lbs/acre with both. Most of the difference was apparently due to the added nitrogen; fertilizer alone increased yields to 6573 lbs/acre, whereas irrigation alone raised yields only to 3292 lbs/acre. Even the unfertilized rainfed wheat represented an output of N from the system in the harvested grain of about 60 lbN/acre. It seems unlikely that these yields can be maintained in perpetuity without additional inputs. Within the irrigated wheat treatments, Robert Norris (Weed Science) found that weed populations were dramatically higher in the unfertilized control, which never achieved a closed canopy, relative to the wheat receiving N fertilizer.

A mixture of *Lana* vetch and *Miranda* pea (40:80 lb/acre) accumulated 180 lbN/acre (Figure 2) by the end of March 1994, which exceeds the 150 lbN/acre applied to the fertilized irrigated wheat. It remains to be seen how much of this N will be available to wheat grown the following winter (1994-1995). The legume cover crop consumed about 6 cm water, relative to fallow plots, which could conceivably outweigh the benefit from the additional N. The cover crops may also

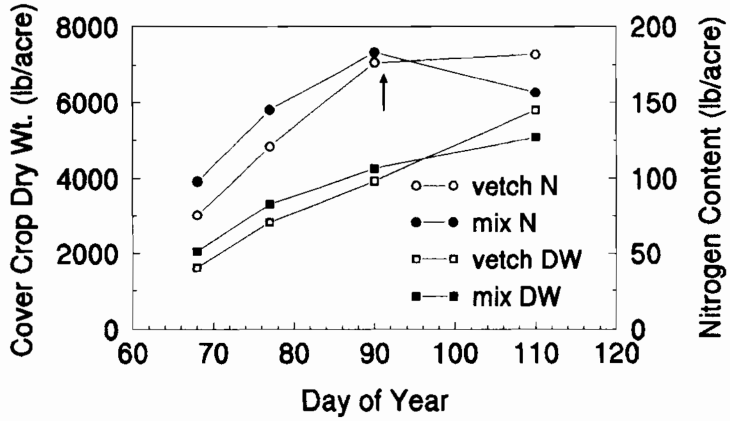


Figure 2. Accumulation of biomass and N by two different cover crops.

have beneficial effects on soil water status, over a longer period, by improving soil structure. The net result of these short- and long-term effects will probably not be known for years.

In the first year, N supplied by the legume cover crop was apparently not sufficient to meet the complete needs of a following corn crop. Grain yield of corn with the cover crop as sole N source averaged only 7,659 lb/acre, compared to 13,450 lb/acre for corn that received 270 lb fertilizer N/acre. Part of the yield difference may be explained by the three-week delay in corn planting relative to the conventional corn (May 5 *vs.* April 14) required to allow growth, incorporation (April 1), and partial decomposition of the cover crop. Earlier incorporation would have significantly limited the N supplied by the cover crop (Figure 2). Despite 180 lbN/acre in the cover crop, N deficiency appears to have limited yields of corn relying on one winter's legume cover crop as sole N input. The organic corn, also planted April 14, received composted poultry manure at 8 ton/acre in addition to the cover crop. The manure increased yields to 9,213 lb/acre.

Future Directions

Long term trends in crop yield are only one indicator of sustainability. Profitability, resource use efficiency, and environmental impact are also important. Data collected so far will allow us to compare the profitability of different cropping systems and to measure some aspects of resource use efficiency (e.g., water use efficiency). Our ability to assess environmental impact is currently more limited. In particular, we are not yet monitoring leaching of nitrate and pesticides from individual plots. Jan Hopmans and Graham Fogg (Land Air and Water Resources) have submitted a grant proposal to develop and test a vadose-zone sampling device to remedy this deficiency. Sampling by Graham Fogg at LTRAS has already contributed to the development of isotopic methods for determining the origin of nitrate in groundwater. Research on dust production from field operations has also been carried out at LTRAS, under the direction of Michael Singer (also LAWR).

In addition to monitoring and comparing the performance of the different cropping systems, research at LTRAS is expected to contribute to our understanding of the processes and mechanisms responsible for these differences in system performance. Preliminary research by Donald Phillips (Agronomy and Range Science) and Kate Scow (LAWR) on various aspects of soil microbiology has been conducted or is currenty underway at LTRAS, and additional work by several other faculty members is anticipated as external funding becomes available.

The LTRAS facility welcomes additional collaborators for research consistent with the overall emphasis on agricultural sustainability and environmental impact. Given budget constraints, only research directly related to the current experiment can be accomodated at present. Eventually, LTRAS is expected to expand to include other crops (e.g., perennials) and management practices (e.g., reduced tillage). The eventual relocation of Animal Science facilities to a nearby site will facilitate collaboration on the role of animals in sustainable farming systems.

Soil Microbe Contributions to Plant Nutrition and Soil Quality

Donald A. Phillips and Cecillia M. Joseph
Dept. of Agronomy & Range Science, University of California, Davis, CA 95616

Background

The beneficial effects of soil microbes on plants are well-known. Some microbes make direct contributions to plant nutrition as symbionts that supply nitrogen in root nodules (*e.g. Rhizobium* bacteria) or increase the transfer of phosphate from soil directly into root cells (*e.g.* mycorrhizal fungi). Other bacteria such as *Azospirillum* increase general uptake of minerals by stimulating root growth. Fluorescent pseudomonad bacteria are effective biocontrol agents that promote plant growth by inhibiting pathogens. All soil microbes improve long-term plant nutrition indirectly by trapping mineral nutrients in microbial biomass. Portions of those elemental components in microbial populations become available to plant roots as the bacteria and fungi recycle them for new cell growth. Such interactions conserve mineral nutrients and decrease leaching losses. For these reasons microbial biomass is generally viewed as a crucial component of productive soils and an important factor in soil quality.

The Problem

Unfortunately there is no easily available and widely used method that accurately characterizes the microbial component of soil quality. Moreover even when beneficial bacteria are present in agricultural soils, poor root colonization often limits their agronomic contribution (Weller, 1988). Thus the problem is primarily one of growth: Promoting growth of beneficial microbes generally in soil and enhancing their numbers on root surfaces. This problem is especially acute during transitions from conventional to organic management because plant growth under the latter conditions depends more on microbial interactions with mineral nutrients and pathogens. Techniques that enhance growth of beneficial microbes or quantify the presence of optimum populations would be helpful for both conventional and organic growers.

One Solution

To some extent the problem of managing soil microbes can be addressed by increasing soil organic matter. However, not all organic matter works equally well for this purpose. For example, pouring sugar solutions on soil promotes rapid growth of atypical microbial communities, while growing plants and incorporating crop residues allows slow development of beneficial microbial populations. Obviously some components of crop residues or living plant exudates either 1) inhibit deleterious microbes or 2) promote beneficial organisms. Quantifying changes in the causative chemical factors and defining how they affect microbial growth offer one constructive approach to this problem.

Different cropping systems and management strategies produce varying amounts of soil organic matter and support diverse levels of microbial activity (Dick, 1992). Thus a first step toward identifying natural chemical factors that regulate microbial populations involves monitoring changes in soil properties during management transitions. The second, more difficult step requires linking changes in particular compounds to responses of beneficial and deleterious soil microbes.

Our Approach

Our group is dedicated to developing a rapid, reproducible technique for monitoring soil quality that detects natural regulatory chemicals and quantifies microbial populations responding to those compounds. Our experience in this area comes from past work defining alfalfa signal compounds that affect *Rhizobium meliloti* (Phillips et al., 1994). We postulate the presence of soil signature compounds that are released from residues of different crop species, and we speculate that signal molecules are released by living roots to stimulate growth of desirable soil microbes or inhibit growth of pathogens. We are analyzing natural soil chemicals in the Long Term Research on Agricultural Systems (LTRAS) plots at UCD to identify changes during a transition from conventional alfalfa cultivation to equilibrium cultures of other crops. We are also assessing natural soil chemicals in the Sustainable Agriculture Research and Education (SARE) plots at UCD to identify signature and signal molecules in these plots that have already reached equilibria under conventional and organic management plans. Finally, we are isolating microbial genes in a beneficial soil bacterium, *Rhizobium meliloti*, and a pathogen, *Agrobacterium tumefaciens*, that are regulated by signal molecules from soil.

Initial Results and Conclusions

Extracting air-dried, finely screened soil with water produced an unremarkable chromatogram in HPLC analyses (Fig. 1A). However, significant amounts of diverse molecules were extracted in water from the same soil after a methanol treatment (Fig. 1B). Our preliminary interpretation of these results is that the methanol treatment lysed or increased permeability of microbial cells to such an extent that compounds present in those cells could be recovered in the subsequent aqueous extraction. We are in the process of verifying this point by adding bacterial cells to soil before extraction.

Our complete extraction method involves extracting soil with methanol, partitioning the methanol against ethyl acetate, and finally reextracting the soil with water. The three fractions produced by this procedure contain quite different types of molecules. Applying this method to alfalfa rhizosphere soil we find that pterocarpans and coumestans are in the ethyl acetate fraction; condensed tannins and other polymeric phenols are in both the ethyl acetate and the methanol; and the largest quantities of compounds are in the final water extract.

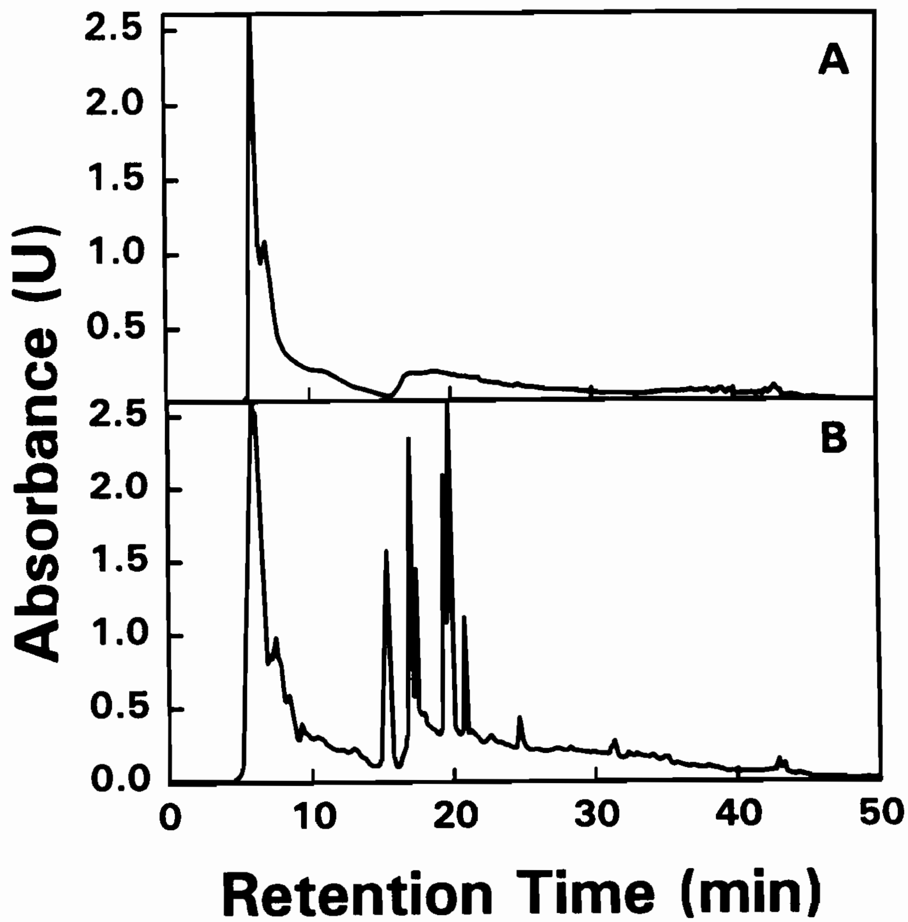


Figure 1. HPLC chromatograms produced from alfalfa rhizosphere soil extracted by **A)** water or **B)** methanol followed by water. Fractions were separated on a C_{18} column eluted with a methanol:water gradient (0-100%, 0-30 min.) and 100% methanol (30-50 min.).

Comparing aqueous extracts produced by that method from three soils suggests several preliminary conclusions (Fig. 2). First, the extract taken from alfalfa rhizosphere soil (Fig. 2A) is remarkably similar to the extract taken from bulk soil in wheat plots grown after alfalfa was plowed down (Fig. 2B). We view the peaks visible in Figure 2B as possible signature compounds from alfalfa because they persist in the soil, and we postulate that the 17-minute peak in the rhizosphere soil (Fig. 2A) is a signal compound released from the living roots. Our concept of alfalfa signature compounds is supported by the different HPLC profile measured for soil from oat/vetch plots that had been rotated with common bean for 4 years (Fig. 2C). Clearly all of these tentative conclusions must be confirmed with more rigorous comparisons involving various crop species, different soil types, and diverse management plans. We predict, for example, that the LTRAS wheat plots

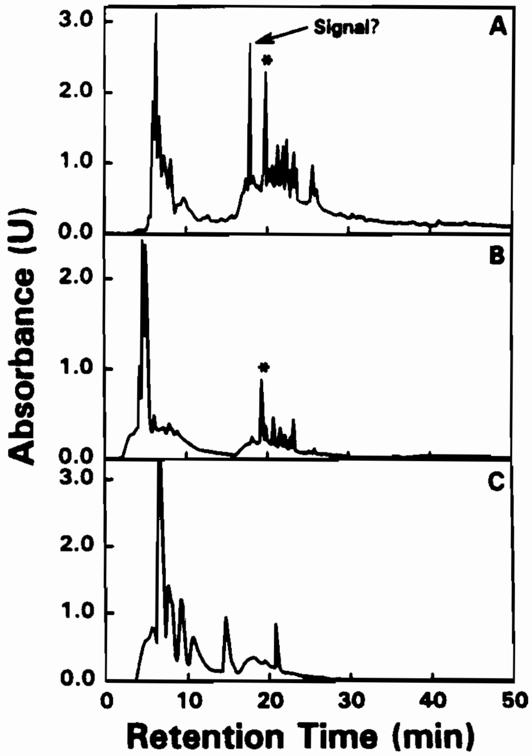


Figure 2. HPLC chromatograms produced from soil collected from **A)** alfalfa rhizospheres at the Kearney Agricultural Research Center, **B)** LTRAS wheat plots where alfalfa had been grown for several years previously, or **C)** SARE oat/vetch plots. Aqueous fractions were obtained from soil after methanolic extraction comparable to Figure 1B. The peak indicated by an asterisk (*) was identified as uridine on the basis of ^{1}H-NMR, ^{13}C-NMR, MS, UV-visible and HPLC retention data.

Acknowledgment Soil extraction work described here was made possible by a grant from the University of California Division of Agriculture and Natural Resources Sustainable Agriculture Research and Education Program. Our complementary studies on how natural chemicals regulate bacterial growth are being supported by the US National Science Foundation and the USDA-NRICG program.

References

Dick, R.P. 1992. A review: long-term effects of agricultural systems on soil biochemical and microbial parameters. Agric. Ecosyst. Environ. 40:25-36.

Phillips, D.A., F.D. Dakora, E. Sande, C.M. Joseph and J. Zon. 1994. Synthesis, release and transmission of alfalfa signals to rhizobial symbionts. Plant and Soil 161:69-80.

Weller, D.M. 1988. Biological control of soilborne plant pathogens in the rhizosphere with bacteria. Ann. Rev. Phytopathol. 26:379-407.

Water Uses--General Overview

J. Sorensen

(Paper not submitted in time for inclusion in Proceedings.)

WATER QUALITY-- ANALYSIS AND INSTRUMENTATION

Nat B. Dellavalle
Dellavalle Laboratory, Inc.
Fresno California

Water quality means very different things to different people. The agriculturist, the environmentalist and the sanitarian each have very different definitions of quality. Water quality also means different things to the same person at different times or places. A housekeeper wants soft water inside but when outside, as a horticulturist wants hard water. Someone working with Colorado river water may have little interest in boron or sodium concentration while one working in the San Joaquin Valley must be interested in both. Instrumentation follows the definition.

As we learn more about water and how its quality affects the world or our part of the world the definition of quality changes. Thirty years ago there was little concern about arsenic or selenium in agricultural waters.

Instrumentation for determining water quality like the definition of water quality is changing. Instrument manufacturers and others are developing new equipment. The new equipment enables us to learn about more water quality parameters and more about each parameter. New effects of water quality are discovered or are of interest. Researchers with an interest in water quality, among others, drive the interest in new instrumentation. And that cycle goes on and on.

Instrument selection is or should be based upon application, the purpose for the results of analysis. What degree of accuracy and precision is needed to make the decision the information is intended to support? What detection level is required? Will the results be used to meet regulatory requirements? The regulatory agency may specify the method and therefore the equipment to be used. What volume of samples is to be analyzed? Are results needed on a real-time basis?

For example, a variety of methods can be used to estimate pH. They range from indicator papers costing a few cents to sophisticated meters costing several thousand dollars. Indicator paper will do to determine if acidified irrigation water has reached the end of a drip line, but will not meet EPA requirements for evaluating drinking water. Inexpensive battery operated models are useful for field operation where real time more accurate information is needed.

A range of equipment is available for estimating electrical conductivity. EC meters not much larger than a ball point pen are good for field work but do not have the accuracy or range for many laboratory operations.

Field kits are available for a variety of applications. Many have been developed to meet EPA requirements. They are designed around EPA methods and detection limits. Some include colorimeters, pH meters, electrical conductivity meters and other sophisticated equipment. Kits do not come with all of the skills needed to perform sampling and analysis. They are best used in the hands of a trained professional who understands what can interfere with the analysis and quality control and assurance procedures that produce acceptable results and in conjunction with a conventional lab.

Economics of scale are another important consideration. Kits are designed to produce results in the field where real time information is valuable. Kits or more sophisticated portable laboratories are useful at cleanup sites where expensive equipment and manpower is standing by. Analysis of large numbers of samples are more economically produced in an automated laboratory at a fixed location. Some types of analysis must be performed within specified times following sampling in order to accurately reflect conditions sampled or to comply with EPA protocols. Kits are very useful in remote areas. Labor is not included with kits. Field time may be more valuable collecting additional samples or performing other work.

Instrumentation has changed greatly over the last 30 years. Thirty years ago instrumentation in an agricultural water analysis laboratory could be limited to a pH meter an electroconductivity meter and volumetric glassware. A balance, flamephotometer and colorimeter rounded out most commercial agricultural water analysis laboratories at a cost of a few thousand dollars. Today's commercial agricultural water analysis laboratory must do other types of analysis to be competitive. Equipment will include an inductively coupled plasma spectrophotometer or an atomic adsorption spectrophotometer, a chloridometer and other equipment in addition to the ones listed above. Much of the equipment will be automated and may perform several analyses simultaneously.

Change is at a much faster rate than in the passed. Twenty years ago there was an expectation that a new Atomic Adsorption Spectrophotometer would be in service until it wore out. Not so today. Most new instruments will be obsolete long before they wear out. A maximum life of less than five years is a reasonable expectation. Newer instruments are automated and computer controlled. Computers collect, evaluate the data and print a report.

In addition to more complex and costly equipment, a higher standard of quality control is demanded. A very high standard is set by EPA and other regulatory agencies. To be competitive a water laboratory must have EPA or California Department of Health Services (DHS) certification. Specific methods must be used. Over ten percent of the samples processed must be quality control standards. Many clients require EPA or DHS certification even if their application does not in order to be assured that the laboratory has a minimum QC system. One cannot assume that analysis will only be for internal use by the client. That may be the intent until the client needs to trade or market water. If a public water way is used for convenience, the water must meet specific standards and the analysis must be performed by a certified laboratory.

Even though the equipment is more costly and a higher standard of quality is required, prices for analyses are increasing slower than the rate of inflation. In many cases prices are decreasing. Laboratories are larger, more specialized, more automated with higher throughput than in the past. This trend is expected to continue. In addition to lower cost for traditional analyses, many times more analyses can be obtained for the same cost. For example, with ICP spectrophotometry iron and manganese can be added to an agricultural suitability package for little increase in cost.

Only an organization that performs tens of thousands of determinations per year can conduct analyses at rates competitive with today's commercial laboratories. A real need for real time numbers or analysis that must be performed at a remote location may justify the cost of a small lab. Cost savings will not .

Clients have more diverse needs for water analyses than in the past. Traditional agricultural suitability included electrical conductivity, calcium, sodium, carbonate, bicarbonate, nitrate, chloride, boron and pH. Evaluation for use in drip systems includes iron and manganese. Sand, silt, allege bacteria and other contaminants many also be of interest.

More agricultural firms will be regulated. Wastewater discharge requirements include various types of analyses. Agricultural drainage must meet drinking water standards including maximum contamination limits for selenium, arsenic, molybdenum, chromium, uranium. Dairies are required to analyze wastewaters for total dissolved solids, sodium, chloride, coliform bacteria, total nitrate, ammonical nitrogen, phosphate, and potassium. Dried fruit processors must monitor total and inorganic dissolved solids, pH, iron, manganese, nitrate and total nitrogen, and potassium. The analysis is required even when disposal is on the property where produced or if used in the course of crop production.

For most agricultural and horticultural users, the important or critical contaminants are much the same. The most important being salinity, estimated by electrical conductivity, as it affect the ability of plants to extract water. The effect on infiltration is estimated using an interaction between salinity, calcium, magnesium and sodium content. Specific ions (sodium, chloride and boron) are also of wide concern. Table 1 from Ayers and Westcot (1985) presented for easy reference. Addition interpretative information can be obtained from UC, Cooperative Extension or your agricultural laboratory representative which hopefully is Dellavalle Laboratory, Inc.

Table 1
GUIDELINES FOR INTERPRETATION OF WATER QUALITY

Potential Irrigation Problem	Units	none	slight to moderate	severe
		---------- Degree of Restriction of Use ---		
Salinity *(affects crop water availability)*				
EC_w	dS/m	<0.7	0.7 - 3.0	.> 3.0
Infiltration *(affects infiltration rate of water lint soil, Use ECw and SAR together)*				
SAR = 0 - 3 and **EC_w** =		> 0.7	0.7 - 0.2	< 0.2
3 - 6		> 1.2	1.2 - 0.3	< 0.3
6 - 12		> 1.9	1.9 - 0.5	< 0.5
12 - 20		> 2.9	2.9 - 1.3	< 1.3
20 - 40		> 5.0	5.0 - 2.9	< 2.9
SPECIFIC ION TOXICITY *(affects sensitive crops)*				
Sodium (Na)				
surface irrigation	SAR	< 3	3 - 9	> 9
surface irrigation	SAR	< 3	3 - 9	> 9
Chloride (Cl)				
surface irrigation	me/l	< 4	4 - 10	> 10
sprinkler irrigation	me/l	< 3	> 3	
Boron (B)	mg/l	< 1.7	0.7 - 3.0	> 3.0
Miscellaneous effects (*affects susceptible crops*)				
Nitrogen (NO_3-N)	mg/l	< 5	5 - 30	> 30
Bicarbonate (HCO_3) (*overhead sprinkling only*)	me/l	< 1.5	1.5 - 8.5	> 8.5

Ayers, R. S. and D. W. Westcot. 1985. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29 Rev. 1. FAO Rome.

EQUIPMENT METHODS OF RECLAMATION

Hal Collin, President
Agristruction, Inc

Soil is the foundation of agronomic plant growth. Growing location is dictated by climatic conditions. It is almost never economical to transport soils to a preferred growing location if they are any distance apart. Therefore reclamation and enhancement of the soil at its place of origin is often an essential element to improve plant growth and productivity.

The physical modification of soil takes into consideration soil texture, structure, hardness, moisture, water holding capacity, intended irrigation methods (if any) as well as the needs of the crop to be grown. Chemical modification well not be addressed in this presentation. It must stressed that before starting any physical soil modification, evaluation of the soil profile is paramount. Soil maps are helpful but often the land has been leveled or ripped since mapping and therefore the profile has changed. Viewing backhoe pits large enough for a person to enter is the preferred method of evaluation. With the cutaway one can visually inspect the texture, color, structure and hardness of a soil profile as well measure depth and thickness of each soil change(aka: strata or lens). Augering a hole will destroy the ability to compare hardness. The exact measurement of depth and thickness of each soil type is also less accurate when measured with the auger.

The goal of the physical soil modification is to enhance water and root penetration, improve drainage in an effort to improve the rate of plant growth, yield and quality. This is usually accomplished by creating a friable homogeneous soil profile. Compacted soils need to be fractured; stratified soils need to be mixed. Although physical soil modification methods are historically analyzed on deep penetration (beyond 30" deep), operations,

principals are the same for shallow soil work.

The equipment that is applicable to physical soil modification is the ripper, slip plow, moldboard plow, backhoe pits, or trenching. The last two applications are known to only have been used on permanent crops to date. The considerations for determining the method of equipment to be used are as follows:

(1) Soil moisture: The general rule here is "the dryer the better." Dryer soils fracture better and at a wider angle than wet soils .

(2) Shank spacing: For ripping the distance between the shank centers should not be greater than the depth of penetration. For slip plowing the width between shanks should be no more than 1 1/2 times the penetration depth for maximum fracturing. Too wide of spacing creates an unfractured zone.

(3) Soil profile: Compacted soil needs to be fractured. Stratified soils need to be mixed. Depth of penetration is a function of the relative thickness, soil characteristics and depth of each soil type as well as plant needs.

(4) Irrigation method: Reclamation efforts should be concentrated in the area of the water source distribution to the plant anticipating where root growth will occur and from where it draws its water. This is more critical to permanent crops in that the wetting area of flood versus low volume irrigation is a much greater difference than with agronomic crops.

The various types of equipment make different impacts on the soil thereby creating different results. A ripper shank will fracture at a 45° angle from tip of the shank to the surface of an average soil; steeper in moist soils and more horizonal (laterally) in dryer harder soils. The slip plow fractures wider, at a 60° to 70° angel plus vertically mulches the soil. The effect is to eliminate the restrictive interface layer between soil stratas and create a homogeneous profile. The moldboard plow turns the soil over and mixes the entire impacted area. One must be cautious not to bury rich productive soil nor bring up a soil tainted with undesirable elements. This is where it is most important to incorporate chemical analysis along with physical analysis before starting a project. Moldboard plowing has proven to be very effective following a flood where a deposit of silt is laid in over productive soil. Moldboard plowing can rapidly bring the productive soil back to the surface. Backhoeing and trenching the planting site for trees and vines has only gained acceptance in regionally elected areas. The cost generally exceeds those of other available methods. While these two approaches do a very thorough job of mixing the soil in the selected area it does no fracturing beyond the borders of the digging and leaves a very defined wall which can create a "coffee cup effect," restricting the percolation of any water beyond the boundary of treatment.

Costs are determined by the pattern of treatment. Costs can vary by soil type up to 400%. This is exemplified by comparison of ripping of a sandy loam in Northern Kings County verses a hardpan in Southern Madera County, both in San Joaquin Valley of California and only 50 miles apart. The question often arises whether to treat in one direction or two directions (or occasionally more). There are more options to consider in permanent crops since the spacing between plants is greater and often the desired depth of penetration is deeper therefore the cost per acre is higher. It is important to remember that the horizontal fracture pattern is approximately equal to the vertical depth of a shank or one and half times the depth of a slip plow. Ripping a second direction maybe beneficial to obtain deeper depth of penetration but there is only a marginal increase in the fracture pattern of the pre-ripped zone in most soils.

Where mixing of the soils is required and slip plow is the selected method of reclamation, multiple directions will increase the area impacted. A slip plow can be made in any width, most range from 9" wide to 20" wide. The soil directly impacted by the slip plow as well as a buffer zone on each side of the slip plow is vertically mulched. Depending on the soil type and moisture, the buffer zone will experience a vertical mulching of various degrees starting from the bottom of the slip plow and angling to the surface of the soil to a point beyond the slip plow edge up to 75% of the width of the slip plow. The slip plow is viewed as an implement for mixing the soil but it also delivers an enhanced fracturing pattern over that of conventional ripping.

Moldboard plowing is available up to five feet deep. The moldboard plow completely turns over the soil and impacts a greater percentage of soil but at a significantly greater cost then ripping or slip plowing. When going to deeper depths it is most important to check the chemical ramification to the soil from this type of treatment. There are occasions where deep slip plowing or moldboard plowing may bring up some undesirable elements. But if the equipment treatment destroys a subsoil strata that was previously impervious to water and retained undesirable elements at a level detrimental to the plants, the physical treatments can break these barriers allowing an accelerated rate of leaching and to a greater depth then was experienced before the reclamation work was performed.

In summary, soil is the foundation of plant life. Improving its potential through chemical and physical reclamation can offer on going and long lasting effects when properly managed. Without such a foundation all other growth improvement practices are often mediated if not negated. Proper soil reclamation methods with equipment include:

(1) **EVALUATE SOIL PROFILE**

(2) **DETERMINE PROPER MODIFICATION IMPLEMENTS**

(3) **COORDINATE CHEMICAL AND PHYSICAL SOIL MODIFICATIONS**

(4) **IMPLEMENT PLAN**

Cover crop incorporation and gypsum applications to improve soil physical properties in salinized soils

J.P. Mitchell, M.J. Singer, T. Prichard, D. Peters, D.M. May,
R.O. Miller, D. Munk and C. Shennan
University of California, Davis.
C.J. Phene and J.D. Rhoades
USDA-ARS

Abstract

This recently-completed 3-yr field study evaluated the effectiveness of winter cover crop incorporation and surface gypsum applications relative to conventional fallows for maintaining/improving soil physical properties, stand establishment and crop productivity in a cropping system relying on saline drainage water for irrigation. Six amendment/soil cover treatments were imposed on a rotation of tomato-tomato-cotton as summer crops. Drainage water accounted for about 70% of the total water applied each season. Yields of tomatoes irrigated with saline water were maintained relative to non-saline irrigation in year 1, but were decreased by 33% in year 2. Estimated cotton lint yields of plants irrigated with drainage water were similar to yields of plants irrigated with non-saline water. Soil surface crust strength measured by micropenetrometer was lower in gypsum and cover-crop amended plots relative to saline-water irrigated fallow plots during the period of cotton seedling emergence in the third year of the experiment. Water stable aggregation was also increased following cover crop incorporation relative to saline fallows. Following two seasons of saline drainage water reuse, emergence of cotton seedlings was highest in gypsum-amended plots, but considerably lower in cover crop incorporated plots. Mechanisms accounting for poor establishment following cover crop incorporation may include higher incidences of seed and seedling pathogens in plots where cover crop residues had been incorporated into the soil, and stubble-reinforced surface crusts that resulted in interconnected slabs that impeded timely seedling emergence. These findings and increasing soil surface ECe and SAR values during the course of this study point to the need for special management practices for sustained crop production with saline drainage water.

Objectives

The objective of this project was to compare the relative effectiveness of winter cover crop incorporation and gypsum application in cropping rotations employing cyclic reuse of saline drainage or shallow groundwater for:

1. improving/maintaining good soil physical properties, as measured by soil crust strength and water stable aggregates, and for
2. improving the emergence and yields of summer crops in the rotation

Experimental Procedures

A 3-yr study was conducted at the UC West Side Research and Extension Center in Five Points, CA, in which six winter cover crop/fallow treatments were imposed upon a rotation of tomato, tomato and cotton as summer crops. The winter treatments were:

1. barley/summer saline irrigation water
2. vetch/summer saline irrigation water
3. barley-vetch/summer saline irrigation water
4. surface-applied gypsum/summer saline irrigation water
5. fallow/summer saline irrigation water
6. fallow/summer nonsaline irrigation water

The tomato and cotton crops received low EC (0.3 dS m^{-1}) California Aqueduct water for germination and establishment, and saline water from a shallow well (EC = 8.0 dS m^{-1} and SAR = 19 mmoles l^{-1}) afterwards. Cover crops were sprinkle-irrigated with about 1.5 - 3 inches of Aqueduct water to ensure good establishment prior to the onset of winter rains. The experimental design was a randomized complete block, with four replications, and each treatment plot large enough to allow normal field operations. A saline screening nursery was also conducted during each winter to determine good performing legumes and non-legumes in terms of biomass and N-productivitiy under saline West Side SJV winter conditions.

Conclusions

Our results demonstrate that cyclic reuse of saline subsurface drainage water for irrigation may conserve good quality water and provide a means of sustaining crop productivity over short terms. Soil surface salt and boron accumulation however, may be major constraints to this cropping strategy and will limit productivity if appropriate irrigation/leaching and crop management practices are not followed. Special management for stand establishment may be required in saline drainage water reuse systems including shallow seed placement, keeping the soil surface moist, and using mechanical crust-breaking implements when appropriate. Winter cover crop incorporation did not improve stand establishment of subsequent crops following saline drainage water irrigation. In our system, cover crop incorporation resulted in interconnected surface crusts that actually seemed to impede timely seedling emergence. Cover crop incorporation did however, result in slight improvements in soil water stable aggregation following saline water irrigation relative to bare fallows. Surface applications of gypsum may be useful in cotton stand establishment in reuse systems. Net increases in soil water storage (0 - 210 cm) during the winter due to rainfall were about 2 inches less than under cover cropped conditions than under winter fallows.

J.P. Mitchell (209) 891-2660

Drainage and the Tulare Lake Basin

D. Davis

Handouts will be distributed at meeting.

SOIL AND WATER AMENDMENTS: SURFACE OR SUBSOIL APPLICATIONS

Allan Fulton
UC Soils and Water Farm Advisor, Kings County

The author acknowledges Jerry Rivers of Growers Testing Service in Visalia, Craig Hornung of Soil Solution Systems, Inc. in Visalia, Ron Mattos, Grower, Hanford, Scott Schmidt, Agronomist and Phil Denton, Laboratory Supervisor, J.G. Boswell Co., Corcoran, and Jim Oster, Extension Soils and Water Specialist, UC Riverside for their time and energy given to support these studies.

Introduction:

This paper contrasts two field studies. One was completed in 1990 and the other in 1992 in Kings County. In one setting water amendment improved water infiltration and increased cotton yields to profitable levels. In the second situation, water amendment did not provide any measurable benefit either to the soil or crop.

The soil and water conditions at each site are described in detail to better understand the different responses. The discussion will identify conditions where water run amendments are appropriate and where land applications of amendments at higher rates may be more appropriate.

Site Descriptions:

The responsive site was located approximately two miles south of Hanford and the unresponsive site was located southwest of Corcoran in the Tulare Lake bed. Table 1 summarizes the soil and water characteristics of each site. Both sites consisted of non-saline but sodic soils in the top 18 inches. Improved soil physical properties to assure soil tilth and adequate soil permeability was desired at both sites.

Table 1. Soil and water conditions at the Hanford and Corcoran Sites.

ID	pH	SP	EC_e/ EC_w	Ca	Mg	Na	HCO_3	SAR
		%	dS/m	------------	meq/l	------------		
SELECTED SOIL ANALYSES TO A DEPTH OF 18 INCHES								
Hanf.	8.2	35	1.1	0.6	0.2	8.9	2.8	15.4
Corc.	7.8	64	1.3	1.2	0.3	12.1	3.8	14.0
SELECTED WATER ANALYSES								
Hanf.	8.1	----	0.8	0.5	0.04	7.6	5.9	14.6
Corc.	7.6	----	0.7	1.7	1.2	3.4	3.1	2.8

Water Amendment Treatments:

Hanford:

At Hanford, calcium was added into the irrigation water by injecting a continuous slurry of gypsum into the well water. Solution grade gypsum was applied at a relatively high rate of 4.0 meq Ca/l or about 1000 lbs per ac-ft water. Treatment began after the last cultivation in late June 1990 and was used for each irrigation until cutoff in late August. Approximately 1.7 ac-ft water per acre was amended during 6 irrigations.

Two checks approximately 3.0 acres in area were treated with gypsum and used as replicates in the study. Each treated check was separated by a 3.0 acre untreated check that was evaluated as a control. Soil water content was measured before and after each irrigation, salinity and sodicity was determined in the soil and irrigation water before and after treatment, and cotton was commercially harvested, weighed, and ginned separately from each check.

Corcoran:

At Corcoran, sulfuric acid (93 % purity) was added to the irrigation water beginning the first crop irrigation in June of 1992. Sulfuric acid was used instead of solution grade gypsum because it was simpler to add to large irrigation onflows and the soils were inherently high in lime content.

Acid was applied at two rates of 25 and 50 gallons per irrigation which equates to 375 and 750 lbs per acre per irrigation. The average depth of applied water per irrigation was 0.6 ac-ft per acre. The low rate was equivalent to adding 4.4 meq Ca/l to the water or 1040 lbs pure gypsum per acre-ft of applied water. The high rate of acid equates to 2080 lbs pure gypsum per acre-ft of applied water or 8.8 meq Ca/l. Three irrigations (one in June, early July, and early August) were treated with the low rate of acid. Only the June and July irrigations were treated with the high rate of acid.

These were high rates of acidification. Typical rates of acidification are usually 10 gallons per irrigation or about 150 lbs per acre per irrigation. We elected to use the higher rates in an effort to insure a measurable effect on soil tilth, soil permeability, and cotton lint yields. Other field experiments at the lower rate of acidification had given inconclusive results. The primary concern of using such high rates of acidification was corrosion and deterioration of irrigation pumps. Bicarbonate levels in the irrigation water and high levels of soil lime were sufficient to neutralize the acid once it was applied to the soil.

There were four replicates of each acid treatment plus an untreated control. Each plot within a replicate consisted of about 25 acres. Soil salinity and sodicity, soil fertility, crop nutrition, and leaf water potential were measured in each plot regularly through the season. Cotton was commercially harvested and ginned from each plot separately.

Results:

Table 2 shows the cotton lint yields for each irrigation water treatment at both sites. At Hanford, yield was consistently higher in the gypsum treated plots. Lint yield increased by an average of 198 lbs/ac. Lint yields in the Corcoran study yielded an average of 45 to 63 lbs/ac higher in the acid treated plots. However, the yield improvement was inconsistent. Despite the higher average yield in the plots treated with acid, the control (untreated) plots yielded higher or as high in two of the four replicates.

Table 2. Summary of cotton lint yields at the Hanford and Corcoran water amendment studies.

Hanford		Corcoran	
Water Treatment	Lint Yield (lbs/ac)	Water Treatment	Lint Yield (lbs/ac)
Control	965	Control	1436
4.0 meq Ca/l as gypsum	1163	4.4 meq Ca/l as acid	1499
		8.8 meq Ca/l as acid	1481
Significance	$p<0.05$	Significance	N.S.

Table 3 provides the chemical soil characteristics at each site when treated with water amendment and left untreated. At Hanford, water run applications increased the average root zone salinity (EC_e) while the exchangeable sodium decreased significantly in the root zone. The net effect was a reduction in soil sodicity, improved soil permeability, and improved crop water status during mid to late season. This effect was also verified by significantly higher soil water content measurements in the gypsum treated plots.

Table 3. Summary of soil chemical characteristics after water amendment in the top 18 inches of soil.

Hanford				Corcoran			
Water Treatment	pH	EC_e	ESP	Water Treatment	pH	EC_e	ESP
Control	8.2	1.1	15.4	Control	7.8	1.3	14.0
4.0 meq Ca/l as gypsum	7.9	1.3	10.7	4.4 meq Ca/l as acid	7.8	1.6	14.3
				8.8 meq Ca/l as acid	7.9	1.4	14.1
Significance	NS	*	**	Significance	NS	NS	NS

* denotes significance at $p<0.05$, ** denotes significance at $p<0.01$, and NS indicates no statistical significance.

At Corcoran, there was no evidence of any effect by the sulfuric acid on soil chemical properties despite the unusually high application rates. Soil pH, salinity, and exchangeable sodium were unaffected by in the top 6 inches of soil or in the total depth of 18 inches of soil.

Discussion:

Irrigation water quality and soil texture were the most distinguishing features between sites. Water quality criteria suggest that the soil tilth and permeability problems at the Hanford site most likely originated with continuous use of the sodic well water.

The Corcoran site was irrigated with water relatively balanced with respect to its cation and anion chemistry. The same water quality criteria would suggest that it had less affect on physical soil properties. This suggests the sodic soil condition was inherent in the soil and independent of the irrigation water.

The Hanford site was sandy loam texture and the Corcoran site was the Tulare clay series indicating a significantly higher clay fraction at Corcoran. It infers a soil with a substantially higher cation exchange capacity and a much greater capacity to adsorb exchangeable sodium and calcium than the sandy loam near Hanford. With this in mind, one might expect that it would take considerably more exchangeable calcium to modify the sodic soil chemistry at the Corcoran site than at Hanford.

It is hypothesized that the failed response of water treatments at Corcoran is not due to the fact that the calcium amendment is unnecessary. Instead, it may be due to inadequate quantities of exchangeable calcium being added to the soil through water run applications of sulfuric acid. Prior research by Zahow and Amrhein (Soil Sci. Am. J., 1992) showed significant increases in soil permeability on the same Tulare clay series when exchangeable sodium percentages were reduced 12.0 to 6.4.

Estimates of sulfuric acid required to provide sufficient calcium to achieve this reduction in exchangeable sodium percentage equate to 8000 lbs per acre. Even at the extremely high rates of acidification used in the Corcoran study it would require about 7 years of repeated application to provide this level of amendment through the water. At traditional rates of 10 gallons acid per irrigation it may require decades to achieve the improvement. In this instance, land applications may be more appropriate than water run applications of amendments. Furthermore, mechanical incorporation (i.e. slip plowing, ripping) of the amendment would transport the exchangeable calcium deeper into a sodic soil profile more rapidly than depending on transport by water movement only. The calcium-sodium exchange could occur more rapidly deeper in the profile.

Conclusions:

- Water run applications of chemical amendments are beneficial particularly where the irrigation water is of sodic composition. There is evidence that they are also beneficial in low electrolyte irrigation water ($EC_w < 0.2$ dS/m). Favorable crop responses and improvement in soil chemical and physical properties are most likely to occur earliest and with less amendment on sandy or loam textured soils with lower cation exchange capacities.

- Land application of chemical amendments may be more appropriate than water run amendments on soils where the sodic soil conditions appear inherent in the soil profile and less related to the irrigation water quality. Water run applications on fine textured soils with high cation exchange capacities may require many years of treatment at low rates before a favorable response occurs.

- In the latter case, where substantial amounts of chemical amendment may be required to improve the chemical and physical properties of the soil, the level of crop response and economic feasibility is unknown and deserving of further research and understanding.

Nitrate Nitrogen Losses Below the Root Zone of Irrigated Cotton: Impact of BMP Implementation

Jack Watson, Katie Reffruschinni, Mike Sheedy, Susan Cordell,
Bryan Anthony, Sam Stedman, Rick Gibson
Extension Water Quality Specialist, Assistant in Extension, Research Specialist, Graduate Student,
Campus Agric. Center Director, County Extension Director, Agricultural Extension Agent, respectively.
University of Arizona

Introduction

Although regulations that require the implementation of so-called Best Management Practices for groundwater quality protection are in place or are being developed in many states, quantitative data regarding the actual reduction in nitrogen losses to groundwater is fairly sparse. This is in contrast to the availability of data describing the reduction in nutrient losses to surface water from the implementation of appropriate Best Management Practices (BMPs).

One of the considerations in the development of Best Management Practices is the site specific nature of the practices that are considered "best". The potential for increased losses of mobile nutrients, such as nitrate-nitrogen, to groundwater as the result of implementing BMPs for surface water protection, is one consideration which is well recognized in the scientific community, but which is seldom considered during debates about public policy. Yet, it is the consequence of such "technical" issues that can undermine the otherwise beneficial impact of BMPs. Regulatory agency staff and their technical advisory committees can then be faced with the need to develop strategies for water quality protection that allow for "real world" circumstances, while constrained by statutes or the legal interpretation of statutes which **do not** recognize the vagaries of nature.

Arizona's version of water quality protection legislation requires the on farm implementation of Best Management Practices to minimize groundwater quality degradation from nitrate-nitrogen. On the surface, the statute appeared quite reasonable, and seemingly allowed for the development of fairly specific BMPs that were appropriate for different regions of the state. However, legal staff within the state Attorney General's office interpreted the statute to imply that all BMPs had to be implemented in every agricultural setting. Technically, this meant (for example) that BMPs for water management with drip irrigation had to be implemented on every field, BMPs for water management on fields irrigated with sloping furrow irrigation systems had to be implemented on every field, and BMPs for use with sprinkler systems had to be implemented on every field.

Because of this legal interpretation, the staff and advisory committee (which included a number of growers) of the Arizona Department of Environmental Quality needed to create a series of BMPs that could be sensibly applied to all agricultural cropland. They approached the problem by developing very general BMPs, and requiring the implementation of appropriate activities (Guidance Practices) which, when taken together, would accomplish the goal of minimizing nitrogen losses to groundwater and satisfy the requirements of the more generally defined BMPs.

Grower Practices

The first task in evaluating the impact of implemented Guidance Practices is to determine the "baseline" of nitrate nitrogen losses that occur under somewhat typical conditions. Several cotton growers in central Arizona participated in a Hydrologic Unit Area project to minimize losses of nitrate nitrogen to groundwater. The project was conducted by USDA-SCS, Cooperative Extension, and USDA-ASCS. As part of the project, field samples were collected by Cooperative Extension staff throughout a growing season to identify for the grower cooperators whether it was likely that a portion of their applied nitrogen was being lost below the soil root zone. The sampling depths and strategies were determined in cooperation with a clientele advisory group. An experiment station research project was developed to make use of these samples to estimate the amount of nitrate nitrogen lost from selected locations within a field during selected times of the season.

A similar estimate of nitrate nitrogen losses was made based on a field research study at the University of Arizona's Maricopa Agricultural Center. Short staple cotton was grown on a sandy loam to sandy clay loam soil under two irrigation regimes (70% and 90% irrigation application efficiency). The timing and rate of irrigation water application was determined using a computerized checkbook irrigation scheduling method. Soil samples were collected from the field to determine the soil water content at "field capacity" (i.e. after two days of drainage and redistribution following irrigation). Crop water use was estimated from weather data obtained from an on-site weather station. The actual irrigation efficiencies were slightly different from 90% and 70%, due to the inability to perfectly control irrigation water applications, in spite of relatively small field plot size.

Results from four cooperator sites (#1&#2 in 1991, #3&#4 in 1992) and the two experimental treatments at the Maricopa Agricultural Center (1991 and 1992) will be presented here. Each cooperator would be characterized as conscientious, with regard to the application of nitrogen fertilizer and irrigation water. Soil conditions and intensity of management varied somewhat. Each employed practices that would be recommended for the purpose of meeting the required BMPs. The following tables provide information on soil type, nitrogen and water application amounts, as well as Guidance Practices employed to meet BMPs. The cooperator sites will be identified as 1,2,3,4; the MAC sites as MAC 70% and MAC 90%.

Table 1. Site identification, soil type, nitrogen application amount, water application amount.

Site	Soil Type	Pre plant N	Total N Application	Water	Yield
		lbs/acre		ac-in/acre	bale/ac
Coop #1	Clay Loam	16	80	44	2.0
Coop #2	Sandy Loam	330[1]	420	50	2.5*
Coop #3	Sandy Loam	8	150	29	2.0
Coop #4	Silt Loam	15	60	38	3.5
MAC 90% - 91	Sandy Clay Loam	90[2]	145	37	2.3
MAC 70% - 91	Sandy Clay Loam	90[2]	145	43	2.7
MAC 90% - 92	Sandy Clay Loam	0	130	30	2.6
MAC 70% - 92	Sandy Clay Loam	0	130	37	2.7

[1] Most of the N applied was from a 10 ton/ac manure application.

[2] Preplant N recommendations not followed by (then) research farm manager.

*Long staple cotton yield.

The application of 420 pounds of nitrogen per acre by Cooperator #2 occurred primarily as the result of a heavy application of manure (10 tons/ac) before planting. The amount of nitrogen that became available during the growing season has been estimated to be between 20% and 40%. It is likely that most of the nitrogen that became available, did so after mid-June, due to the fact that the rate of organic matter decomposition would be greater during the hotter summer months.

The particular practices used by each cooperator to minimize nitrate-nitrogen losses below the root zone of the crop were somewhat varied (Table 2). Arizona's BMPs require the addition of only the amount of irrigation required for plant growth, timed so that it is applied when the crop needs it. The BMPs also require the application of only the amount of nitrogen required for plant growth, timed so it is applied when the crop needs it, and applied in a manner that maximizes plant use of the nitrogen. Obviously, Cooperator #2 was unable to accomplish that BMP through the use of manure. Specific Guidance Practices that are often recommended to meet the BMPs in furrow irrigated cotton production include: preplant soil testing for early season nitrogen application recommendations, in-season petiole sampling for determining the need for additional nitrogen, planning to split nitrogen applications based on stage of plant growth and quantified plant growth parameters, irrigation scheduling based on estimated crop water use from local weather data or soil moisture monitoring, irrigation scheduling based on crop stress indicators, and irrigation application amounts based on soil water holding capacity.

Two of the cooperators (#1 & #3) used a computer based irrigation scheduling technique to determine the timing of irrigations and the amount to apply. Cooperator #1 changed managers mid-season, the second manager being more conscientious with regard to environmental concerns than was the first manager. The second manager seemed to **under**irrigate to a similar degree that the first manager had overirrigated, however, resulting in yield losses. It also became clear during the season that the parameters necessary for the proper use of the program were not well understood by the cooperators. The manager for cooperator #1 failed to obtain field data for soil water holding capacity at "field capacity" and "wilting point", although reasonable estimates were available from the local SCS office. This manager also assumed an irrigation efficiency of nearly 100%; quite unreasonable even considering the soil type (clay loam). Cooperator #3 had water control problems, choosing not to use borders to delineate an irrigation set. Even though he attempted to apply appropriate amounts of water, the soil infiltration rate was so slow that he was unable to apply enough water to the field before the irrigation water broke over furrows at the end of the field and moved to adjacent portions of the field.

Thus, the availability and even "use" of an available tool for implementation of BMPs does not ensure its "correct" use. Neither does it ensure that field conditions will be adequate to enable the grower to efficiently implement a recommended activity The consequences to these cooperators with regard to yields were devastating. Both seriously underirrigated, with yield loss estimates of 20%, due to the water stress imposed on the crop. The results of this poor application of the scheduling program will make it difficult to ever convince either grower or their associates to adopt a similar practice in the near future.

Table 2. Practices used at each site to meet BMPs.

Site	Practice Employed	Purpose
Coop #1, #2, #4 MAC 90% & 70%*	**Preplant Soil Test**	**Determine initial nitrogen fertilizer required**
Coop #1, #2, #3, #4 MAC 90% & 70%	**Petiole Nitrate Test**	**Determinine timing of in-season nitrogen applications.**
Coop #1, #3 MAC 90% & 70%	**Computer based scheduler**	**Determine irrigation timing and amount required**
Coop #2	**Infrared thermometer scheduler**	**Determine irrigation timing**
Coop #4	**Historical Water Use and Soil Water Holding Capacity**	**Determine irrigation timing and amount required.**

*Although soil samples were collected, data was **not** used by the farm manager to plan the initial fertilizer application in 1991.

Cooperator #4 had the most easily managed soil, and also had a well engineered irrigation system and field layout. This cooperator also was the most aware of crop nitrogen needs, soil characteristics, and crop water use patterns. Much of this knowledge was based on past experience, as well as in-season plant tissue analyses. Because of the high water holding capacity of the soil, and previous experience with the particular field, this cooperator was able to schedule irrigations based upon historical water use data and irrigate only 3 times during the season. Not only were his yields very high, but his irrigation costs were low.

Cooperator #2 had a difficult to manage field. The soil had a high leaching potential (fine sandy loam), the field was somewhat longer than that of the other cooperators (1250 feet), and the capacity of the irrigation delivery system was only marginally adequate during times of high crop water use (late June through the end of the season). The field also had a sidefall of 0.1 inch per 100 feet, creating a difficulty maintaining adequate irrigation water application to the high side of the field while preventing excessive applications to the low side of the field. Further, the field had a "high spot" about 2/3 of the way down the field, resulting in poor uniformity of water distribution down the length of the field. Results of this "high spot" were observed by the project's technical staff as reduced vegetative growth in the area. It is also reflected in the depth of penetration of water in that portion of the field as well as an increased depth of water penetration about halfway down the field due to excessive ponding created by the high spot.

The decision to apply manure as a nitrogen source apparently resulted in a reduction in available nitrogen early in the season, which was the reason for additional applications of nitrogen during the growing season. The large amount of available nitrogen that existed at the end of the season due to the decomposition of the manure created further problems with defoliation. Thus, in spite of good intentions, the constraints placed on the grower by the physical configuration of the field and the manure application made management difficult.

Nitrogen Losses

On each field, four plots were established to which potassium bromide was applied at selected times during the season. Soil samples were collected following selected irrigations during the season, and the depth of bromide movement was determined from soil sample analyses. This permitted the evaluation of the depth of movement of applied irrigation water, since bromide is transported through soil with water, rather than being attracted to soil particles. Analyses for nitrate nitrogen also permitted the evaluation of the amount of nitrate nitrogen carried by the irrigation water below the most active region of the plant root zone (approximately 5 feet). The loss estimates represent losses of nitrogen applied during the year in which the plots were established, and as such do not represent any loss of nitrogen that was present in the active root zone at the beginning of the year. The following table (table 3) presents the depth to which the bromide was transported, and by inference, the depth to which irrigation water moved. Estimates of nitrate nitrogen losses are presented in table 4.

Table 3. Depth, in feet, to which irrigation water moved through the soil on each site.

Site	Timing of Bromide Application	Timing of Soil Sampling	Depth of water movement (feet) Location			
			Plot 1 (Head)	Plot 2	Plot 3	Plot 4 (Tail)
Coop #1	Preplant	Post Harvest	7.5	5.0	6.0	9.0
Coop #2	Preplant	Post Harvest	5.5	>10.0	3.5	>10.0
Coop #3	Preplant	Post Harvest	3.5	3.5	2.5	>10.0
Coop #4	Preplant	Post Harvest	>10.0	4.5	4.5	5.5
			Rep 1	Rep 2	Rep 3	Rep 4
MAC 90% - 91	Preplant	Post Harvest	3.0	4.0	9.0	8.0
MAC 70% - 91	Preplant	Post Harvest	8.0	9.0	8.0	8.0
MAC 90% - 92	Preplant	Post Harvest	3.0	4.0	6.0	
MAC 70% - 92	Preplant	Post Harvest	5.0	7.0	9.0	

As seen from the previous and following tables, a substantial variation occurred over each field. This scenario is quite familiar to us, considering the variation in the infiltration of water observed in a field, creating a non-uniform irrigation application. While non-uniform irrigation application is usually evaluated solely in terms of the length of time irrigation water remains ponded on the soil surface (opportunity time), non-uniform irrigation is a combination of both opportunity time and the soil hydraulic properties. For a constant opportunity time, a soil with a high infiltration rate would have more water infiltrating into it than a soil with a low infiltration rate. A field uniformity evaluation based on opportunity times, however, would predict the same amount of water infiltrated the soil at both places. Consequently, an opportunity time based infiltration uniformity evaluation would also suggest the same amount of nitrate nitrogen leaching would occur throughout the field. Obviously, from the information presented in tables 3 and 4, this is not the case.

As evident from table 1, the application of large amounts of nitrogen or irrigation water is not necessary to produce good yields. Also evident, however, is the fact that under application of water seriously reduces cotton yields. As alluded to in the discussion of practices followed by the managers for cooperator #1, adequate amounts of water on a seasonal basis do not imply that the crop was unstressed during the season. This scenario is sometimes observed in central Arizona when initial irrigations result in an overapplication of water, so that a grower's crop budget for water begins to run short just at the time irrigation water is most critically needed. Other data obtained from this project, as well as from other similar projects recently conducted in the state indicate that the first one or two irrigation of the growing season have the greatest potential for nitrate nitrogen losses if nitrogen is available in the soil at that time. These two irrigations also present the greatest problems for water control on level fields due to a rough furrow surface slowing water advance, and thereby reducing the irrigation application uniformity. A clear observation from tables 1 and 4 is that no matter how little nitrogen and water is applied, nitrogen losses occur. This should be a "common sense" observation, since plant uptake of water and nutrients decreases under stress conditions. It is also clear, however, that excessive nitrogen applications result in large nitrogen losses from the root zone.

It is also a noteworthy observation that the reduced water and fertilizer nitrogen applications to the field plots at MAC in 1992, did not necessarily reduce the amount of nitrogen lost during the season from the in-season applications. It is likely, however, that the decrease in N application reduced the amount of residual N in the soil profile that was available for loss during the following season. Thus, as often stated in the literature, reducing inputs will not necessarily be immediately reflected in reduced losses.

Table 4. Estimate of nitrate nitrogen lossed below the active root zone of irrigated cotton.

Site	Timing of Bromide Application	Timing of Soil Sampling	Nitrate-nitrogen lost (lbs/acre) Location Plot 1 (Head)	Plot 2	Plot 3	Plot 4 (Tail)	Mean
Coop #1	Preplant	Post Harvest	48	0	41	89	44
Coop #2	Preplant	Post Harvest	147	196	0	>24	>92
Coop #3	Preplant	Post Harvest	0	0	0	46	12
Coop #4	Preplant	Post Harvest	18	0	0	14	8
			Rep 1	Rep 2	Rep 3	Rep 4	
MAC 90% - 91	Preplant	Post Harvest	0	0	20	26	12
MAC 70% - 91	Preplant	Post Harvest	68	31	12	32	36
MAC 90% - 92	Preplant	Post Harvest	9	38	11		19
MAC 70% - 92	Preplant	Post Harvest	30	23	13		22

As with most business ventures, timing is everything. Further, the improper use of a procedure to determine the timing and amount of irrigation water application can be as disastrous as using nothing. In such a scenario, personal experience can be a better practice. The success of cooperator #4 confirms that experience coupled with a sound understanding of soil properties and crop water use can be an outstanding practice for minimizing nitrate nitrogen losses as well as obtaining profitable yields. This is not to imply that experience is all that is necessary for BMP implementation; it is clear, however, that the most effective implementation results when the grower has a solid understanding of principles of soil water management.

Finally, it should be stated that, except for the large N application by cooperator #2, the inputs to the fields were very conservative. Although variations in N losses were observed, these variations appear to be controlled more by field variability, rather than by practice implementation. As such, it should be expected that conscientious BMP implementation will result in seasonal N losses of between 10 and 50 lbs/acre, for the kinds of cotton production systems under consideration here. Of particular interest is the fact that reduced irrigation at the MAC sites in 1992 did not result in reduced N losses. This again highlights the fact that crop stress reduces yields, resulting in reduced N utilization by the crop; consequently N losses are not reduced by extreme irrigation water reductions.

Western States Agricultural Laboratory Exchange Program

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

Introduction

With growing utilization of *"best management practices"* in agriculture greater attention is placed on the accuracy of soil and plant analysis information. Although agricultural laboratories generally conduct internal quality assurance procedures there are very few external quality assurance (performance testing) programs for the industry. In the Midwest, agricultural laboratories have been mandated to participate in quality testing certification programs. Nationally, legislation hasbeen drafted for the accreditation of all laboratories performing agricultural related analysis. This report summarizes results of a volunteer performance testing program developed jointly by the University of California Davis and Utah State University for the laboratory industry. The program is supported by a grant from the Fertilizer Research Education Program (FREP) administered by the California Department of Food and Agriculture.

The Program

The objectives of the program are to: (1) provide an external quality assurance program for the individual agricultural laboratory; (2) develop a framework for long-term quality assurance of the agricultural laboratory industry; and (3) identify variability of specific analytical methods. The program involves a quarterly exchange of three soil and three plant samples for the assessment of the analytical quality of soil fertility/salinity and plant nutrient analyses using standardized analytical methods. Specific soil analyses include: saturated paste percentage, pH, EC, soluble cations, SAR, Cl and B; NO_3-N; extractable phosphorus, extractable K, Ca and Mg; micronutrients; total nitrogen and organic matter. Specific plant analyses include: extractable NO_3-N, PO_4-P, Cl; total N, P, K, S, Ca, Mg and micronutrients. Specific analyses maybe completed by more than one method. Exchange materials represent a broad range of agricultural soils and crops collected from over the Western United States, including certified reference botanical materials. Quarterly reports for each sample are prepared containing information on: the number of participants; minimum value reported; maximum value; mean, standard deviation; and relative standard deviation (RSD %). Outlier values are identified using the ratio of extreme value technique developed by Dixon and

---

[1] University California Davis and Utah State University.

Massey (1951). The technique is based on a ratio between a single reported value and the range of all reported values. Outliers are then deleted and a new mean and standard deviation are calculated for each analysis. Results of individual laboratories are evaluated based on established warning and control limits based of ± 2 and ± 3 times the standard deviation of the new mean.

Results

For the 1994 program 102 laboratories were enrolled from twenty-one Western states and Canada, 42 of which were from California. Results of the soils analyses indicate methods exhibiting the highest precision were the saturated paste percentage, soil pH, soil nitrate, total Kjeldahl nitrogen and organic matter, by the Walkley-Black method (Table 1). Methods consistently displaying the greatest variability (RSD > 40%) were: soluble cations and anions in the saturated paste extract, extractable phosphorus, and organic matter-loss on ignition. Soil nitrate variability as expressed as RSD was less than 20 % across all soils using the cadmium reduction method. Generally all four methods used for determining soil nitrate found equivalent concentrations independent of soil sample (Figure 1). Nitrate as determined by ion selective electrode was more variable than two of the four analytical techniques evaluated. Results for extractable soil phosphorus, using bicarbonate, were highly variable (RSD > 40 %). Statisitcal tests indicated soil bicarbonate phosphorus results were not normally distributed and skewed towards high values. A high bias was noted on all soil samples and was attributed to 20 % of the reporting laboratories consistently reporting values 1.5 times the mean (Figure 2). Variability of 30-50% and a high bias is of significance concern for this method since it is extensively used for phosphorus fertilizer recommendations for crops in the Western United States. Soil extractable potassium, as determined by ammonium acetate had an RSD of 12-18 % for all soils except those of very high concentrations. Of the micronutrients DTPA-zinc and how-water extractable boron had the highest variability , RSD 25 - 40 %.

Results for the plant analysis program, indicate that N by combustion, total P, and Mg analyses were the most precise measurements with RSD values ranging from 4 to 15 %. Although, there was good agreement between reported combustion and Kjeldahl nitrogen values, combustion values were consistently higher across all samples tested. Chloride results were highly variable independent of sample. Of significant concern was the high degree of variation in nitrate analysis independent of method and botanical material analyzed (RSD > 35 %). Variability in nitrate increased (RSD > 100 %) as mean concentrations decreased below 1000 ppm. Results were comparable across methods for quantitative analysis of P, S, Mg, Zn, and Mn. Boron results were highly variable for all three methods evaluated independent of sample. Calcium and Cu concentrations were generally lower when determined by dry ash digestion techniques. Overall accuracy and precision of reported results, based on the use of a NIST reference sample, were excellent for N, P, K, Mn and Cu.

Evaluation of temporal variation during 1994 of soil analyses results indicate electrical conductivity (EC), soil nitrate (cadmium reduction method), pH, Bray phosphorus, ammonium acetate extractable cations, DPTA copper, total Kjeldahl nitrogen and Walkley-Black organic matter variations were less than 3 % between exchanges. Soil soluble chloride, boron, zinc results were highly variable over time. Temporal variation of plant analyses indicate total nitrogen (combustion and Kjeldahl), P, K, Ca, Mg, Mn, Cu variation were less than 3 %. Exceptional variability was noted for boron, nitrate and ortho phosphate analyses.

Summary

The Western States Program has been highly successful based on positive feedback from the industry and the large number of participating laboratories. The program has shown that Agricultural laboratories are providing quality soil and plant analyses and are willing to improve. It has identified several soil and plant analytical procedures which will require the attention of the industry for improvement. Work is currently underway addressing possible method problems associated with the soil bicarbonate procedure which resulted in biased high values in 1994 program. This program will continue in 1995 with addition of four new soil analytical methods; SMP buffer pH, soil NH_4-N, SO_4-S and cation exchange capacity. It is hoped that this program can be developed in into a recognized accreditation program for the agricultural laboratory industry.

Literature

Dixon and Massey. (1951) pp. 68-78. ed. W.J. Dixon *IN*: Introduction to Statistical Analysis, McGraw-Hill Book Co.

Gavlak, R. D. Horneck and Robert O. Miller. 1994. Plant, Soil and Water Reference Methods for the Western Region. Western Region Extension Publication WREP 125.

Sterrett, S.B, C.B. Smith, M.P. Mascianica, and K.T. Demchak. 1987. Comparison of analytical results from plant analysis laboratories. Commun. Soil Sci. Plant Anal. 18(3) 287-299.

Table 1. Western States Sample Exchange Program results for soil samples 94102 and 94103.

Soil		**94102**			**94103**		
Analysis	**Units**	**Mean**	**Stdev**	**RSD %**	**Mean**	**Stdev**	**RSD %**
Salinity							
Sat. Paste	%	43.9	6.0	14	54.2	7.0	13
pH - sp		5.2	0.26	5	7.5	0.28	4
ECe - sp	dS/m	2.8	0.6	21	0.5	0.1	22
HCO3 - sp	mmolc/L	1.2	1.50	122	5.5	5.06	93
CO3 - sp	mmolc/L	0.0	0.0	280	0.2	0.3	193
Ca - sp	mmolc/L	5.1	1.15	22	3.1	0.91	29
Mg - sp	mmolc/L	6.2	1.4	23	1.3	0.4	28
Na - sp	mmolc/L	14.7	1.86	13	0.6	0.36	59
SAR - sp	mmolc/L	5.9	0.4	7	0.4	0.2	58
Cl - sp	mmolc/L	20.6	8.10	39	1.2	1.39	112
B - sp	mg/kg	0.2	0.2	65	0.2	0.1	71
Fertility							
pH (1:2)		5.4	0.2	4	7.8	0.3	4
NO3 - Cd. Red.	mg/kg	11.8	2.4	21	7.1	0.8	11
NO3 - ISE	mg/kg	11.2	3.3	29	8.5	3.2	38
NO3 - CTA	mg/kg	12.7	1.8	14	9.2	1.1	12
NO3 - Oth.	mg/kg	12.3	3.4	27	8.7	3.6	41
P - Bicarb	mg/kg	11.7	3.7	31	7.8	4.4	56
P - Bray	mg/kg	8.0	4.5	56	12.6	4.2	34
P - Meh. 3	mg/kg	13.4	4.7	35	64	80	124
P - Other	mg/kg	290	59	20	201	505	251
K - AmAc	mg/kg	102	17	17	620	112	18
Ca - AmAc	mg/kg	860	245	28	5475	1840	34
Mg - AmAc	mg/kg	471	97	21	691	156	23
Zn - DTPA	mg/kg	4.4	0.7	17	1.1	0.3	28
Mn - DTPA	mg/kg	176	68	39	11.7	3.6	31
Fe - DTPA	mg/kg	110	40	36	8.5	2.7	32
Cu - DTPA	mg/kg	6.9	1.08	16	1.7	0.24	15
B-Hot Wat.	mg/kg	0.8	0.3	33	0.6	0.3	49
TKN	%	0.1	0.01	13	0.2	0.02	13
OM - WB	%	1.7	0.3	20	2.9	0.3	11
OM - LOI	%	2.9	0.73	26	4.7	1.52	33

* Mean and standard deviation based on reduced data set outliers removed.

Figure 1. Box plot of of soil nitrate concentrations for sample 94101 by four methods: cadmium reduction, ion selective electrode chromotropic acid and other (multiple methods not listed).

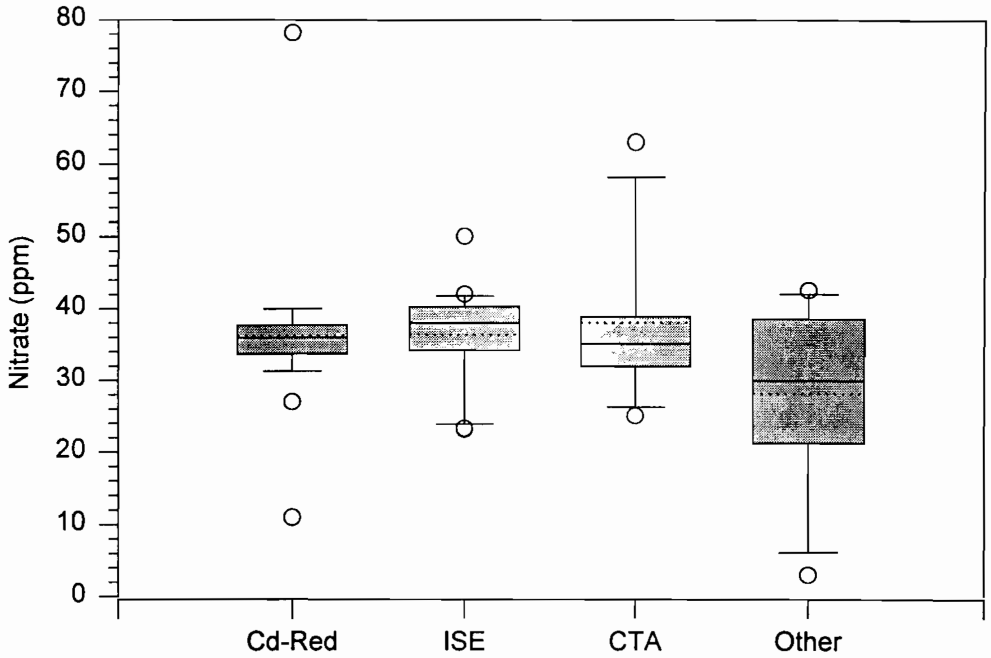
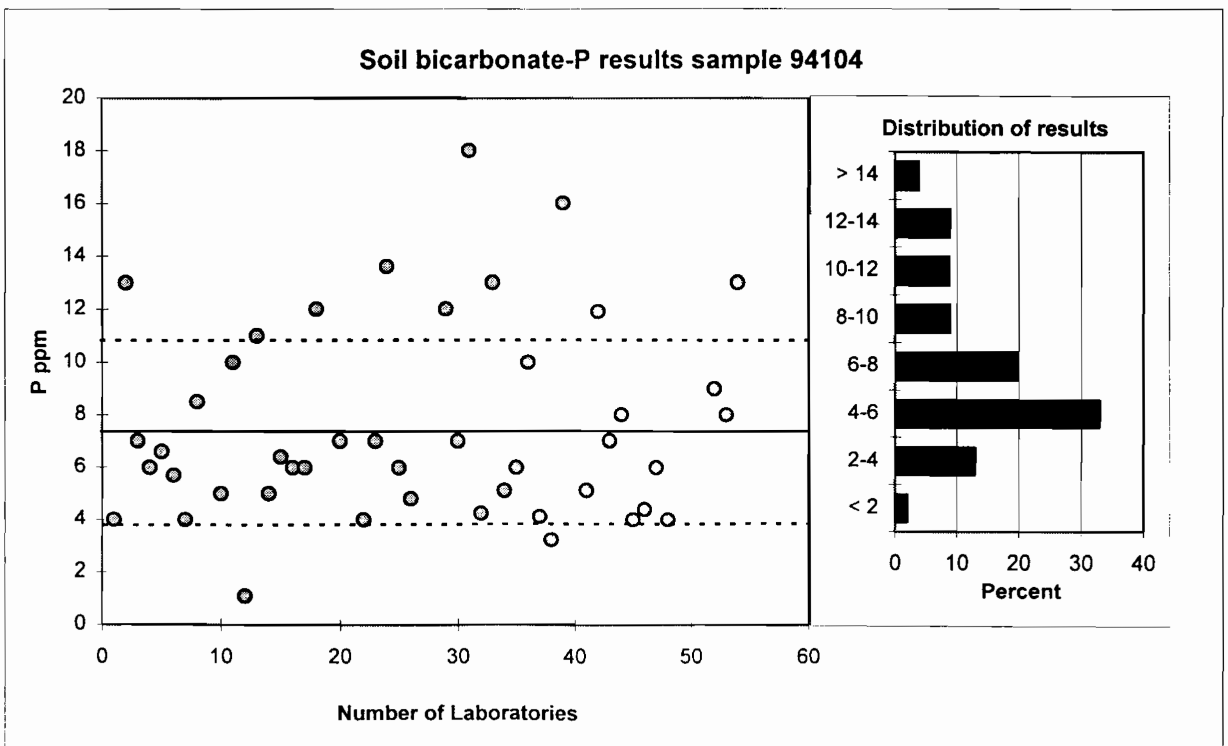


Figure 2. Scatter plot and distribution profile of reported values for soil bicarbonate phosphorus for sample 94104. Mean and standard deviation 7.3 and 3.4 ppm respectively, outliers removed.



Effects of Nitrogen Fertilization on Three Diseases of Almond Trees

Beth L. Teviotdale
Extension Plant Pathologist
University of California, Davis/Kearney Agricultural Center

INTRODUCTION

Nitrogen nutrition affects the severity of numerous plant diseases. In general, high nitrogen levels tend to exacerbate disease problems. Fireblight of apple and pear and brown rot of peach and nectarine are examples of tree diseases influenced by nitrogen nutrition. Both diseases are worse in trees having high nitrogen fertilization programs. Thus there is precedent that some tree diseases may be ameliorated by altering nitrogen fertilization. At present we have a unique opportunity to assess the effects of nitrogen nutrition on three diseases of almond trees.

Diseases of the flowers, fruit and foliage of almond trees often are lumped together under the broad category of "bloom diseases". This designation refers as much to the growth stage at which trees are treated with fungicides as to the plant parts which are attacked. Of the several diseases in this group, we will be investigating brown rot blossom and twig blight and green fruit rot.

Brown rot blossom and twig blight is a disease of almond trees caused by the fungi *Monilinia fructicola* or *M. laxa*. Although both fungi can attack almond flowers, *M. laxa* is almost exclusively the pathogen found associated with this disease in nature. The disease is exacerbated in years of heavy rainfall during bloom and causes both current-season crop loss, by destroying the flowers, and future yields because fruiting spurs also are killed. Some very susceptible cultivars, such as Butte, may have serious brown rot infections even in years of relatively little rainfall during bloom. Because almonds are not self fertile, almond orchards are planted with at least two cultivars which act as pollinators for each other. If brown rot destroys the flowers on one cultivar, the crop on the other cultivar also is in jeopardy. Most orchards in the state are treated at least once during bloom with fungicides for brown rot control. Where the disease is particularly severe or in areas of potential high rainfall most years, many orchards our routinely treated twice during bloom.

Green fruit rot may be caused by the fungi *Botrytis cinerea*, *Sclerotinia sclerotiorum* or either of the two brown rot fungi. The disease usually is sporadic and in the past has been attributed largely to *B. cinerea*. Recently, *M. laxa* has been found associated with rotted green fruit and dead shoots and spurs collected from numerous orchards. The fungi appear to initiate growth on dead tissues, such as the cast floral cup or petals, prior to invasion of the green fruit. Infected dead floral parts in contact with green fruit during wet weather lead to green fruit rot. Consequently, the disease is most serious on cultivars such as Carmel that have clustered fruit which retain dead floral parts. Spring rains then provide the climate for infection. Little is known about green fruit rot, and control practices for the disease are not well defined. For Botrytis or Sclerotinia green fruit rot, the recommended control is fungicide application at full bloom. This coincides with treatment for brown rot blossom and twig blight. We have evidence that post bloom fungicide treatments may reduce brown rot green fruit rot.

Hull rot, the third disease we are studying, occurs during the last stages of fruit maturation. As the almond fruit matures, the mesocarp (hull) splits along the ventral suture. At first the opening of the hull is very small, the hull is green and fully attached to the pedicel. As the split widens, the hull turns a dull tan, loses moisture and loosens from the tree. By harvest, the hulls of most almond fruit are fully open, dry and leathery. Some fruit fall from the tree, but most remain attached by a few vascular elements and are easily shaken from the tree by mechanical harvesters.

Hull rot is caused by several fungi: *Rhizopus stolonifer, R. circinans, R. arrhizus, M. fructicola* and *M. laxa*. The most common and important are *R. stolonifer* and *M. fructicola*. None attack the outer hull surface of the almond fruit but establish infection through the inner surface of the hull any time during dehiscence (hull split). The infection causes lesions on the hull and usually fungal growth is visible to the unaided eye. A toxin (shown to be fumaric acid in *R. circinans*) produced by the fungi is translocated to and kills the subtending tissues. The nutmeat is not harmed, but valuable fruiting wood is destroyed. The disease is most severe on the widely planted cultivar Nonpareil. Hull rot is associated with vigorous, heavily bearing orchards.

Little is known about hull rot. Soil and plant debris are probably the sources of *Rhizopus* spp. inoculum, but inoculum sources for *M. fructicola* have not been identified in almond orchards. Insects and air currents are the suspected agents of spore dispersal.

No fungicide program is available for control of hull rot, and none is likely to be developed given the difficulty in coverage needed to provide protection and the desire to reduce fungicide applications. Furthermore, fungicide residues on hulls, which are fed to livestock, would pose an additional problem. For control, early harvest and cultural practices that encourage air movement thereby keeping humidity down are recommended. In other research, we found that alterations in irrigations near harvest reduce hull rot incidence.

PROCEDURES

To date, most of our work on the effects of nitrogen levels on disease has been on hull rot. We worked in orchards where experiments on nitrogen nutrition were conducted. The orchards (Numbers 1 and 2) were located in Stanislaus County and the experimental design, randomized complete block, was the same for both. Orchard 1 was planted 1:1:1 with cultivars Nonpareil, Price, Carmel and Orchard 2 was planted 1:1 with cultivars Nonpareil and Carmel. The treatments were: oat cover crop, clover cover crop, 0, 125, 250, and 500 lbs N/acre. Yields and leaf nitrogen contents of individual trees were taken in 1989 before nitrogen treatments were imposed. Trees having similar pre-treatment yields and leaf nitrogen contents were grouped to provide two adjacent trees in each of four replications of each treatment. The two data trees were embedded in the center of plots which were three rows wide and four trees long. Nitrogen was applied as ammonium sulfate 21 percent. Each year one third the annual total nitrogen placed in

April each year and the remaining two thirds in October. Orchards were irrigated immediately following fertilizer placement.

Leaf nitrogen data were obtained from 100 leaves per tree collected in June by Dr. Steve Weinbaum who conducted the nitrogen nutrition study. Trees having leaf nitrogen content of <2.0% are considered deficient, and leaf nitrogen contents of 2.0-2.2%, 2.2-2.5%, and >2.5% are rated as low, medium and high, respectively.

Natural infection was assessed in all six nitrogen treatments in both orchards in 1992 and in the 0, 125, 250, and 500 lbs N/acre treatments in Orchard 1 in 1993. We counted the strikes (clusters of dead leaves) and estimated the inches of wood killed per tree immediately after trees were shaken for harvest. We also collected a 2.0 lb sample of fruit from beneath each test tree in each plot from which 100 fruit were drawn to ascertain percent hulls infected by hull rot fungi.

Inoculation experiments were conducted in the 0, 125, 250 and 500 lbs N/acre treatments in Orchard 1 in 1993. Twenty-five fruit/rep having firmly attached hulls and healthy associated leaves were inoculated with 10^4 conidia per ml suspensions of *R. stolonifer* and *M. fructicola*. Percent hull infection and leaf death were determined at harvest.

In 1993, brown rot blossom blight was evaluated in Orchard 2. All brown rot strikes on the two data Nonpareil trees and on the 10 Carmel guard trees were counted on 26 May.

RESULTS AND DISCUSSION

Natural incidence of hull rot generally increased with increasing amounts of applied nitrogen (Tables 1 and 2). In inoculation experiments, a similar pattern was found but was less pronounced in either orchard, and *Monilinia* caused more dead leaves and infected hulls than did *Rhizopus* (Table 3). Brown rot blossom blight also increased with increasing nitrogen levels (Table 4). Leaf nitrogen content reflected the levels of nitrogen applied and increased in each treatment in 1993 over that found in 1992 in both orchards (Table 5).

Leaf nitrogen contents above the range considered sufficient appear to cause marked increases in hull rot and brown rot. Our research in the coming year, 1995, should shed more light on the effect of nitrogen fertilization on these and green fruit rot diseases of almond.

Table 1. Natural incidence of hull rot in cv Nonpareil almond trees fertilized with four levels of applied nitrogen or two cover crops. Stanislaus County, 1992.

Treatment (nitrogen, lb/acre)	Avg. number strikes per tree		Avg. inches dead wood per tree		Avg. percent hulls naturally infected with			
					Monilinia		*Rhizopus*	
	Orch 1	Orch 2	Orch 1	Orch 2	Orch 1	Orch 2	Orch 1	Orch 2
500 N	34.5	191.0	5.5	241.0	8.8	13.8	16.5	23.8
250 N	36.2	181.7	6.2	109.2	7.7	8.5	14.2	27.5
125 N	19.7	92.2	5.5	63.5	8.5	5.0	10.7	19.5
0	22.5	62.0	0.0	23.0	10.5	7.8	6.5	18.3
Oats	21.2	67.7	4.0	21.5	17.5	6.2	4.2	26.7
Clover	20.7	46.7	0.0	22.5	9.7	10.3	6.7	20.8

Table 2. Natural incidence of hull rot in cv Nonpareil almond trees fertilized with four levels of applied nitrogen or two cover crops. Stanislaus County, 1993.

Treatment (nitrogen, lbs/acre)	Strikes/tree		% Naturally infected hulls			
			Orchard 1		Orchard 2	
	Orchard 1	Orchard 2	*Monilinia*	*Rhizopus*	*Monilinia*	*Rhizopus*
500 N	59.2	39.5	57.0	0.0	64.0	8.0
250 N	47.1	33.5	59.0	0.0	49.0	8.0
125 N	22.5	24.5	49.0	3.0	44.0	1.0
0	27.4	17.2	34.0	0.0	44.0	1.0

Table 3. Effect of four levels of applied nitrogen on hull infection and leaf death of cv Nonpareil almond fruit inoculated with the hull rot pathogens *Monilinia fructicola* or *Rhizopus stolonifer*. Stanislaus County, 1993.

Treatment	Dead leaves, percent		Infected hulls, percent	
	Orchard 1	Orchard 2	Orchard 1	Orchard 2
Nnitrogen, lbs/acre)				
500 N	56.8	49.0	76.5	74.7
250 N	58.0	51.0	69.1	65.2
125 N	47.5	39.1	71.1	60.7
0	50.8	38.5	65.9	60.3
Pathogens				
Monilinia	83.1	84.6	98.2	96.5
Rhizopus	57.2	33.0	69.2	54.2
Control	19.5	15.7	44.6	45.1

Table 4. Effect of four levels of applied nitrogen on natural incidence of brown rot of almond trees. Stanislaus County, 1993.

Treatment	Strikes/tree		Leaf
(nitrogen, lbs/acre)	Nonpareil	Carmel	nitrogen, %
500 N	13.0	60.8	2.68
250 N	9.0	61.2	2.52
125 N	5.5	24.7	2.46
0	4.2	19.0	2.28

Table 5. Percent leaf nitrogen content of cv Nonpareil almond trees, Stanislaus County.

Treatment	Orchard 1		Orchard 2	
(nitrogen lbs/acre)	1992	1993	1992	1993
500 N	2.48	2.74	2.36	2.68
250 N	2.44	2.68	2.24	2.52
125 N	2.30	2.52	2.21	2.46
0	2.24	2.36	2.13	2.28

TIME OF APPLICATION OF UREA TO CITRUS FOLIAGE INFLUENCES YIELD, FRUIT SIZE AND SCARRING BY CITRUS THRIPS

Carol J. Lovatt, Associate Professor of Plant Physiology
Department of Botany and Plant Sciences, UC-Riverside

Joseph G. Morse, Professor of Entomology
Department of Entomology, UC-Riverside

INTRODUCTION:

Foliar-applied urea was demonstrated in the early 1960's to be as efficacious as nine other sources of nitrogen supplied to the soil in maintaining yield of orange trees (Leonard et al., 1961). Embleton and Jones (1974) provided evidence that maximum nutritionally-attainable yields for sweet oranges were obtained with annual nitrogen rates of 0.45 to 0.65 kg per tree, regardless of the method of application. Foliar application of nitrogen fertilizer to citrus has not been widely adopted commercially. Due to the limits in the amount of nitrogen that can be applied in a single application, up to five foliar sprays may be required each year to provide the recommended annual rate of nitrogen, creating the perception that foliar nitrogen fertilization is more expensive because several applications are required to maintain yield. Thus, it is necessary to demonstrate that foliar nitrogen fertilization is cost-effective in order to encourage citrus growers to abandon the use of soil-applied nitrogen in favor of foliar-applied urea.

Earlier results of Sharples and Hilgeman (1969) suggested that urea applied to the foliage at the proper time might have a beneficial effect on yield. They were able to obtain yields of `Valencia' oranges over a 7-year period with only 0.23 kg N total per tree split between two foliar applications of urea, one in February and a second in late April to early May, that were statistically equal to yields obtained with 0.45 or 0.91 kg N per tree as ammonium nitrate supplied to the soil. Similarly, recent research (Ali and Lovatt, 1994) demonstrated that a properly-timed winter prebloom (mid-January or mid-February) application of low-biuret urea to the foliage of the `Washington' navel orange (0.16 kg N per tree) significantly increased yield and fruit number per tree each year compared to control trees receiving soil-applied nitrogen for the three consecutive years of the study. The number of commercially valuable fruit with diameters 6.1 to 8.0 cm increased significantly as yield increased (r^2=0.88). Without taking into account the increase in the number of fruit of packing carton sizes 88 and 72, which have a greater dollar value, and despite the loss in yield due to a freeze in December of year two of the study, the average net dollar return per acre per year for trees receiving foliar low-biuret urea versus soil-applied low-biuret urea was approximately $450 and $400 for applications made in mid-January and mid-February, respectively (Ali and Lovatt, 1992). Consistent with the hypothesis that timing is important, mid-November and mid-December sprays were less effective. Of additional benefit, Embleton and Jones (1978) and Embleton et al. (1986) documented that foliar application of nitrogen substantially reduced nitrate pollution of ground water, even when used to only partially replace soil-applied nitrogen.

Growers in the San Joaquin Valley comprise a majority (59%; 91,000 acres) of California's citrus acreage and have historically used chemicals to control citrus thrips. Broad-spectrum materials such as dimethoate and formetamate, the two main pesticides used over the last 15 years to control citrus thrips are devastating to biological control agents such as *Aphytis melinus* DeBach (Morse and Bellows, 1986), which can be used to control red scale in citrus. Thus, current use of chemicals to control citrus thrips precludes the use of biological control for other insect pests. A non-pesticide strategy to control citrus thrips would aid in converting the San Joaquin Valley to biological control (Luck et al., 1986).

A predacious mite, *Euseius tularensis* (*E. hibisci*) Congdon and McMurtry, a polyphagous natural enemy of citrus thrips, appears to provide some biological control, especially when citrus thrips pressure is light (Tanigoshi and Griffiths, 1982; Tanigoshi et al., 1984, 1985). However, during warm periods after petal-fall, citrus thrips levels can rapidly increase to levels that the predaceous mite has trouble controlling. A selective material that could reduce the level of citrus thrips before or at this time would be helpful. Preliminary results from both laboratory and field experiments provide evidence suggesting that foliar-applied low-biuret urea might be effective in reducing citrus thrips population levels. The only other selective materials presently available for citrus thrips control are sabadilla (Veratran D) and ryania (Ryan 50), both marginally effective botanical baits when mixed with sugar, and the newly registered abamectin (Agir-Mek). Both are in short supply. If, as expected with increased interest in citrus integrated pest management including *Aphytis* releases for California scale control, a moderate number of growers start to use one or both of these materials, supply could not meet demand.

The objective of the present study was to test the hypothesis that foliar urea applied within the period April 1 to June 1 can do triple duty (i) as a "non-pesticide" to control citrus thrips and reduce fruit scarring, (ii) as a "growth regulator" to improve fruit set and increase yield without reducing fruit size or quality, and (iii) as a nitrogen fertilizer by supplying a portion of the nitrogen to be applied in a given year thus reducing the amount applied to the soil. The goal of our research was to determine whether there is an optimal time for foliar application of urea that will successfully improve fruit set and yield and control citrus thrips to reduce fruit scarring that would be cost-effective. If successful, the results of our research will not only improve citrus productivity and grower profits, but will also reduce pollution to the groundwater from nitrate and reduce the amount of chemical pesticides currently used to control citrus thrips.

PROCEDURES:

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

There were five treatments each replicated as eight randomized blocks (six rows wide by 15 trees long). Data was collected from six individual trees per block for a total of 48 data trees per treatment. Foliar low-biuret urea was applied each year on approximately April 7, April 21, May 5, or May 20 for treatments 1 through 4, respectively. Treatment 5, the control, was Paramount Citrus' current management practice, consisting of soil-applied nitrogen. Total nitrogen analyses were done annually in September on each of the 240 data trees in order to monitor the total nitrogen status of the tree as is currently done commercially and to determine the contribution to total N made by each treatment over the 3 years of the field trial.

Harvest was in March of each year, with harvest for year three scheduled for March 1995. Fruit weight per tree, fruit number per tree, fruit size for all fruit on each of the 240 data trees, and degree of thrips scarring on all fruit on 120 data trees were determined.

RESULTS:

Foliar applications of low-biuret urea consistently raised the NH_3-NH_4^+ content of both the young and mature leaves by 100 to 150 μg per g dry weight leaf tissue, but this increase was only evident for sampling dates 1 to 3 days after the foliar urea application. Eight days after the foliar application of urea, the levels of NH_3-NH_4^+ in either young or mature leaves were not significantly different from the control leaves on the same date or the time zero leaves collected the day before the foliar application of urea.

Total nitrogen content of the leaves for all trees used in the research increased from 2.5% in September 1991 to 2.9% in September 1992. The spring application of low-biuret urea may contribute to the annual nitrogen requirement of the tree, but it was not possible to tell the effect of the urea sprays versus that of the soil-applied N from the leaf analyses provided to us by Paramount Citrus. Individual data trees were sampled in September 1994 in order to be able to detect treatment effects.

The results of the study provided clear evidence that a spring foliar application of low-biuret urea had no negative effect on the population densities of beneficial predatory mite, *Euseius tularensis*. There was no significant difference in the number of predacious mites per leaf for trees on which 500 mites had been released on March 19, 1992, independent of whether these trees were left as controls or were subsequently sprayed with low-biuret urea on the date indicated. The number of mites per leaf was not due to a natural increase in the population by immigration during the course of the study, since the control trees on which no mites were released had significantly lower numbers of mites per leaf on both sampling dates.

Spring foliar applications of low-biuret urea had no statistically significant effect on the population densities of *Scirtothrips citri*. The high degree of variability in the number of thrips in each of the replicate samples made it impossible to detect statistically significant differences due to any of the treatments.

Spring foliar applications of low-biuret urea had no statistically significant effect on fruit scarring determined as either on-tree evaluations of fruit on the outside of the tree in September or evaluation of total fruit per tree at harvest in March. While not significant at the 5% level, it is interesting to note that for both years of the study, the late May (May 20, 1992 and May 25, 1993) foliar application of low-biuret urea resulted in the lowest degree of fruit scarring, especially severe scarring (Table 1). This trend was observed for both the on-tree and harvest evaluations for both years of the study. Although not significant at the 5% level, it is also worth noting that for both years of the study, the second date of foliar application of urea (April 21, 1992 and April 27, 1993) had the highest percent scarring, especially severe scarring. In year two, the mean percent of fruit severely scarred by citrus thrips was significantly less at the 10% level for trees receiving the late May application of low-biuret urea compared to trees receiving the late April application (Table 1). Neither value was significantly different from the control or from trees receiving urea to the foliage in early April or early May.

In the first year of the study, which was an "on" year, there were statistically significant differences at the 5% level between dates of urea application to the foliage in terms of total weight of fruit per tree and the number of fruit of packinghouse carton size 56 (fruit with diameters between 8.1 and 8.8 cm). The date of foliar urea application had no statistically significant effect on other sizes of fruit. The May 20, 1992 foliar application of low-biuret urea had the highest total fruit weight and the highest number of fruit of packinghouse carton size 56. In both cases, the May 20, 1992 low-biuret urea application was statistically better at the 5% level than the April 7 and May 5 spray dates. However, the April 7, April 21, and May 5 treatments were not statistically different from the control at the 5% level. At the 10%

level, the May 20, 1992 foliar application of urea resulted in significantly more total weight of fruit per tree and more fruit per tree of packinghouse carton size 56 than the control and all other treatments, except the April 21, 1992 urea application.

In the second year of the study, which was an "off" year, there was no significant effect at the 5% level on the kg and number of fruit per tree. There was, however, a statistically significant increase in the kg of fruit of packinghouse carton size greater than 56 (fruit with diameters greater than 8.8 cm) for trees receiving the May 25, 1993 foliar application of low-biuret urea compared to the control trees receiving soil-applied nitrogen. Trees receiving the May 25, 1993 foliar application of low-biuret urea had significantly more fruit of packinghouse carton size 56 than trees receiving the early April 13 foliar application of urea.

Repeated Measure Analysis was used to test the effect of the time of foliar-urea application on fruit yield, number and size over the two years of the study. The late May foliar application of low-biuret urea significantly ($P \leq 0.05$) increased yield (kg) and both the kg and number of fruit of packinghouse carton size 56 per tree compared to trees receiving foliar applications of low-biuret urea in early April or early May, but was not significantly different from the control trees receiving soil-applied nitrogen or from trees receiving a foliar application of low-biuret urea in late April (Table 2). There was no significant effect on the kg or number of fruit in any other size category.

DISCUSSION:

Our results suggest that urea will not have much impact in preventing scarring of fruit when thrips pressure is great. The performance of urea in reducing the percentage of fruit scarred by thrips in a light thrips year remains to be determined. The results provide evidence that a properly-timed spring (late May) foliar application of low-biuret urea significantly increased yield by increasing both the weight and number of large-sized fruit (packinghouse carton size 56) with some reduction in the degree of severe fruit scarring by citrus thrips. Trees receiving the late May foliar application of low-biuret urea averaged 11 kg more fruit than the control trees receiving soil-applied nitrogen over the two years of the study. This represents an additional 0.65 17-kg carton of fruit per tree. At a typical planting density of 96 trees per acre, the late May foliar application of low-biuret urea would yield 63 additional cartons per acre. For the cost/benefit analysis, the following values were used: (*i*) price of $8.00 per 17-kg carton despite the fact that the late May foliar application of urea increased the number of fruit per tree of packinghouse size 56 and had no effect on any other fruit size and subtracted $2.29 per carton for packinghouse handling of the extra cartons (per Connelly Melling; Dole) to calculate profit; (*ii*) 56.8 liters (15 gallons) Unocal PLUS per acre at $16.50 per acre; and (*iii*) spray rig application at $25.00 per acre to calculate expenses with all other expenses being the same, although there really is the expense of a soil application of nitrogen to the control trees which was not included. Net return to the grower for the late May foliar application of low-biuret urea was an average of $318 per acre per year.

Table 1. Effect of Time of Application of Low-Biuret Urea to the Foliage of the 'Washington' Navel Orange on the Percent of Fruit at Harvest Severely Scarred by Citrus Thrips.[z]

Date Urea Applied to Foliage	%Severely Scarred Fruit Year 1	$P \leq 0.10$	%Severely Scarred Fruit Year 2	$P \leq 0.10$
early April	20.65	a	11.93	ab
late April	21.99	a	14.03	a
early May	20.89	a	11.09	ab
late May	16.09	a	9.67	b
control-soil applied N	18.94	a	11.08	ab

[z] Average yield for all treatments was 269 ± 13 and 141 ± 4kg fruit per tree in years 1 and 2, respectively.

Table 2. Effect of Time of Application of Low-Biuret Urea to the Foliage of the 'Washington' Navel Orange on Yield for the Two Years of the Study

Date Urea Applied to Foliage	Yield kg/tree	$P \leq 0.05$	56s kg/tree	$P \leq 0.05$
early April	197	b	53	b
late April	210	ab	60	ab
early May	201	b	56	b
late May	215	a	65	a
control-soil applied N	204	ab	60	ab

LITERATURE CITED:

Ali, A. G. and C. J. Lovatt. 1992. Scientific rationale and economic incentives: Winter application of foliar urea. Citrograph 78:7-9.

Ali, A. G. and C. J. Lovatt. 1994. Winter application of low-biuret urea to the foliage of `Washington' navel orange increased yield. J. Amer. Soc. Hort. Sci. 119: (in press).

Embleton, T. W. and W. W. Jones. 1974. Foliar-applied nitrogen for citrus fertilization. J. Environ. Quality 3:338-392.

Embleton, T. W. and W. W. Jones. 1978. Nitrogen fertilizer management programs, nitrate-pollution potential, and orange productivity. *In* D. R. Nielsen and J. G. MacDonald (eds.), Nitrogen in the Environment, Vol. 1. Academic Press, New York, pp. 275-295.

Embleton, T. W., M. Matsumura, L. H. Stolzy, D. A. Devitt, W. W. Jones, R. El-Motaium, and L. L. Summers. 1986. Citrus nitrogen fertilizer management, groundwater pollution, soil salinity and nitrogen balance. Applied Agr. Res. 1:57-64.

Leonard, C. D., I. Stewart, and I. W. Wander. 1961. A comparison of ten nitrogen sources for `Valencia' oranges. Florida State Hort. Soc. 74:79-86.

Luck, R. F., J. G. Morse, and D. S. Moreno. 1986. Current status of integrated pest management in California citrus groves. *In* R. Cavalloro and E. D. Martino (eds.), Integrated Pest Control in Citrus Groves, Proc. Experts' Meet./Acireale/26-29 March 1985. A. A. Bal kema, Boston, pp. 533-543.

Morse, J. G. and T. S. Bellows. 1986. Toxicity of major citrus pesticides to *Aphytis melinus* (Hymenoptera: Aphenlinidae) and *Cryptolaemus montrouzieri* (Coleoptera: Coccinellidae). J. Econ. Entomol. 79:311-314.

Sharples, G. C. and R. H. Hilgeman. 1969. Influence of differential nitrogen fertilization on production, trunk growth, fruit size and quality and foliage composition of `Valencia' orange trees in central Arizona. Proc. 1st Intl. Citrus Symp. 3:1569-1578.

Tanigoshi, L. K. and J. Griffiths. 1982. A new look at biological control of citrus thrips. Citrograph 67:157-158.

Tanigoshi, L. K., J. Fargerlund, J. Y. Nishio-Wong, and H. J. Griffiths. 1985. Biological control of citrus thrips, *Scirtothrips citri* (Thysanoptera: Thripidae), in southern California citrus groves. Environ. Entomol. 14:733-741.

Tanigoshi, L. K., J. Y. Nishio-Wong, and J. Fargerlund. 1984. *Euseius hibisci*: its control of citrus thrips in southern California citrus orchards. *In* D. A. Griffiths and C. E. Brown (eds.), Acarology VI, Vol. 2. Ellis Horwood, Chichester, England, pp. 717-724.

Land application of manure waters: Nutrient content

Deanne Morse and Larry Schwankl
University of California, Davis

Background

The California dairy industry is home to some 1.16 million cattle and their replacements. The manure from these animal is handled in solid or liquid forms. Solid manure is stacked and often transported off farm as a soil amendment or compost feed stock, or is utilized on the producer's dairy operation (bedding and/or a soil amendment). The liquid manure includes solid manure that was collected with water or recycled water, and wash water from the milking facility. This water may or may not go through a solid separation step (gravity or mechanical) prior to being held in a holding, storage or treatment pond. The ultimate fate of liquid manure water is land application. Common crops to receive some form of manure waters are corn and cereal grains, alfalfa, some orchards, and cotton land prior to planting.

If the sole concern of land application of manure water was for disposal purposes, it would not matter when or where water was applied. Such circumstances could lead to contamination of underlying groundwater via over application of water/nutrients and deep percolation. The reality is that California's Porter Cologne Act (5) already states that land application of animal manures occur at appropriate rates. The purpose of the existing law, and of amendments to the Coastal Zone Management Act (3) is to minimize the potential contamination of water resources by applying nutrients at agronomic rates and at appropriate times.

The concept of nutrient management is a simple academic procedure. Nutrients should be applied at the appropriate rate and time. This implies that plant nutrient needs are known and that nutrient content of all nutrient sources is also known. Although nutrient needs of some plants are known, there are many other plants with undefined nutrient needs. It is easy to determine the nutrient content of commercial fertilizer by reading a label. It is more difficult to determine the nutrient content of an organic nutrient source (manure solids or liquids). Such determination requires sampling and testing the source.

Nutrient management is gaining greater attention from regulatory personnel, from individuals who advise growers and producers and from growers and producers themselves. In some situations, costs can be reduced by managing nutrients more effectively. Recent passage of the Coastal Zone Act Reauthorization Amendments (3) and the accompanying (g) guidance (6) has prompted the State Water Resources Control Board to re-evaluate its non-point source program. During this process a series of Technical Advisory Committees were established to address a variety of subjects.

Nutrient management was one committee.

This paper will discuss the variability in nutrient content of irrigation waters. However, this is only one part of the picture. Irrigation waters must be managed to distribute the nutrients uniformly and to prevent deep percolation. Irrigation water management strategies will be covered in a companion paper (4).

Key questions

Manure water is land applied throughout California. Until the following series of questions is answered, it is recommended that manure waters be tested at least twice annually during land application and also after any major additions of fresh water to the storage pond.

The key questions to answer are:

1) Where should a pond be sampled from to determine nutrient content?

2) How many samples should be taken to have confidence in the values obtained?

3) Do samples taken from the pond reflect the content of nutrients entering a field during the actual irrigation event(s)?

4) Does nutrient content of water vary greatly during an irrigation?

Current Knowledge

Research related to nutrient content of manure water was conducted in early 1980 and has resurfaced in the 1990's. The key conclusion from the earlier work was the recommendation of diluting manure water with 3 to 5 parts of fresh water prior to land application.

Sampling from ponds. Ponds from two dairies were monitored in the spring of 1994 (1). Pre-dewatering samples were taken from the ponds at the surface and at five foot depth intervals from the surface to the bottom. Six locations were used within each pond. Sampling was accomplished by use of a flat bottom boat and a bomb sampler. Samples were analyzed for total solids (TS), ammoniacal-N (NH_4-N), total kjeldahl N (TKN), phosphorus (P), potassium (K), and electrical conductivity (EC). Four samples were taken daily during the subsequent dewatering.

Pond 1 was located in Tulare County. Cows are housed in dry lots and corrals. Feed alleys and the milking area are flushed. The pond is used as temporary storage. Pond water is not recycled. The pond is 90 x 600 ft. Solids settled near the inlet at one end of the pond. Pond depth varied from 6 to 16 ft. A total of 19 samples were taken during the pre-dewatering phase, and 40 samples were taken during the dewatering phase. Data from the pre-drawdown and the drawdown event are presented in Table 1.

Table 1. Average nutrient content of six dairy pond locations (by depth from the surface) and ranges and average nutrient content of samples taken from drawdown of a Tulare County dairy pond. Units expressed in pounds of nutrient per acre-inch of water applied.

	Ca	Mg	NH4-N	TKN	K	TS
			lbs/ac-in			
Pre-drawdown						
Surface	19.7	8.3	26.5	31.7	44.8	461
5' below	19.3	7.8	25.1	37.8	39.4	4650
10' below	18.4	8.1	26.6	56.9	39.8	11938
bottom	17.5	7.3	25.6	47.3	38.9	9990
Dewatering						
Low	9.1	4.6	17.6	24.0	24.0	237
High	14.1	7.1	25.9	34.0	37.4	365
Average	12.0	5.6	21.3	27.8	30.0	285

Nutrient content was stratified from the top to the bottom of the pond. Calcium content of lagoon waters decreased from the surface to the bottom. Ammoniacal-N was similar in absolute values but decreased as a percent of TKN from the surface to the bottom. Total solids increased 20 fold from the surface to the bottom.

The concentration of nutrients at various depths below the surface of the pond were consistently greater than the average value in drawdown samples. This may have resulted from management of the pond prior to and during the drawdown. No agitation existed in this pond.

Flow rate of water leaving the pond fell from 225 gallons/min (gpm) to 185 gpm. This is an important effect of pond height on water flow. Under certain conditions, it may be necessary to alter fresh water dilution rate during an irrigation event.

Pond 2 is located in San Joaquin County. The pond is used for complete storage of wastewater during the winter months. Manure water is recycled as flush water and a stationery incline separator is used. Milk center wash water also is contained in the pond. The pond is 720 x 120 ft. The results from pond 2 monitoring are in Table 2.

Table 2. Average nutrient content of six dairy pond locations (by depth from the surface) and ranges and average nutrient content of samples taken from drawdown of a San Joaquin County dairy pond. Units expressed in pounds of nutrient per acre-inch of water applied.

	Ca	Mg	NH4-N	TKN	K	TS
	lbs/ac-in					
Pre-drawdown						
Surface	16.3	12.5	75.3	235	97	
5' below	16.3	11.6	70.0	241	103	
10' below	17.5	12.6	91.2	276	112	
15' below	18.1	12.2	68.3	299	92	
20' below	15.1	12.8	56.9	277	91	
bottom	16.9	12.1	70.7	282	110	
Dewatering						
Low	11.3	9.8	50.1	88	30	1405
High	24.0	22.3	79.6	390	117	18838
Average	18.8	13.2	61.4	228	78	7070

Overall, the average nutrient content of manure waters from pond 2 was greater than those of pond 1. This is explained by the recycling of water in management of the second pond. Clean water use is minimized, therefore, nutrients in subsequent storage areas are concentrated. There was a great degree of variability of nutrient content at different depths from the surface. Calcium, Mg and NH_4N showed no consistent trends. Total kjeldahl nitrogen increased as depth decreased. The lack of stratification was thought to be due in part from the churning (microbial activity) within the pond and the recycling (movement) of water from the pond. There was a higher concentration of TS and TKN from the surface to the bottom of the pond. The elevated TKN with no apparent increase in NH_4-N is due to increased organic matter (TS).

Average TKN was 27.8 lbs/ac-in water applied (Pond 1) and 228 lbs/ac-in water applied (Pond 2). The large differences are believed to be due to manure handling and management practices.

Nutrients (TKN, P, K, TS) were not distributed uniformly in these ponds. The extent of stratification was thought to be due in part to physical churning of the pond. Nutrient stratification may exist statistically, yet may have little impact on estimation of nutrient content of pond water.

Nutrient content of water during an irrigation event. The nutrient content of the water will be quite similar at the standpipe (leaving the pond) and at the valve (entering the field) as long as there are not other additions of water. Important to note is that plumbing of the irrigation system will have a great impact on the addition of water during an irrigation event. There are a variety of circumstances which result in large differences in the nutrient content of manure waters field. Some irrigation systems are plumbed such that flush water from cow alley lanes go directly to fields and by-pass the pond(s). Additionally, the addition of fresh water to the irrigation system will dilute the nutrient content of the manure water. This dilution rate will change as the fresh water sources are altered (adjusting pumps, ditch water, or canal water). A few examples of when adjustments are made during individual irrigation are when pumps go out, when water entering the field is too thick, or when system water content needs to be increased due to opening additional valves.

In addition to knowing the application rate of nutrients to the field, it is important to understand the nutrient distribution within the field. After irrigating land with high solid content manure water, it is common to see considerable amounts of solids which have settled out of the irrigation water. Settled solids were quantified during a project in 1993 (2). The average quantity of dry solids settled at five locations in the field were 263.2, 33.1, 1.7, 2.8, and 21.2 g/648 cm^2. These were 100 ft from the valve, 1/4, 2/4, 3/4 of the distance from the valve to the end of the field, and 100 ft from the end of the field. A 100 ft^2 area located at the above measurement locations would receive 750, 105, 5.4, 8.9, and 67 lbs of dry solids.

The variability in quantity of settled solids makes one ponder if other nutrients are distributed uniformly within the field. Quarter point samples were taken during an irrigation at half-hour intervals. The data provided a trend which indicated that nutrients appeared to be distributed somewhat evenly throughout the field (2). Data indicated nutrient concentration of settleable solids within manure water is far less than the nutrient concentration of whole manure water.

Future efforts

The reported data indicate tremendous variations in nutrient content and chemical composition of manure water. Methods used to collect, store and utilize manure water effect nutrient content. These data are provided to stress the importance of testing of manure water prior to or during an irrigation event. These data are not provided to answer the question "What is the nutrient content of manure water?"

Current research is dealing with methods to quantify manure water amounts and distribution. Other work will need to focus on techniques to rapidly quantify nutrient content and nutrient content of manure solids from corrals, lanes and separators.

References

1. Morse, D., L. Schwankl, T. Prichard and T. Shultz. 1994. Monitoring manure water pre-irrigations in Central Valley Dairy operations.

2. Morse, D., L Schwankl, T. Prichard and A. Van Eenennaam. 1994. Evaluation of manure water irrigation. Proceedings of the second conference on Environmentally Sound Agriculture. ASAE, St. Joseph, MI. Pp 353-359.

3. PL 101-508. Subtitle C-Amendments to Coastal Zone Management Act of 1972. 101st Congress. November 5, 1990.

4. Schwankl, L. and D. Morse. 1995. Land application of manure waters: irrigation uniformity and efficiency considerations.

5. State Water Resources Control Board. 1992. The Porter-Cologne Water Quality Control Act and Related Codes. As amended through the 1991 session of the California Legislature, Sacramento.

6. U.S. EPA. 1993. Guidance specifying management measures for sources on nonpoint pollution in coastal waters. Office of Water, U.S. Environmental Protection Agency, Washington, D.C. EPA/840/B/92/002.

1.22 million cows

2.6 billion

13.2% of State's Ag income

Land Application of Manure Waters: Irrigation Uniformity and Efficiency Considerations

Larry Schwankl UC Davis
Deanne Morse UC Davis

Land application of manure waters must take into account the concerns of irrigation water management - irrigation efficiency, and application uniformity - as well as important considerations related to nutrient management. While irrigating uniformly and efficiently with a flood irrigation system is a challenging task in itself, adding nutrient management to the responsibilities of the irrigation water manager adds further complexity. Concerns over nitrate contamination of the groundwater make minimizing deep percolation losses when irrigating with manure waters even more critical. Minimizing deep percolation losses requires that the irrigation system be capable of applying water uniformly and that the irrigation water manager apply water efficiently.

Efficiency of irrigation is a measure of how much of the applied irrigation water is "beneficially used". The major beneficial use on irrigation water is supplying the crop water requirements, but water used for leaching of salts is also considered a beneficial use. The formal definition of irrigation efficiency (IE) is:

$$\underset{(\text{IE - \%})}{\text{Irrigation Efficiency}} = \frac{\text{Water Beneficially Used}}{\text{Water Applied}} \times 100$$

When irrigation is applied, it can end up as: (1) water stored in the crop's root zone; (2) deep percolation; or (3) runoff from the field surface. Water stored in the crop's root zone, a beneficial use, is the objective of irrigation. Deep percolation losses - water which passes through the root zone to a depth at which the crop can't utilize the water - is undesirable and always a concern but particularly so for manure water irrigations. Runoff from the field can be a loss from the system and undesirable unless it is collected (e.g., with tail water return system) and reused. For most manure water irrigation systems, tail water runoff is intentionally limited by the manager due to regulations preventing its movement off the producer's land.

Since the main beneficial use of the applied irrigation water is supplying the crop's water needs, the amount of water needed to refill the crop's root zone must be determined prior to an irrigation event. This determination of when and how much to irrigate is irrigation scheduling. Irrigation scheduling can be accomplished in numerous ways, but answering the "when" and "how much" questions is most frequently down via plant evapotranspiration (ET) techniques and/or soil moisture monitoring.

Water application uniformity, while a critical prerequisite for efficient irrigation, is different from irrigation efficiency in that it accounts for how evenly water is applied to the field. If every part of the field received the same amount of irrigation water, the irrigation would be 100% uniform.

The measure most commonly used for quantifying uniformity of furrow and border irrigations is distribution uniformity (DU). It is defined as:

$$\underset{(\text{DU - \%})}{\text{Distribution Uniformity}} = \frac{\text{Depth of Water Applied to Low 1 / 4 of Field}}{\text{Average Depth Applied}} \times 100$$

The depth of water applied to the low 1/4 of the field is the depth of water applied to the 25% of the field which receives the least water. For furrow-irrigated fields, this is usually the 25% of the area at the tail end of the field.

Understanding the interaction of irrigation efficiency and uniformity is the key to understanding good irrigation water management. It is not possible to adequately irrigate a field efficiently unless the water is applied uniformly, but just irrigating uniformly will not guarantee that the irrigation is efficient. To further explain this, two examples may be helpful. First, an irrigation may be efficient but not uniform. This would most likely occur if one portion of the field received adequate water, but the remainder of the field was under-irrigated. Fig. 1 illustrates such an occurrence. Such an irrigation would have a high efficiency, but the non-uniformity of the water application would result in the crop being under-irrigated. In practice, most irrigators would have left the water run longer to ensure that the tail of the field got adequate water. The result would then have been for the head of the field to be over-irrigated with deep percolation resulting.

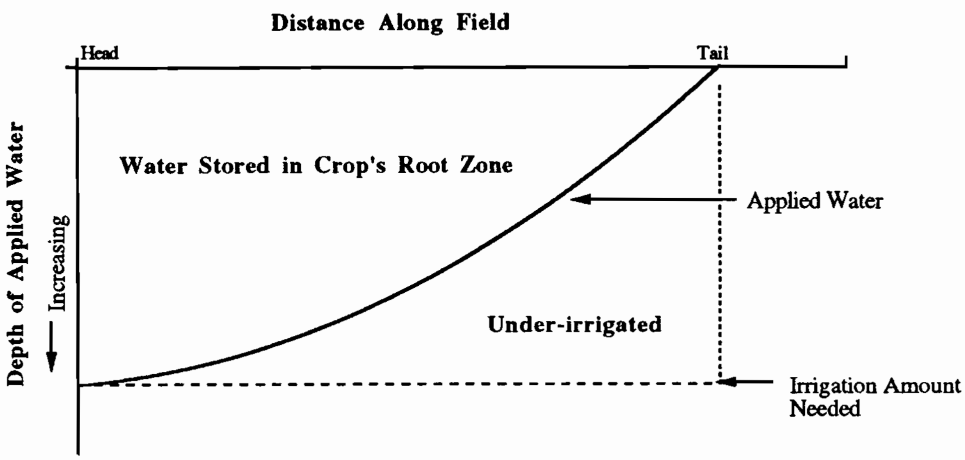


Figure 1. Depth of water applied (in.) versus distance along field for an irrigation which is efficient but non-uniform.

A second example of the efficiency/uniformity interaction is an inefficient, uniformly-applied irrigation. This would most likely occur: (1) due to poor irrigation scheduling by which the irrigation amount needed to be applied was over-estimated; and/or (2) if the applied water was not measured and the irrigation water amount was unknown. Fig. 2 illustrates such an irrigation.

Such an inefficient, uniform irrigation could generate substantial deep percolation, and if manure water was used, increase the risk of nitrate contamination of the groundwater.

The following matrix (Fig. 3) illustrates the combinations of efficiency and uniformity and their impacts. Again, it should be emphasized that the irrigation needs to be uniform and efficient in order to have good irrigation water management.

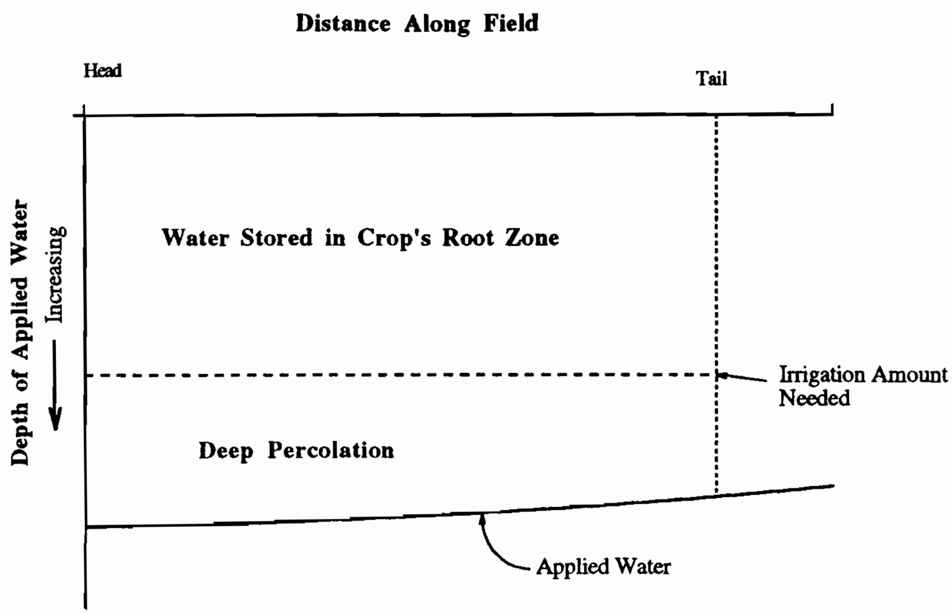


Figure 2. Depth of water applied (in.) versus distance along field for an irrigation which is uniform but inefficient.

EFFICIENCY

UNIFORMITY	Good	Bad
Good	Desired	(1) Deep percolation losses. (2) Runoff losses if not reused.
Bad	Under-irrigation of Crop	(1) Deep percolation losses. (2) Possible under-irrigation of a portion of the crop. (3) Runoff losses if not reused.

Figure 3. Matrix illustrating the potential effects of various combinations of efficiency and uniformity of irrigation events.

A major factor in the uniformity of an irrigation is the infiltration characteristics of the field. Infiltration characteristics change throughout the season with cultural practices, such as ripping and cultivation, often increasing the infiltration rate. Fields with high infiltration rate soils are difficult to irrigate uniformly; thus leading to inefficient irrigation in order to adequately irrigate the entire field. Later season irrigations, when cultivation has been discontinued, are often more uniform and efficient due to a lower water infiltration rate of the soil.

A major difficulty faced by manure water irrigators is measuring the amount of water they are applying. Many of the common flow meters cannot be used due to the amount of foreign matter in the water which can become entangled on the flow meter's propeller or turbine. The authors have successfully used doppler flow meters for measuring manure water flows. While expensive, doppler meters strap to the outside of a pipe and are portable and accurate.

Up to this point, the discussion of uniformity and efficiency considerations for manure water irrigation has been generic to anyone who is doing furrow or border irrigation. While there is little reason to believe that irrigation water with manure water added, or even straight manure water, will change the irrigation system performance, the negative consequences of causing deep percolation losses when irrigating with manure water are potentially greater.

The hazard of nutrient contamination, particularly nitrate contamination, of the groundwater by deep percolation from manure water irrigations will be affected by: (1) nutrient levels in the irrigation water; (2) the chemical form of nitrogen in the irrigation water; (3) soil characteristics such as permeability, porosity, and texture; and (4) soil nutrient levels prior to irrigation. Information is not available to predict what the nutrient content will be of the deep percolating water resulting from a single irrigation event of a particular water quality. The authors are conducting work which attempts to quantify the fate of water and nutrients on a seasonal basis. Soil sampling (prior to planting and following harvest), monitoring of irrigation efficiency and uniformity, as well as water quality during irrigation, and crop nutrient levels at harvest are measured. From this information, along with crop water use estimates, a water and nutrient balance for the crop growing season can be estimated.

The following scenarios illustrate three of the combinations of irrigation efficiency and uniformity shown in Fig. 3. The fourth combination - good efficiency and good uniformity - is what is desired of an irrigation event. Each of these scenarios has a potential impact on groundwater quality depending on the amount of deep percolation and the nutrient content (e.g. nitrogen) of the irrigation water.

Scenario 1 is an irrigation which is uniformly applied, but is inefficient. In this case, the irrigation system is performing acceptably, but the management is not adequate. Irrigation scheduling is not being practiced and/or water applications are not being measured. The correct amount of irrigation water is not being applied, and deep percolation is being produced. If manure water is used for irrigation, the potential exists for movement of nutrients downward with the deep percolating irrigation water. To improve the irrigation efficiency and decrease the amount of deep percolation, either the irrigation amount should be decreased to more closely match the soil moisture depleted since the previous irrigation event, or the interval between irrigations should be increased. The latter alternative should be closely investigated by growers since there is frequently a minimum amount of water which can be applied in order that water be advanced across the field. A good management technique may be to match this minimum application amount with an appropriate irrigation interval based on crop water use. During this interval between irrigations, crop water use would be equivalent to the irrigation amount needed to advance water across the field.

Scenario 2 is irrigation which is efficient but non-uniform. On the average, the correct amount of water is applied to the field. For example, if 3 inches of water has been depleted from the soil profile by crop water use, for each acre irrigated, 3 acre-inches (81,450 gallons) of water would need to be applied. While this would likely be the methodology for calculating the water to be applied, it is not strictly correct when the irrigation is non-uniform. For furrow irrigation, the non-uniformity usually results in the head of the field being over-irrigated while the tail of the field is under-irrigated. The over-irrigation at the head of the field would produce deep percolation - a potential contamination hazard if manure water is used - and would result in irrigation inefficiency. Thus, even though on the average the correct amount of water was applied, the application non-uniformity still would result in deep percolation and a potential hazard if manure water was used for irrigation.

Scenario 3 is irrigation which is inefficient and non-uniform. Such irrigation results from poor management (e.g. lack of irrigation scheduling) as well as an irrigation system which applies water non-uniformly. This is the worst of all cases because it holds the potential for the greatest amount of deep percolation being produced and an accompanying hazard for groundwater contamination by nutrients if manure water is utilized.

Fig. 4 shows a matrix similar to Fig. 3, but Fig. 4 includes the potential contamination hazard if manure water is used for irrigation.

UNIFORMITY \ EFFICIENCY	Good	Bad
Good	Desired Minimal hazard to groundwater	(1) Deep percolation losses. (2) Runoff losses if not reused. (3) Hazard of gw contamination if manure water is used. Extent of hazard dependent on amount of over-irrigation.
Bad	(1) Under-irrigation of crop (2) Hazard of gw contamination if manure water is used.	(1) Deep percolation losses. (2) Possible under-irrigation of a portion of the crop. (3) Runoff losses if not reused. (4) High hazard of gw comtamination if manure water is used.

Figure 4. Matrix illustrating the potential effects of various combinations of efficiency and uniformity of irrigations utilizing manure water.

There are a number of steps a manure water manager should take to maximize irrigation efficiency and minimize deep percolation. The first major step is to practice irrigation scheduling. This entails estimating crop water use between irrigation events. This is most easily done be estimating the crop evapotranspiration (ET). Crop ET is available from numerous sources such as UC Cooperative Extension, CA Department of Water Resources CIMIS program, and private consultants. The second step is to know the rate of water application via the use of flow meters. These first steps are "do-able" by all and require minimal physical changes in the irrigation system.

A third step is to improve irrigation application uniformity. This entails evaluating current irrigation water application practices and taking steps to improve the application uniformity if necessary. These changes could include: (1) field slope adjustments; (2) shortening field lengths;

and/or (3) adjusting flow rates. These irrigation system changes will often require a monetary investment.

The above three steps would be undertaken by any manager attempting to improve his irrigation water management practices. The manager irrigating with manure water must take additional steps to include nutrient management in his practices. Nutrient practices taken to apply sufficient nutrients for crop needs while preventing over-application include: (1) soil sampling prior to planting to determine the nutrients available for crop use; (2) estimating crop nutrient requirements; and (3) estimating irrigation water nutrient levels at each irrigation event.

In summary, combining good irrigation water management to attain good water application uniformity and good irrigation efficiency, with appropriate nutrient management will result in minimizing deep percolation losses and reducing the hazard of groundwater contamination. The following information is necessary for an irrigation manager who uses manure water: (1) crop water use (evapotranspiration) information, (2) the application rate of the irrigation system, (3) soil nutrient content at the beginning of the cropping season, (4) crop nutrient requirements, and (5) nutrient content of the irrigation water.

Using Stable Isotopes for Identifying Nitrogen That Originates From Animal Waste as Compared to Other Sources

D.E. Rolston, G.E. Fogg, D.L. Decker, and D.T. Louie.
Land, Air and Water Resources, University of California, Davis

Introduction

Nitrate (NO_3) contamination of groundwater is a common occurrence in California. Multiple sources of NO_3^- contamination generally occur within the same watershed or groundwater basin. Some of the NO_3^- contamination sources are animal feedlots, horse corrals, dairy waste lagoons, manure applied to land, municipal sewage effluent, onsite sewage disposal systems, urban and agricultural fertilizer, native soil organic matter, and possibly geologic sources. It is often difficult to ascertain which of these multiple sources may be contributing to NO_3^- in groundwater.

One technique which has been used as a tool for source identification is the nitrogen (N) isotope method (Kreitler, 1975; Wolterink, 1979). It is based on measuring the two stable isotopes of N (^{14}N and ^{15}N) in NO_3^- of the sample. The percentage of the two isotopes are nearly constant in the atmosphere at 0.366 % ^{15}N. However, because of the slight difference in atomic mass of the two isotopes, certain chemical and physical processes often preferentially utilize one isotope, causing a relative enrichment of that isotope in the product and a relative enrichment of the other isotope in the remaining reactants. Because of these isotopic fractionation processes, NO_3^- from various N sources has been shown to have different N isotope ratios (Kreitler, 1975). This ratio in a sample depends on the series of reactions that formed the N compound and the composition of its precursors. It is usually compared with the ratio in the atmosphere to express the relative enrichment or depletion of ^{15}N with respect to the atmosphere. This value is called $\delta^{15}N$ defined by

$$\delta^{15}N(ppt)=\{[(^{15}N/^{14}N)sample-(^{15}N/^{14}N)standard]/[(^{15}N/^{14}N)standard]\}x1000$$

If the sample is enriched in ^{15}N relative to the atmosphere, then the $\delta^{15}N$ value is positive, and if the sample is depleted in ^{15}N, then the $\delta^{15}N$ is negative. From literature sources (Kreitler, 1975; Gormly and Spalding, 1979; Wolterink, 1979, and others), the $\delta^{15}N$ values from soil organic nitrogen, fertilizer, and animal waste range from +2 to +8, -3 to +2, and +9 to +20, respectively. It is obvious that there is considerable variability within source type which may also impact on the ability to distinquish one source from another.

The overall goal of this study was to thoroughly evaluate the use of N isotope ratios as a tool for identifying NO_3^- contamination sources in groundwater for California conditions. A specific goal was to measure $\delta^{15}N$ in soil water and groundwater in vertical profiles directly beneath various sources of NO_3^- contamination. Two regions of California, the Salinas and Sacramento Valleys were chosen for study because of their generally different hydrogeologic characteristics, yet representing many alluvial valley situations.

Field Sampling

Each study region contained sampling sites that represented four different sources of NO_3^-: NO_3^- from natural soil organic matter, manufactured fertilizer, animal feedlot/dairy, and onsite sewage disposal systems (septic). Soil and subsurface sampling was accomplished by drilling and sampling with a hollow-stem auger and California split spoon sampling system. An 8-inch diameter continuous flight hollow stem auger was used with a 2.5-inch diameter California split spoon, sampling ahead of the auger. Core was taken continuously from the ground surface to the water table. Subsamples of the core were taken approximately every 5 ft. and were preserved and archived for analysis.

A groundwater sample was collected from the bottom of each borehole upon reaching the groundwater table. A sample was taken using a bailer through the inside of the auger.

After the soil core was taken in the field, the soil sample for chemical analysis was placed in a polyethylene zip-lock bag and placed in a ice chest filled with dry ice. The sample was then transferred to a freezer until it was processed.

Chemical and Isotope Analyses

Prior to extraction, the soil sample was taken from the freezer and allowed to thaw sufficiently so that a representative sub-sample could be taken. A 150-g soil sample was extracted with 750 mL of deionized water and filtered. Steam distillation was used to convert the inorganic forms of N in the soil-water extracts to a stable form of ammonium (NH_4) salt needed for N isotope analysis. The $\delta^{15}N$ was determined by a contract laboratory experienced in natural abundance N isotope work.

A subsample of the soil-water extract of approximately 40 mL was used to analyze for chloride (Cl), nitrite (NO_2), NO_3^-, and sulfate (SO_4) with an ion chromatograph. The EC (electrical conductivity) and pH measurements were taken as soon as possible on a second subsample, followed by analysis on the ammonium analyzer for NH_4.

Results and Discussion

Nineteen boreholes were drilled during this study. Examples of profile $\delta^{15}N$ for only the animal sources and comparison with other sources will be discussed. The lithology key representing the major subsurface material types is given in Fig. 1.

Figure 2 gives the results for the borehole drilled at the Davis site. This site was beneath a horse corral which had been in use for at least 15 years. The subsurface lithology is nearly uniform with depth, and consists of mud and muddy sand. The $\delta^{15}N$ results of about +10 throughout the vertical subsurface profile were consistent with an animal waste source. Aside from the high SO_4 value near the surface, the chemistry results are unremarkable, though consistent. The NO_3 concentrations in the vadose zone were much higher than the natural soil organic matter sites. Denitrification does not seem to be occurring much at this site. The groundwater sample showed a slightly lower $\delta^{15}N$ value than the soil water.

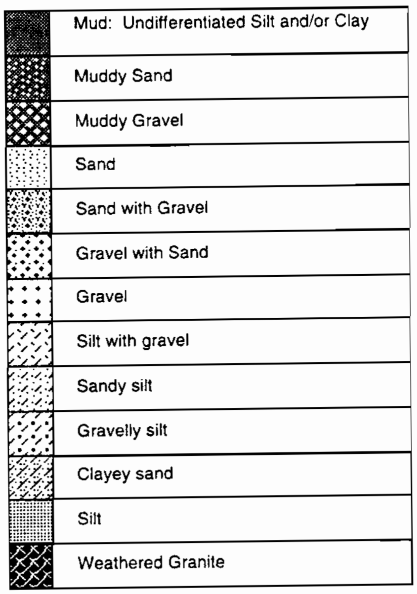


Figure 1. Borehole lithology key representing the major subsurface material types.

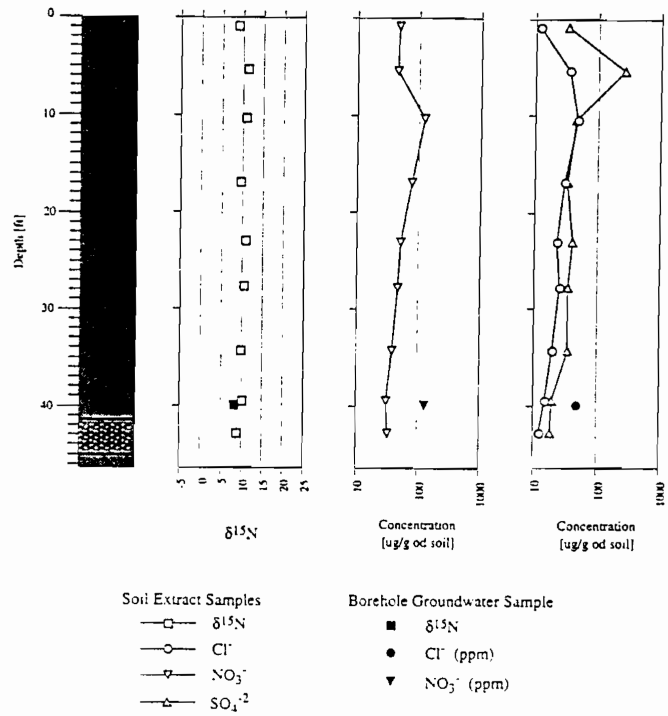


Figure 2. Lithology, $\delta^{15}N$, and concentrations of Cl, SO_4, and NO_3 with depth at the Davis animal site. Concentrations of the N species are as NO_3.

Three boreholes were drilled in two of four abandoned dairy waste evaporation ponds and the animal feeding pens at a site in the Salinas Valley. Figure 3 gives the results from the borehole drilled in the dairy feedlot. The subsurface lithology for this site is fairly complicated, but is dominated by sands and mud. Of the three boreholes, Fig. 3 shows the most consistent $\delta^{15}N$ results, having a nearly constant value with depth. One of the other boreholes had an unexpectedly high $\delta^{15}N$ value at the surface, possibly due to the fill material. The remaining $\delta^{15}N$ values were consistent with those of Figure 3.

Statistical comparisons of the differences in mean $\delta^{15}N$ for the various source types and locations were made. Figure 4 is a comparison plot of the four source types for all data of both the Davis and Salinas areas. The center horizontal line of each "diamond" is the mean $\delta^{15}N$ for that source. The width of the "diamond" is a relative indication of number of samples for that source. The range of data are shown by the individual symbols, and the 95% confidence limits of the means are represented by the vertical height of each "diamond". The circles represent significant difference of mean values based on the Tukey-Kramer test. The angle of intersection between two circles indicates whether the means are significantly different at a 95-percent confidence level. An angle greater than 90° indicates no significant difference and an angle less than 90° indicates significant difference between means. Figure 4 shows that the mean $\delta^{15}N$ values for the agricultural (fertilizer) source was not significantly different from the mean of the natural background source at the 95% confidence level. The animal sources were significantly different from septic sources and the fertilizer and/or natural sources.

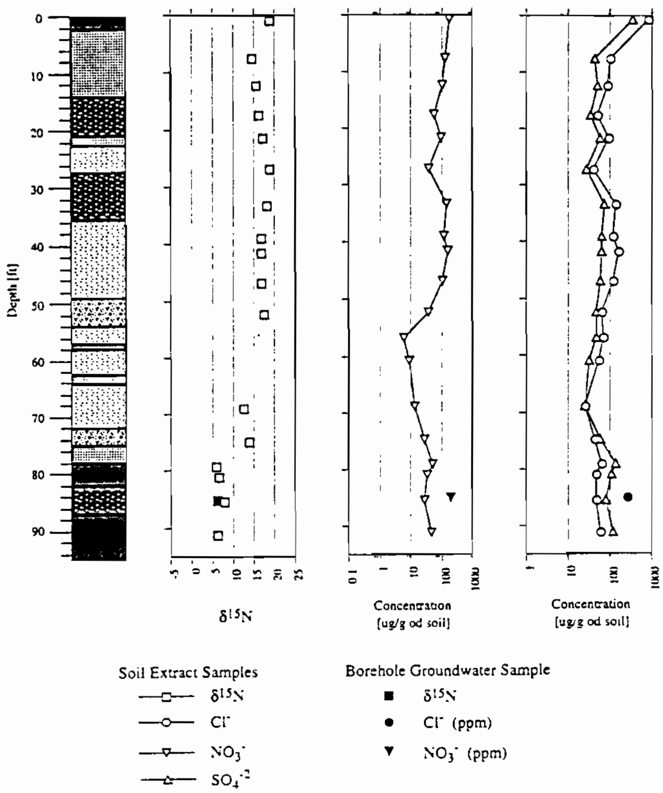


Figure 3. Lithology, $\delta^{15}N$, and concentrations of Cl, SO_4, and NO_3 with depth at the Salinas animal feedlot site. Concentrations of the N species are as NO_3.

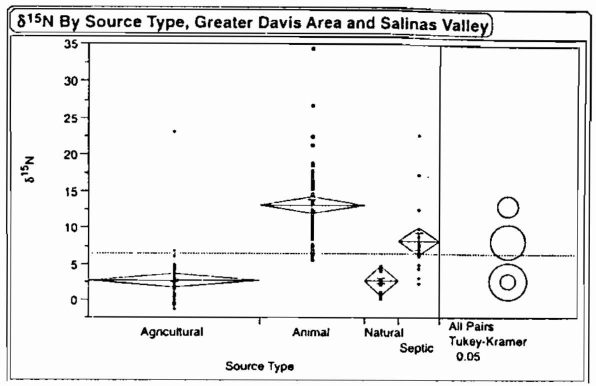


Figure 4. Statistical comparisons of mean $\delta^{15}N$ values for the combined Davis and Salinas data.

Summary

Nitrate contamination of ground water is a serious and widespread problem. Nitrogen isotope ratios of subsurface and groundwater nitrate have been used to identify sources. In this study, nitrogen isotope ratios ($\delta^{15}N$) were measured on nitrate extracted from core samples removed from the soil surface to the water table below natural, fertilizer, septic, and animal sources located within two alluvial valleys of California. The $\delta^{15}N$ remained fairly constant with depth indicating little denitrification during transport. The $\delta^{15}N$ from natural sources varied from about 0 to 4 and were not significantly different from those of fertilizer sources. The $\delta^{15}N$ of animal sources varied from about 8 to 20 and was dependent upon site and animal source. The $\delta^{15}N$ of septic sources varied from about 2 to 12 and was significantly different from that of animal sources. Nitrogen isotope ratios tend to be site specific and should be measured below suspected sources in the vadose zone and in ground water.

References

1. Gormly, J.R., and J.F. Spalding. 1979. Sources and concentrations of nitrate-nitrogen in groundwater of the central Platte region, Nebraska. Groundwater 17(3):291-301.

2. Kreitler, C.W. 1975. Determining the sources of nitrate in groundwater by nitrogen isotope studies. Bureau of Economic Geology, University of Texas at Austin, Report of Investigations No. 83, 57 pp.

3. Wolterink, T.J., H.J. Williamson, D.C. Jones, T.W. Grimshaw, and W.F. Holland. 1979. Identifying sources of subsurface nitrate pollution with stable nitrogen isotopes. Environmental Protection Agency, EPA-600/4-79-050, 151 pp.

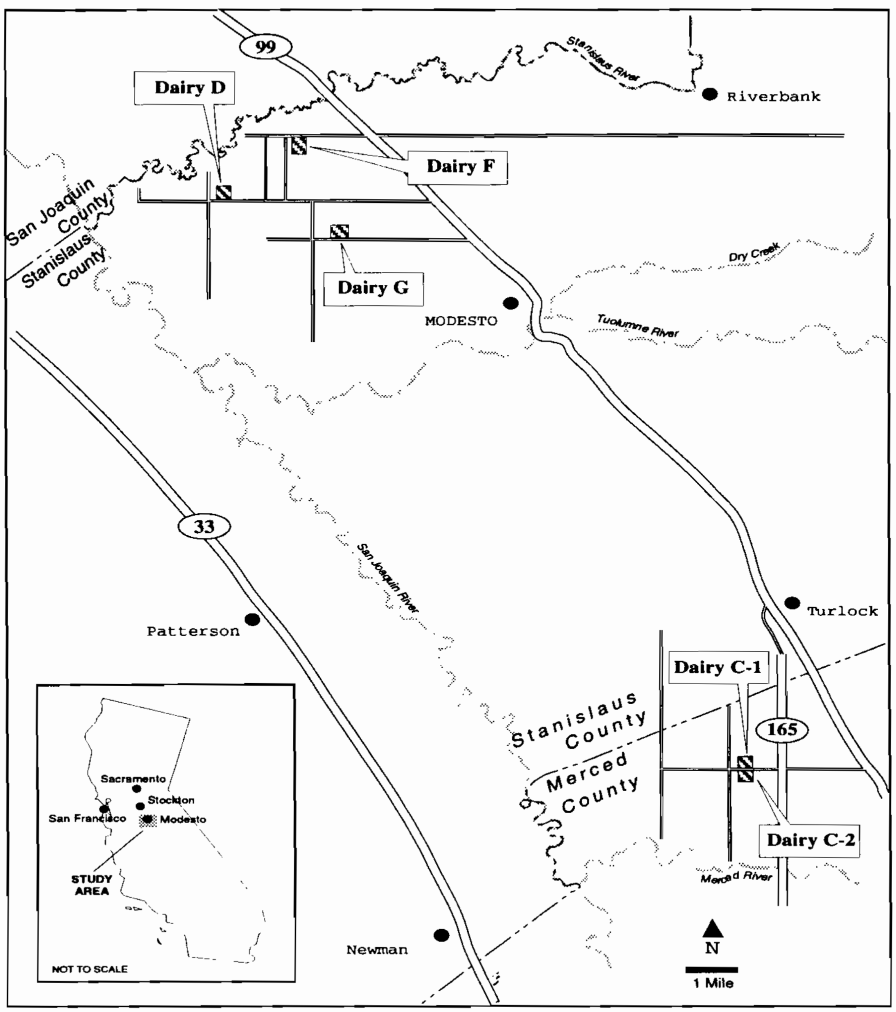
Monitoring and Evaluation of Water Quality Under Central Valley Dairy Sites

Harley H. Davis
Central Valley Regional Water Quality Control Board
Sacramento, CA

Introduction

The Central Valley Regional Water Quality Control Board received funding from the Federal Statewide Basin Planning Program to evaluate the impact of dairy waste management practices on ground water quality. In June 1993, a drilling company installed forty-four shallow monitoring wells at five cooperating dairies using these funds. Dairies were selected to determine what usually occurs under typical well run dairies. Regional Board staff located monitoring wells in or near the corrals, waste water ponds and fields at the cooperating dairies. The dairies are in Merced and Stanislaus Counties near the cities of Modesto and Turlock. Figure 1.0 shows the location of these cooperating dairies. Dairies C-1 and C-2 are in Merced County. Dairies D, F and G are in Stanislaus County.

Figure 1.0 Vicinity and Dairy Location Map



Profile of Cooperating Dairies

The sizes of the dairies in the study vary between 400 and 900 milk cows. Average dairy size for Stanislaus and Merced Counties is about 350 milk cows. The dairies in the study have been in operation for at least fifteen years. Two of the dairies began in the 1910's but have been modernized and expanded extensively.

Dairy operations are typical of dairies in the two counties. They include the use of corrals, dairy waste water retention ponds and irrigated crop land. Crop land receives dairy waste water. Manure is either flushed from feed or free stall alleys into waste water ponds or scraped from corrals and piled for various uses. At three of the dairies, solids are separated from liquid wastes before the liquid enters the ponds.

Crop land management is also typical of dairies in the region. Oats, barley, wheat, corn and alfalfa are grown for feed in 18 fields on 528 acres surrounding the five dairies. In addition, one dairy grows wine grapes in three fields covering 180 acres.

Nearly all the fields received dairy lagoon waste water in 1993. Only three of the twenty-one fields received dry manure solids in 1993. Besides nitrogen in the waste water, every dairy except Dairy F in Stanislaus County added nitrogen in commercial fertilizer to its crop land. The two other dairies in Stanislaus County applied 100 to 112 pounds of commercial nitrogen fertilizer per acre in 1993. The two dairies in Merced County applied from 204 to 306 pounds of commercial nitrogen fertilizer per acre in 1993. Rough calculations of crop nitrogen needs showed that there might be potential to reduce fertilizer applications to some fields. In 1994, the two Merced County dairies and one in Stanislaus County will be using less commercial nitrogen fertilizer. The field managers for these dairies will determine the effect of reducing commercial fertilizer on crop growth and yield.

Soils at the cooperating dairies have sandy and course materials throughout the profile. These soils provide conditions that are generally conducive to the movement of soluble chemicals. Nitrates from the soil profile can migrate into the shallow ground water aquifer under such highly permeable soils. The sandiest soils with the greatest permeability are found at the two Merced County dairies. The Stanislaus County dairies in the study area have higher contents of clays and silts. These soils are less permeable than the soils of the two Merced County dairies. However, the soils at the Stanislaus County dairies are still highly permeable to the movement of soluble chemicals such as nitrates.

Summary of Preliminary Monitoring Results

Monitoring wells were sampled five times: (1) in June 1993 after drilling was completed, (2) in September-October 1993 after the summer crop growing season, (3) in March 1994 after winter rains, (4) in June 1994 which completed one year of sampling and (5) in July-August 1994 to determine changes in concentrations during the growing season. The water table is shallow, ranging in depth from 4 to 25 feet below the surface. The monitoring wells were constructed to collect water representative of the top 10 feet of the shallow aquifer.

Monitoring wells were located to determine the probable sources of contamination from waste water ponds, corrals or fields. Background monitoring wells were also located upgradient of the dairy operations. Table 1.0 gives a summary of monitoring well water quality for nutrients and salts. EPA and other standard laboratory methods were used. Nitrates (NO_3) and total dissolved solids are of particular interest to ground water quality.

TABLE 1.0 SUMMARY OF MONITORING WELL WATER QUALITY

DAIRY NAME	PO_4-P	NH_3-N	TK-N	NO_2-N	NO_3-N	TOTAL N	TDS	EC
	I——			mg/L			——I	µs/cm
Dairy C-I								
NUMBER OF SAMPLES	7	10	21	8	30	24	24	24
AVERAGE (MEAN)	0.82	0.53	1.04	0.39	86	90	1536	2248
MAXIMUM	2.3	5	9.6	1.2	250	251	4100	6120
MINIMUM	0.16	<0.05	<1.0	0.02	13	14	390	530
Dairy C-2								
NUMBER OF SAMPLES	7	19	28	9	35	28	28	28
AVERAGE (MEAN)	1.67	13.7	6.5	0.11	50	54	1323	2146
MAXIMUM	5.2	93	57	0.42	140	93	2300	3160
MINIMUM	0.36	<0.05	<0.5	<0.1	0.77	4	420	455
Dairy D								
NUMBER OF SAMPLES	9	17	37	9	41	36	36	36
AVERAGE (MEAN)	1.1	0.53	3.5	0.01	49	52	1276	2046
MAXIMUM	2.8	4.6	38	0.1	200	201	2000	3240
MINIMUM	0.38	0.27	<0.5	<0.1	<0.02	3	370	620
Dairy G								
NUMBER OF SAMPLES	10	14	39	11	50	40	40	40
AVERAGE (MEAN)	1.14	4.5	1.4	0.05	49	50	1060	1681
MAXIMUM	2.4	26	22	0.6	120	120	2200	3270
MINIMUM	0.32	0.07	0.62	<0.02	7.4	8	580	985
Dairy F								
NUMBER OF SAMPLES	12	16	48	13	60	48	48	48
AVERAGE (MEAN)	1.28	0.4	1.1	0.17	30	32	1079	1697
MAXIMUM	3.5	3.8	6.8	0.5	130	130	2200	3140
MINIMUM	0.38	0.1	<0.5	<0.02	1.5	3	270	449
SUMMARY OF DAIRIES								
NUMBER OF SAMPLES	45	76	173	50	216	176	176	176
AVERAGE (MEAN)	1.2	4.4	2.46	0.13	49	52	1217	1911
MAXIMUM	5.2	93	57	1.2	250	251	4100	6120
MINIMUM	0.16	<0.05	<0.5	<0.02	<0.02	3	270	449
STANDARD DEVIATION	0.98	17.6	12.4	2.57	44	43	612	915

Total dissolved solids (TDS) and electrical conductivity (EC) are measurements of the salinity of water. TDS concentrations ranged from 270 to 4100 mg/l. EC varied from 449 to 6120 µs/cm. For all monitoring wells, the mean TDS was 1217 mg/l and EC was 1911 µs/cm. The ratio of TDS to EC averaged 0.65 but ranged from 0.37 to 0.99.

Acceptable water quality concentrations for salts vary with the intended use. Livestock, irrigated agriculture and drinking water are the primary uses of ground water in the vicinity of the dairies. According to the USGS in the Study and Interpretation of Chemical Characteristics of Natural Waters (1989), some investigators recommended an upper limit of nearly 5,000 mg/l of dissolved solids in water to be used by livestock.

Agricultural water quality goals are 450 mg/l for TDS and 700 µs/cm of EC as recommended by the Food and Agriculture Organization of the United Nations (1989). However, different crops are sensitive to varying levels of salinity. Most fruit and nut crops are sensitive to EC levels from 700 to 1,200 µs/cm. Concentrations above these levels result in reductions in crop yields. But many grasses and some grain crops, such as barley and oats, are more tolerant to higher salt levels in irrigation water. These crops tolerate EC values from 4,000 to 6,500 µs/cm without loss in crop yields.

Primary drinking water standards have not been recommended for TDS. However, the 1962 U.S. Public Health Service secondary drinking water standard states that TDS should not exceed 500 mg/l if other suitable water supplies are available.

Salinity concentrations varied among the monitoring wells in the fields ponds and corrals. Figure 2.0 displays averages for samples collected from June 1993 through August 1994. The monitoring wells in the fields showed the lowest concentrations averaging 925 mg/l of TDS. The monitoring wells in corrals averaged 1689 mg/l of TDS. TDS concentrations in monitoring wells near the waste water ponds averaged 1294 mg/l. Average for all monitoring wells in the study was 1217 mg/l of TDS.

Table 1.0 displays nitrogen concentrations in the monitoring wells. Nitrate as nitrogen ranged from less than the detectable limit of 0.02 mg/l near an irrigation water pond to 250 mg/l under a corral. The average nitrate as nitrogen for the monitoring wells in the dairy study was 49 mg/l. The national drinking water standard for nitrate as nitrogen is 10 mg/l which is equivalent to 45 mg/l of nitrate. High concentrations of nitrates in drinking water have caused methemoglobinemia which is commonly know as blue baby syndrome. Nitrates in irrigation water provide nitrogen as a nutrient to crops.

Monitoring wells away from the corrals and ponds in four of the five dairies had nitrate nitrogen concentrations below 10 mg/l. These low concentrations indicate that the regional shallow aquifer contains low nitrate levels. Lowest concentrations of nitrates generally ranged from 3 to 14 mg/l. These lowest concentrations were at well locations that were minimally affected by the dairy operations. Concentrations in what were expected to be the background wells showed that these particular wells were most likely influenced by dairy operations or other nitrogen sources.

Total dissolved solids (TDS) and electrical conductivity (EC) are measurements of the salinity of water. TDS concentrations ranged from 270 to 4100 mg/l. EC varied from 449 to 6120 µs/cm. For all monitoring wells, the mean TDS was 1217 mg/l and EC was 1911 µs/cm. The ratio of TDS to EC averaged 0.65 but ranged from 0.37 to 0.99.

Acceptable water quality concentrations for salts vary with the intended use. Livestock, irrigated agriculture and drinking water are the primary uses of ground water in the vicinity of the dairies. According to the USGS in the Study and Interpretation of Chemical Characteristics of Natural Waters (1989), some investigators recommended an upper limit of nearly 5,000 mg/l of dissolved solids in water to be used by livestock.

Agricultural water quality goals are 450 mg/l for TDS and 700 µs/cm of EC as recommended by the Food and Agriculture Organization of the United Nations (1989). However, different crops are sensitive to varying levels of salinity. Most fruit and nut crops are sensitive to EC levels from 1300 to 3000 µs/cm. Concentrations above these levels result in reductions in crop yields. But many grasses and some grain crops, such as barley and oats, are more tolerant to higher salt levels in irrigation water. These crops tolerate EC values from 6,000 to 10,000 µs/cm without loss in crop yields.

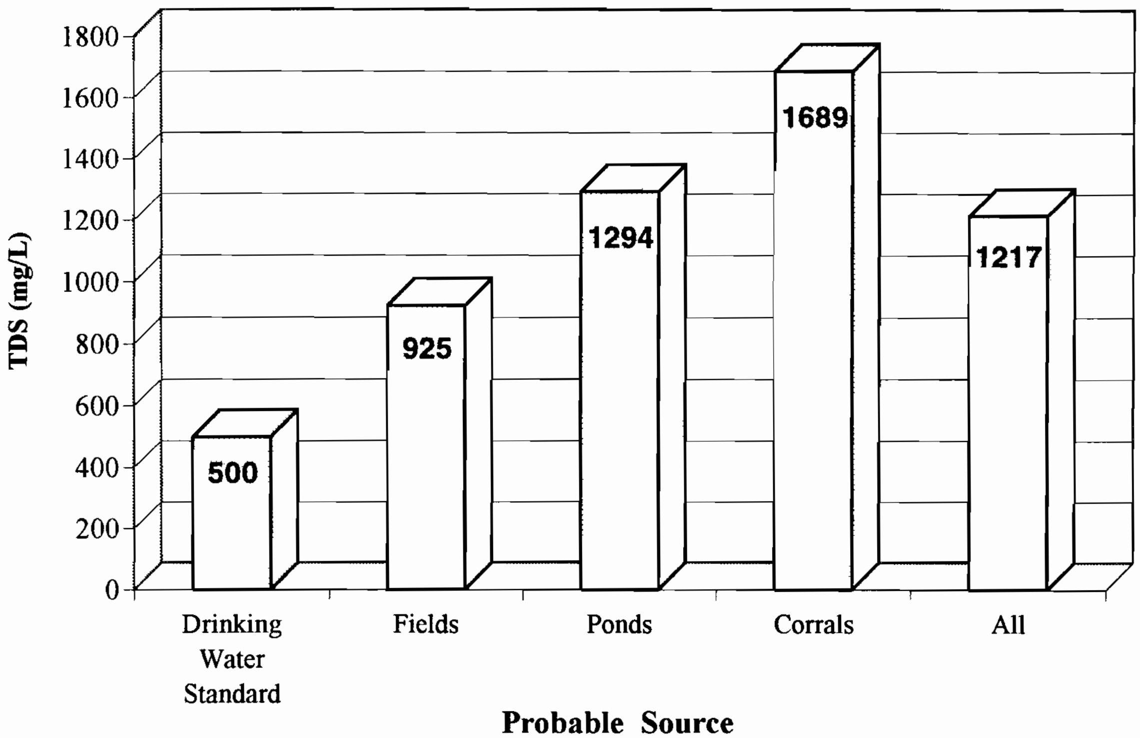
Primary drinking water standards have not been recommended for TDS. However, the 1962 U.S. Public Health Service secondary drinking water standard states that TDS should not exceed 500 mg/l if other suitable water supplies are available.

Salinity concentrations varied among the monitoring wells in the fields ponds and corrals. Figure 2.0 displays averages for samples collected from June 1993 through August 1994. The monitoring wells in the fields showed the lowest concentrations averaging 925 mg/l of TDS. The monitoring wells in corrals averaged 1689 mg/l of TDS. TDS concentrations in monitoring wells near the waste water ponds averaged 1294 mg/l. Average for all monitoring wells in the study was 1217 mg/l of TDS.

Table 1.0 displays nitrogen concentrations in the monitoring wells. Nitrate as nitrogen ranged from less than the detectable limit of 0.02 mg/l near an irrigation water pond to 250 mg/l under a corral. The average nitrate as nitrogen for the monitoring wells in the dairy study was 49 mg/l. The national drinking water standard for nitrate as nitrogen is 10 mg/l which is equivalent to 45 mg/l of nitrate. High concentrations of nitrates in drinking water have caused methemoglobinemia which is commonly know as blue baby syndrome. Nitrates in irrigation water provide nitrogen as a nutrient to crops.

Monitoring wells away from the corrals and ponds in four of the five dairies had nitrate nitrogen concentrations below 10 mg/l. These low concentrations indicate that the regional shallow aquifer contains low nitrate levels. Lowest concentrations of nitrates generally ranged from 3 to 14 mg/l. These lowest concentrations were at well locations that were minimally affected by the dairy operations. Concentrations in what were expected to be the background wells showed that these particular wells were most likely influenced by dairy operations or other nitrogen sources.

Figure 2.0 Concentration by Source of Total Dissolved Solids in Monitoring Wells

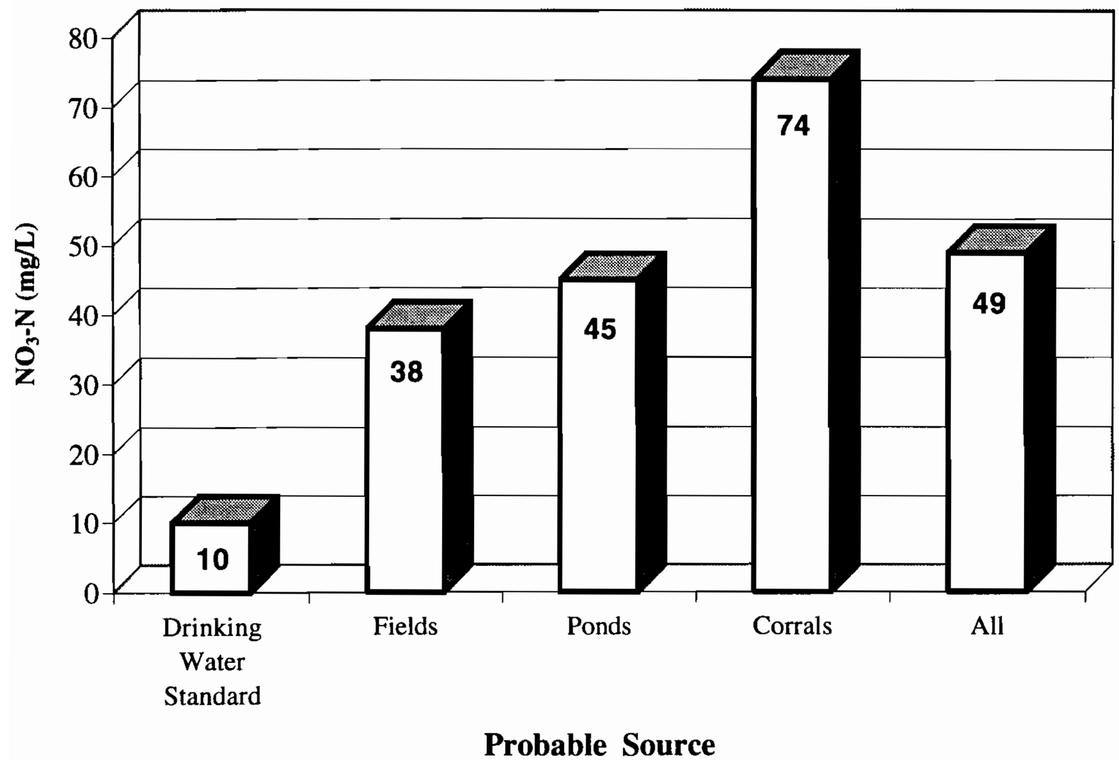


Average concentrations of nitrate in monitoring wells varied among the fields, ponds and corrals. Figure 3.0 displays these concentrations for samples collected from June 1993 through August 1994. The fields showed the lowest concentrations averaging 38 mg/l of nitrate nitrogen. The monitoring wells in corrals averaged 74 mg/l of nitrate nitrogen. Nitrate nitrogen near the waste water ponds averaged 45 mg/l of nitrate nitrogen. The average of all monitoring wells in the study was 49 mg/l. All averages were above the drinking water standard of 10 mg/l.

Most drinking water wells in the vicinity of the dairies draw from aquifers greater than 100 feet deep but at least one known nearby domestic well draws from the shallow aquifer of the monitoring wells. Local public health officials during review of new well applications normally limit the use of surface and shallow aquifers for drinking water. They require well seals that prevent surface contamination and well screening below shallow ground water.

Use of waters from the monitoring well aquifer would be limited to more salt tolerant crops. The nitrates from this aquifer would be of benefit to the nitrogen supply of agricultural crops. However, the salt content would most likely need to be diluted to prevent crop damage and loss of production. Nitrates from the shallow ground water of the monitoring wells could be removed by reusing this water on crops. Use of shallow ground water for irrigation would provide a savings in fertilizer and well water pumping expenses. Pumping costs from shallow ground water would be less costly than the expense of pumping from deeper wells that are commonly used for irrigation.

Figure 3.0 Concentration by Source of Nitrate Nitrogen in Monitoring Wells



MANAGEMENT PRACTICES:

Their Regulation and Economic Impact

Valerie J. Mellano, Ph.D.
Environmental Issues Advisor
UC Cooperative Extension, San Diego County

Alleviation and prevention of water pollution from animal production enterprises is the focus of this presentation. Technologies used successfully, new technology needs and management measures will be identified, as well as economic impacts of these practices. In addition, technologies and practices for measuring and monitoring of water quality are examined, as are the major federal and state regulations regarding animal waste and water quality concerns.

Existing practices for confined animal operations in California, particularly dairy, feedlots and poultry will be described. These include treatment and storage of solid and liquid wastes, improvements in structures, livestock and dietary manipulation, waste and wash water utilization, and funding sources available for development of these practices.

Comparisons are made among practices in four regions of the state: North Valley, South Valley, San Francisco Bay, and Southern California. New facilities siting is addressed with respect to location, and size of the of the entire operation, as well as components within the operation. Management for range animal operations is addressed, primarily animal and vegetation management, rather than waste and water management. Conservation practices and the development of a ranch or watershed plan are also described.

Monitoring for water quality is discussed, describing both inexpensive and high technology methods. This can be as simple as record keeping of land applications of animal manures, and photography to record the status of water bodies and vegetation, or it can include more involved methods such as continuous monitoring of water quality utilizing extensive laboratory analysis. Descriptions of monitoring concepts for rangeland surface waters and confined subsurface and ground waters are also addressed.

The development of a best management practice program for the San Diego ares will be addressed, emphasizing the importance of local needs and individual resourcefulness.

POTENTIAL FOR UTILIZING BLENDED DRAINAGE WATER FOR IRRIGATING WEST SIDE, SAN JOAQUIN VALLEY PISTACHIOS

Louise Ferguson
Pomology Department, University of California, Davis
Kearney Agricultural Center

Blake Sanden
Kern County Farm Advisor

Steve Grattan
Land, Air & Water Resources
University of California, Davis

Abstract

The objective of this project is to determine the relative salt tolerance of the four major pistachio rootstocks used in the west side of the San Joaquin Valley. Five different Ec_w treatments, 0.75, 2.0, 4.0, 6.0, and 8.0 will be applied through the 1994, 1995 and 1996 irrigation seasons. Treatments were designed to approximate drainage waters with Na, SO_4, Cl, and Ca, predominating in that order, with a Na:Ca ratio of 3. Boron will be added up to 10 ppm. Leaf and soil baseline levels were obtained in 1993 and in 1994 before treatments began, respectively. The first results of effects on plant growth will be available fall of 1994.

EVALUATION OF REGULATED DEFICIT IRRIGATION FOR PISTACHIO ORCHARDS

David Goldhamer and Cindy Greene
Department of Land, Air and Water Resources
Hydrologic Science Section
University of California, Davis
Kearney Agricultural Center

Hung Li
Irrigation Engineer

Paramount Farming Company
Bakersfield, CA

Regulated deficit irrigation (RDI) is the practice of purposely creating water deficits during specific times of the growing season in order to save water while minimizing or eliminating negative impacts on yield or crop revenue. Ideally, RDI should hold the promise of enhancing a yield component in order to provide the motivation necessary for growers to adopt the practice. The time-course development of pistachio nuts appears to offer an ideal period to implement RDI. This is the 6-week period from mid May (after full shell size has been attained) through early July (the onset of rapid kernel growth). Three large RDI test sites have been established with cooperating growers in the central and southern San Joaquin Valley. Early results indicate that 6-10 acre-inches/acre of water can be saved without reducing yield or fruit quality. There is some evidence that pistachio RDI increases shell splitting and may reduce shell staining, both of which would increase crop revenue. Additional seasons are needed to confirm these observations.

An Organic Versus Conventional Farming System in Kiwifruit

Janine K. Hasey, R. Scott Johnson, Roland D. Meyer
and Karen Klonsky
University of California Cooperative Extension
Yuba City, Parlier and Davis.

A kiwifruit vineyard converted to an organic system was compared to a conventionally farmed vineyard from 1990 through 1992. January or March applications of composted chicken manure (organic system) or NH_4NO_3 plus $CaNH_4(NO_3)_3$ through microsprinklers during the growing season (conventional system) were applied to give nearly equal rates of N. Soil analyses indicated a trend towards a higher pH in the organic system over time. In 1992, there was a higher NH_4-N and lower NO_3-N concentration for the organic than for the conventional system. Leaf nitrogen levels from the organic system were consistently lower than those from the conventional system but were not deficient. Leaf concentrations of sodium increased over the three-year period in the organic system. Chloride levels were also higher in the organic system but not to phytotoxic levels. Organically grown fruit was as firm or firmer than conventionally grown fruit at harvest and four months after harvest. Damage from latania scale or omnivorous leaf roller was minimal in both systems except for scale damage in the organic system in 1992. This is not unexpected since the organically acceptable pesticides are effective. 1992 repack losses were less for organically grown fruit. In the organic system where composted chicken manure was applied, a lower nitrogen release rate and a greater volatilization of NH_3-N was thought to be responsible for lower nitrogen in the leaf tissue.

IRRIGATION AND MIDDLES MANAGEMENT IN ALMONDS

Blake Sanden and Martha P. Gonzalez
University of California Cooperative Extension -- Kern County

Orchard cover crops of resident or cultivated species have a long history in California. Benefits consist of improved infiltration/aeration, decreased dust at harvest, and potential habitat for beneficial insects. Disadvantages have been considered to be an increased water requirement, decreased harvest efficiency, and potential frost damage at bloom. Previous work in the San Joaquin valley found that almond orchards with vegetative middles used more water than when middles were kept free of vegetation. This study was an attempt to examine the impacts of four middles management alternatives on water penetration and use, orchard yield and vegetation management.

Experimental Design: A completely randomized block design replicated four times in a thirteen year old orchard planted on a Delano clay loam with course sand and irrigated with permanent under-tree sprinklers was set up with four middles treatments. Each plot was 6 rows wide by 27 trees in length. Tree spacing was 24 ft. x 24 ft. offset pattern with bare, eight foot flat berms maintained by residual herbicides. Data was collected from the middle Non-pareil rows. Treatments were: 1) untreated -- resident vegetation; 2) self-reseeding legume mixture of subterranean, crimson, and rose clover, and medic seeded November 1991; 3) fall seeded barley drilled into middles November 1991 and 1992; 4) bare soil with vegetation controlled by periodic application of Roundup + Goal + Surflan + surfactant. Percent cover ratings by species were taken monthly throughout the growing season in each plot. Infiltration was a problem on this soil with rolling topography irrigated with low salinity Friant-Kern canal water. Sets were changed every 6-8 hours at the onset of runoff. Water was not controlled differentially for each treatment. Water ran almost continually from June 1 till harvest cutoff the end of July -- coming back to the same set every 2 1/2 to 3 days.

Four neutron probe access tubes were installed in each plot: one in the middle of the drive between the tree and opposing sprinkler and a second in the berm between the tree and adjacent sprinkler. This arrangement was repeated on a second, nearby tree in each plot. Soil cores of the top six inches were also taken for volumetric water content determination in the middles treatments.

Results: In March '93 relative differences in middles infiltration rates were determined using 4 ft by 4 ft basins constructed of site soils and filled to a depth of 6 inches. By late May the bulk of vegetation in all cover cropped middles was similar to the resident species mix. A modified sprinkler infiltrometer was used in December '93 to obtain more realistic infiltration curves for the bare/herbicide and resident vegetation treatments. Fitted curves for the basin tests yielded a cumulative maximum infiltration after 6 hours of 3.48 inches in the bare middles to 9.53 inches in the resident cover treatment (significant at the 0.05 level). Sprinkler infiltrometer tests for the same treatments yielded 0.89 and 2.11 inches after six hours (significant at the 0.10 level). Sprinkler irrigation water in the overlapping areas of the pattern apply about 1 inch in 6 hours; coinciding with the time general runoff begins in the orchard. Boundary conditions of walls make basin estimates quite high but the ratio of bare/resident total infiltration (0.36) compares favorably with sprinkler infiltrometer tests (0.42).

Evaporation rates in the top 6" from wet soil with bare middles appeared equal to or greater than water use by any cover crop treatment throughout the trial. The mulching/cooling effect of the cover greatly decreased the evaporation potential from this dark colored soil. This was especially true for the peak irrigation season where ET in the top 6 inches ranged from 0.15 to 0.40 in. for 7/27 - 8/2/93 in the resident and bare treatments, respectively. Total middles water use to a depth of six feet for the same period was 1.05 and 1.15 in. for the same treatments. Average middles water use was 1.22 in. overall. No differences were significant at the 0.05 probability level. Potential evapotranspiration estimated by an atmometer on site was 1.77 in. The resulting crop coefficient (Kc) of 0.69 is considerably lower than optimal. Overall water content in the top foot was near field capacity and 55-75% of available at lower depths for this period. Total applied water for the 1993 season was 41.9 in. Yields were measured only for 1992 and averaged 1375 lb/a meats.

Conclusions: Infiltration was improved by over 200% in the resident cover treatment compared to bare no-till middles. To take advantage of this berms should be narrower and set times increased. Soil samples showed high Na and Cl levels indicating inadequate leaching. Vegetative cover, especially after mowing, has a mulching affect that reduces soil temperatures. Evaporation from darker, bare wet soils in an orchard appears to equal or exceed the water use in cover crops for up to one week after irrigation. This study did not allow for differential irrigation management for different treatments. Yield and pest management benefits that might accrue from cover crops require different irrigation strategies.

Agricultural Use of Methyl Bromide. I. Quantifying Emissions

S.R. Yates, F.F. Ernst, J. Gan, A. Mutziger and F. Gao

USDA-ARS and Univ. of California, Riverside

Methyl bromide is a soil fumigant extensively used for the control of nematodes, weeds and fungi. Evidence suggests that methyl bromide may damage the ozone layer and, as a result, is scheduled for phase-out by 2001. The USDA-National Agricultural Pesticide Impact Assessment Program has found that there will be significant adverse economic impacts on the agricultural community if methyl bromide is restricted. To date, quantifying the methyl bromide mass emitted from agricultural fields is highly uncertain. To address this, two field experiments were conducted for a tarped, shallow-injected and a non-tarped, deep-injected application of methyl bromide to determine the emission rate into the atmosphere and the subsurface transport of methyl bromide for these management systems. Both experiments include a field-scale mass balance to quantify the partitioning of methyl bromide and to provide additional evidence that the flux measurements were accurate. This involves measuring the Br^- concentrations before and after the experiment to quantify methyl bromide degradation as well as the soil vapor concentration as a function of distance from soil surface. The volatilization rate was estimated by atmospheric and chamber methods and used to determine the mass lost at the soil surface.

Agricultural Use of Methyl Bromide. II. Experimental Design

F.F. Ernst, J. Gan, A. Mutziger, F. Gao and S.R. Yates

USDA-ARS and Univ. of California, Riverside

Methyl bromide was injected at a shallow depth through close spaced shanks and immediately covered with 1 mil plastic tarping in a 4 ha sandy loam field. Nine months later methyl bromide was deep injected with wide spacing on an adjacent non-tarped 4 ha field. Meteorological, air, and soil gas sampling locations for both fields are shown. On-site and off-site air sampling masts, soil gas sampling probes, deep soil gas sampling equipment, active flux chambers, and soil sampling methods and equipment are illustrated.

Agricultural Use of Methyl Bromide. III. Soil Gas Transport

A. Mutziger, F. Gao, F.F. Ernst, J. Gan and S.R. Yates

USDA-ARS and Univ. of California, Riverside

Two 4 ha sandy loam fields were injected with methyl bromide at 25 or 68cm below the soil surface. For the tarped, shallow-injection experiment, 4-replicated soil gas samplers were positioned at 0 (soil tarped) or 3 (tarp removed), 25, 50, 100 and 150 cm below the soil surface. For the nontarped, deep-injection experiment, two shanks were spaced 170cm apart. At each depth below the soil surface, (15, 25, 37, 50, 75, 100, 125, 150, and 175 cm), four evenly spaced soil gas samplers were installed between a shank and the midpoint between the two shanks. Soil gas samples were collected and concentrations were determined at sampler locations for a period of two months. When the methyl bromide front moved below 175cm, deep samples were collected between 200-500cm. Presented material will include sampling methodology and graphs of the methyl bromide concentration in the soil.

MULTI-PORT SOIL WATER EXTRACTOR FOR MONITORING SOLUTE TRANSPORT THROUGH SOIL

J.A. Jobes and P.J. Shouse

USDA-ARS, U.S. Salinity Laboratory, Riverside, CA.

The principle of soil solution extraction has been known for almost a century. Their advantages are that they are inexpensive, simple to install, continuous sampling is possible, and they are reliable. One disadvantage is that traditional suction samplers are confined to sample soil solution from one depth. Our purpose was to design, build and test a multi-port soil solution extractor for measuring tracer solute at several depths within the soil profile using only one installation access hole. The solution extractor was constructed of PVC pipe and porous PVC material with known hydraulic properties. Our results indicate that soil solution chloride concentrations measured using the multi-port system compare favorably with concentrations in saturation extracts of soil samples.

DESIGNING AND BUILDING A CROP SALT-TOLERANCE DATABASE

A.L. Ulery and M.Th. Van Genuchten

USDA-ARS, U.S. Salinity Laboratory, Riverside, CA.

Crop salt-tolerance data are crucial in the management of salt-affected agronomic systems in arid and semi-arid regions. Numerous field and laboratory experiments have been conducted over the years to obtain these data, leading to generalized salt tolerance lists used by both farmers and researchers. Plant response to salinity is affected by several factors including crop variety, soil, climate, and irrigation conditions. Inclusion of these factors in salt-tolerance models would permit a more realistic and site-specific prediction of crop yield. The required information may be derived from a computerized salt-tolerance database relating crop yield to average rootzone salinity and other parameters affecting crop growth. The data will be retrieved from a collection of some 4000 references established at the U.S. Salinity Laboratory. The database will also include equations so that salinity and yield data reported in different units can be normalized and compared, thus providing a comprehensive data set for subsequent analysis by means of various crop salt-tolerance models.

IMPROVED PRECISION IN $^{15}N-NO_3$ DIFFUSIONS

D.J. Herman, M.L. Hanes, and P.D. Brooks

University of California at Berkeley

Soil extracts are often prepared for NO_3-N isotopic analysis by diffusion. In the conventional method, H_2 bubbles form on the surface of the Devarda's alloy sediment. These eventually surface and burst, spattering the N-traps. This results in erratic N-trapping and poor analytical precision. Our objective was to test a modification of the method which promised to improve NO_3^- recovery and analytical precision. We added a surfactant to $^{15}N-NO_3$ labelled extracts of 10 diverse soils, diffused them as usual, and measured ^{15}N using an isotope ratio mass spectrometer. Using the surfactant, the bubbles are smaller, spattering is minimized, and precision is improved. With this modification, recovery of ^{15}N-labelled NO_3^- added to soil extracts improved from 97.5% to 99.5%, with a two-fold reduction in variance. This precision should be acceptable for most applications involving NO_3^- tracers.

SOIL N-DYNAMICS IN A SIERRA NEVADA SUBALPINE MEADOW

T. Balser, T. Dudley, and M.K. Firestone

University of California at Berkeley

Intensive grazing for the past 100 years has resulted in stream degradation and lowering of the water table in subalpine meadows in the southern Sierra Nevada. This study investigated nitrogen dynamics in 5 plant communities in Templeton Meadow in the Golden Trout Wilderness in order to better understand how to restore the meadows and prevent further degradation. We performed buried core incubations during the 1993 and 1994 growing seasons in sage, wet meadow, old point bar, seasonal channel, and streamside communities. Nitrogen mineralization activity, in combination with water content, instantaneous N pool sizes, and total carbon and nitrogen in the 5 habitats allowed an assessment of the potential of each site for restoration. Sagebrush dominated areas had the largest inorganic nitrogen pools and mineralization rates, followed by wet meadow, old point bars, seasonal stream channels, and streamside vegetation. Each habitat varied in its ammonium:nitrate ratio. Sage had higher nitrate levels, whereas other sites had higher ammonium.

DEVELOPMENT AND TESTING OF A COMBINED TENSION-SOLUTION PROBE

S.J. Essert and J.W. Hopmans

University of California, Davis

The study of water migration and solute transport in soils is of interest to agriculture, industry, and municipalities. For solutes to reach the groundwater, they first must pass through the unsaturated or vadose zone. Accurate characterization of the soil and soil water environment are required if predictions about this transport are to be made. Two properties of interest in characterizing solute transport in soils are solute concentration and soil water potential. Presently, common techniques used to collect this information utilize separate tensiometers and suction solution probes which are very similar in design. The goal of this study was to develop and test a single modified probe that can both measure soil water potential and extract soil water solution simultaneously. In order to measure soil water potential and collect solution sample from a single instrument the porous ceramic cup was split into two separate compartments. Laboratory column experiments were carried out to evaluate the performance of the modified tension-solution probe. The tension-solution probe is being utilized in two ongoing field projects from which data are presented.

SUBSURFACE DRIP IRRIGATION STUDIES FOR COMMON WESTSIDE CROP ROTATIONS

Daniel Munk, Farm Advisor

University of California Cooperative Extension, Fresno, CA

Field studies are being conducted to evaluate agronomic field parameters that influence yield and quality characteristics of field and vegetable crops grown under subsurface drip irrigation. Studies are located at the University of California's West Side Research and Extension Center, using 60-inch bed spacing with drip tape placed at either 8 or 12 inches below the bed surface. The crops being evaluated include cotton, processing tomatoes and cantaloupe in a three-year rotation scheme. Drip tape designs included 12-, 16-, and 24-inch emitter spacings, with both high-flow and low-flow emitter products included. Irrigation water was scheduled using a volume balance approach which incorporated local CIMIS potential evapotranspiration values with either a regionwide or modified regional crop coefficient to estimate crop evapotranspiration. In selected plots, gypsum blocks and neutron probe tubes were installed to monitor the site soil moisture dynamics and to verify the validity of the crop coefficients selected.

Observations indicated that surface soil moisture dynamics in subsurface drip irrigation were more sensitive to irrigation scheduling changes than conventional irrigation systems. Studies conducted in cotton demonstrate that tape design characteristics dictate late season soil wetting patterns found when emitter spacing and discharge rate varied. The most closely spaced emitter designs afforded more rapid and complete replenishment of soil moisture. The resulting soil profile maintained a larger wetted volume compared to lengthy emitter spacing.

Emitter location and frequency appear to be design character-istics that crop managers look for when purchasing a new system. If drip system repairs are required, laterals damaged or irrigation scheduling inaccurate, closely spaced drip tape products are most effective in redeveloping a wetted soil profile.

A GIS-BASED APPROACH TO EVALUATE SOIL SALINITY IN THE BROADVIEW WATER DISTRICT OF CENTRAL CALIFORNIA

H. Wang, D.L. Corwin, L.J. Lund, J.D. Rhoades, P.J. Vaughan, and D.G. Cone

USDA-ARS, Riverside, California

Salinity is a common problem encountered in irrigated lands in semi-arid areas. High soil salinity causes agricultural and environmental problems. The objective of this study is to apply GIS and statistical tools in evaluating and predicting salinity development and the need for the reclamation of irrigated lands. The factors that strongly influence salinity accumulation in Broadview Water District in the Central Valley of California will be identified. The use of a GIS tool, ARC/INFO, in the field scale study of soil salinization will be discussed. A logistic regression model will be developed for salinity prediction. The necessity of reclamation of soil salinity will be evaluated.

SELENIUM PARTITIONING IN SOIL-PLANT-ATMOSPHERE SYSTEM

M. Camps and J.W. Biggar

University of California, Davis

The biogeochemical cycling of Se is a complicated process, due to the existence of different pools and species of Se in the environment. The objective of this research was to do a mass balance study on the selenium cycling. A system was developed in which Se adsorption, plant uptake, and the effect of microbial activity on Se immobilization, reduction and volatilization were studied. Leaching was not considered in this system. Speciation of Se was done when possible. The different processes were studied with and without addition of barley straw. The plant used in this study was barley. Soils used were from Kesterson Reservoir (San Joaquin Valley). Addition of barley straw to Kesterson soils had a significant effect in most of the processes mentioned above.

CONSUMPTIVE WATER USE, BIOMASS ACCUMULATION AND SUGAR YIELD OF FALL-PLANTED SUGARBEETS IN CALIFORNIA

S.R. Kaffka, P. Langner, D. Peters, and G. Peterson

University of California, Davis

A line-source irrigation trial was carried out during two years to quantify water use, biomass accumulation and sugar yields of an October-planted sugarbeet crop in the San Joaquin Valley of California, at a site with low winter rainfall. Irrigation water was applied at rates varying from approximately 110 to less than 25% of estimated crop ET. Measurements with a neutron access probe were used to schedule irrigations and estimate water recovery from the soil to a depth of 3 m. Harvests were made in May, June and July each year. In the first year, winter rainfall was twice the long-term average, and sugarbeet root yields failed to respond to irrigation water gradients until the final harvest in July. In the second year, rainfall was below average and root yields responded to the irrigation gradient at all three harvests, with response increasing with successive harvest. Sucrose concentration was increased by deficit irrigation. In deficit treatments, sugarbeets recovered water to a depth of 1.75 m. Water use, recovery, yield and sucrose concentration are discussed in this paper. Over-wintered sugarbeets can be produced with low amounts of irrigation water.

TRANSIENT THREE-DIMENSIONAL ROOT GROWTH, SOIL WATER FLOW AND NUTRIENT TRANSPORT AND UPTAKE

F. Somma, J.W. Hopmans and I.P. King

University of California, Davis

Characterization of the root system and its response to a variety of soil environmental conditions is essential for a better understanding of soil-plant relationships and plant growth and to control the quantity and quality of water transported between the soil surface and the groundwater. A simulation model was developed, capable of predicting root response to spatially and temporally changing soil environmental conditions. Three-dimensional nutrient transport and uptake was modeled solving the advection-diffusion equation with the finite element method. One, two and three-dimensional analytical solutions were used to validate the numerical model. The nutrient transport and uptake model was then incorporated into an existing three-dimensional finite-element root growth and soil water flow model to predict root response to soil conditions. The two models are interfaced through the root water uptake term, which takes into account active and passive nutrient uptake.

ANALYSIS OF SOIL WATER AND SOLUTE DISTRIBUTION AROUND AN ALMOND TREE UNDER DRIP IRRIGATION

L. Andreu, J.W. Hopmans, L. Schwankl and J. MacIntyre
University of California, Davis

Trickle irrigation of trees results in a three dimensional pattern of water and salts around emitters. Therefore, intensive instrumentation to characterize spatial patterns of soil Water and salts is required. The experimental design of a water balance study in a young almond orchard under drip irrigation is described as well as the methodology developed. This includes the use of neutron probe, TDR, porous ceramic cup solution sampler/tensiometers and laboratory characterization of soil hydraulic properties using the multi-step outflow method. The experimental data give us a data base to evaluate the performance of drip systems, the extent of the wetted soil volume, application efficiency, soil salinization and spatial and temporal distribution patterns. The data will serve as a reference for model validation of soil water regime under a drip irrigation system and will determine optimal sensors placement for best management practices and irrigation scheduling.

FUGITIVE DUST CHARACTERISTICS FROM AGRICULTURAL OPERATIONS IN CALIFORNIA

R. Higashi, T. Fan, R.J. Southhard, M.J. Singer, and

H. Clausnitzer

University of California, Davis

In addition to measuring dust amounts form various agricultural operations, we are investigating the relationship of chemical composition to PM-10 production and cropping system. Organic matter (OM) studies are concentrated on humic structures, using multinuclear NMR and electrophoretic analyses of extracts of source soil associated with dust, and pyrolysis GC-MS analyses of dust samples, source soil, and the extracts. Current evidence suggests a close overall relation of dust organic structures to those in the source soil, with distinct differences in carbohydrate moieties, but we are still at the initial stages of this long-term project. Another goal is to detect "unextractable" pesticide structures bound to humics, using pyrolysis GC-MS. We are also using proton-induced x-ray elemental analysis, plus x-ray fluorescence and proton scattering to determine the elemental and mineral composition of the dust. All of these techniques together enable us to identify selected chemical (fertilizer, pesticide) inputs on conventional plots, and will test the concept of tracing dust back to source soils based on elemental, mineral, and organic signatures.

A PROFICIENCY TESTING PROGRAM FOR AGRICULTURAL LABORATORIES- RESULTS OF THE 1994 PROGRAM

J. Kotuby-Amacher and R.O. Miller

Utah State University and University of California, Davis

The accuracy of soil and plant analysis results are occasionally called into question by laboratory clientele. Although laboratories generally conduct internal quality assurance procedures, there are a few external performance testing programs for the industry. In the spring of 1994, a proficiency testing program was initiated for soil and plant samples for agricultural laboratories in the Western United States to improve the long-term quality of the lab industry. The program involves the quarterly exchange of soil and plant samples on which soil salinity, soil fertility, and plant nutrition analyses are conducted. Over seventy laboratories from nineteen states participated in the 1994 program. Overall, soil salinity and pH analyses were highly reproducible across soils, laboratories, and exchange dates. Variability in soil nitrate results was lower than noted in past exchange programs independent of soil sample. Results for soil phosphorus were highly variable across methods, soils, and laboratories. Plant nitrogen and phosphorus results were consistent across samples, laboratories, and methods. Statistical tools utilized and results will be presented identifying specific soil and plant analytical methods which are variable.

SORPTION PROCESSES CONTROLLING AS SOLUBILITY IN GROUND WATER, TULARE BASIN, CALIFORNIA

S. Gao (UC, Davis), A. Chalmers (USGS), K.K. Tanji (UC, Davis),

and R. Fujii(USGS)

Arsenic concentrations as high as 900 ug/L have been found in groundwater in Tulare basin, potentially influencing both agricultural production and environmental quality. The goal of the current study is to understand and quantify desorption/adsorption processes controlling the solubility of As in ground water. Undisturbed core samples were collected from 7.9 to 9.1 m below land surface (BLS) at site 9A and from 2.4 to 3.6 m BLS at site 31D. High concentrations of iron (16.8 mg/L), manganese (18.1 mg/L) and arsenic present predominantly as arsenite in pore water extracted from site 9A samples indicate reducing conditions. Oxidizing conditions reflected in site 31D pore water are indicated by low iron (<0.2 mg/L) and manganese(<0.1 mg/L) and arsenic present predominantly as arsenate. An isotope (^{73}As) dilution method was used to determine adsorbed As(V) in the 31D sediment sample. The results indicate that ~15% of the total arsenic (3.4 mg/g) on the solid phase is exchangeable, which indicates that there is a potential to contribute As to groundwater.

RESPONSE OF 'HASS' AVOCADO TO DIFFERENTIAL IRRIGATION TREATMENTS

D.E. Stottlemyer, M.L. Arpaia, J.L. Meyer, G.W. Witney, and G.S. Bender

Department of Botany and Plant Sciences

University of California, Riverside

The influence of three irrigation treatments on flowering, yield, tree growth, root distribution, and leaf analysis of mature 'Hass' avocado (*Persea americana* Mill.) was investigated over a six year period (1987-1992). Three irrigation treatments; 60, 80, and 100% of evapotranspiration (ETc) were applied using low-volume spray emitters. The differential irrigation treatments were maintained year round. Irrigation treatments did not affect the timing or intensity of bloom. Yield data from years 2-6 show a significant irrigation effect on cumulative weight and total numbers of fruit per tree. Trees receiving 100% ETc had higher yield/tree. This increased yield was due both to increased fruit numbers and individual fruit weight per tree. Tree growth was also significantly impacted by the irrigation treatments. Trees receiving 100% ETc exhibited the greatest amount of vegetative growth over the study. Yield efficiency (kg fruit/m^3 canopy) was not influenced by irrigation treatment. Irrigation treatment did not significantly influence nutrient analysis taken in the fall of each year.

DRIP IRRIGATION AND FERTIGATION MANAGEMENT CAN MINIMIZE NITRATE LEACHING LOSSES

T.K. Hartz

Department of Vegetable Crops, University of California, Davis

Trials were conducted under California field conditions examining the impact of drip irrigation and nitrogen fertigation regime on in-season NO_3-N leaching losses. Six field studies were conducted, 4 on tomato and 2 on pepper. Seasonal fertigation ranged from 0-440 kg N/ha; irrigation was applied 3X per week, with leaching fractions of 10-25% of applied water. NO_3-N leaching losses were estimated both by suction lysimetry and the use of buried anion resin traps. A similar pattern was seen in all trials. From transplant establishment until early fruit set soil solution at 0.8 m had relatively high NO_3-N concentration (>30 mg/liter), which declined as the season progressed; in the month before harvest soil solution NO_3-N at 0.8 m was consistently below 10 mg/liter (tomato) and 15 mg/liter (pepper) in appropriately fertilized plots. Seasonal NO_3-N leaching estimates were generally below 25 kg/ha (tomato) and 35 kg/ha (pepper), with only modest differences among fertigation regimes. These results suggest that well managed drip irrigation can minimize in-season NO_3-N leaching.

SHALLOW GROUNDWATER USE BY ROW CROPS

S.S. Vail, R.B. Hutmacher, J.E. Ayars,

R.A. Schoneman, and D. Dettinger

USDA-ARS, Fresno, CA.

Column lysimeters were used to determine the influence of shallow groundwater salinity on groundwater uptake by cotton, tomato, and wheat crops. Groundwater salinity in these evaluations was keyed to crop salt tolerance, with groundwater treatments consisting of nonsaline water or 1, 2, 3 or 4 times the Maas-Hofman salinity threshold for yield reduction. Crop evapotranspiration, groundwater uptake, growth and dry matter accumulation and water status were monitored as a function of growth stage. Groundwater uptake in all crops declined significantly beginning at 3 times threshold salinity and was nearly eliminated at 4 times the threshold. Resulting influences on soil profile salinity distribution and root distribution were also determined.

Subsurface Drip Irrigation: Eastern San Joaquin Valley

by Allan Fulton
UC Soils and Water Farm Advisor
Kings Couty

Abstract:

The eastside SJV agricultural setting has changed in recent years. From 1987 to 1993, the acreage of processing tomatoes in eastern Kings County has increased from less than 1500 acres to over 11,000 acres annually and the increase will likely continue. During this same period, eastside farmers have relied more heavily on groundwater to manage consecutive years of drought and the result has been declining water levels, increased well drilling, and higher pumping costs. Eastside growers are motivated to finds ways of reducing energy costs for pumping and to control the decline in groundwater levels. Eastside farming is also more closely located near expanding urban communities where protection of groundwater quality is an issue.

In past experiences, the agronomic and economic success of subsurface drip has been highly dependent on the production setting and management. Subsurface drip irrigation has not always proven to be an economically viable alternative to conventional furrow practices. However, subsurface drip irrigation has consistantly shown potential to save water and energy while improving crop productivity primarily due to the ability to irrigate and fertilize crops frequently. Water and energy savings have been experienced by improving furrow designs and management but have seldom resulted in a production increase to repay the conservation measures, thereby farm profits often decline. The question becomes whether eastside production settings exist where the value of the energy and water savings and improvement in crop production could be sufficient to justify changes to subsurface drip irrigation.

In February 1994, an on-farm study was initiated to develop information on the agronomic and economic feasibility of subsurface drip irrigation under eastside production conditions. The study site is located northeast of Hanford in Kings County. It consists of 18.8 acres of land under subsurface drip irrigation. One-half of the drip system consists of tape buried at a shallow depth (10 inches) and the other half with tape buried deeper (20 inches). One goal is to evaluate the effect of drip tape depth on system durability, tillage, crop germination, water consumption, nutrient recovery, and crop response. A second objective is to understand the economic aspects of subsurface drip as an alternative to sustain farm profits and use limited water resources wisely.

One year of double cropping has been completed. Processing tomatoes were followed by short season silage corn. An advantage in seedling stand establishment and vigor was experienced in both crops irrigated by shallow buried drip. When the processing tomatoes were fertilized identically, a nitrogen deficiency occurred at peak fruit set and bulking in the deep drip system. This required additional fertilizer to correct. The corn silage was harvested in early November following early frosts and rains. Damage to the permanent beds was unavoidable and the deep placed drip appeared better protected. Tomato yields were not affected by drip tape depth.

We experienced a 32 percent reduction in energy demand due to less pumping over the double crop season which represented a $45/ac savings (1.7 ac-ft/ac). Paid tonnage of the processing tomatoes was 2.5 tons per acre higher (valued at $125/ac) in the drip than in furrow irrigated tomatoes of the same variety R-320 (a determinate type variety by Ragu). However, there was no yield advantage in a second tomato variety Heinze 2232 (an indeterminate type variety).