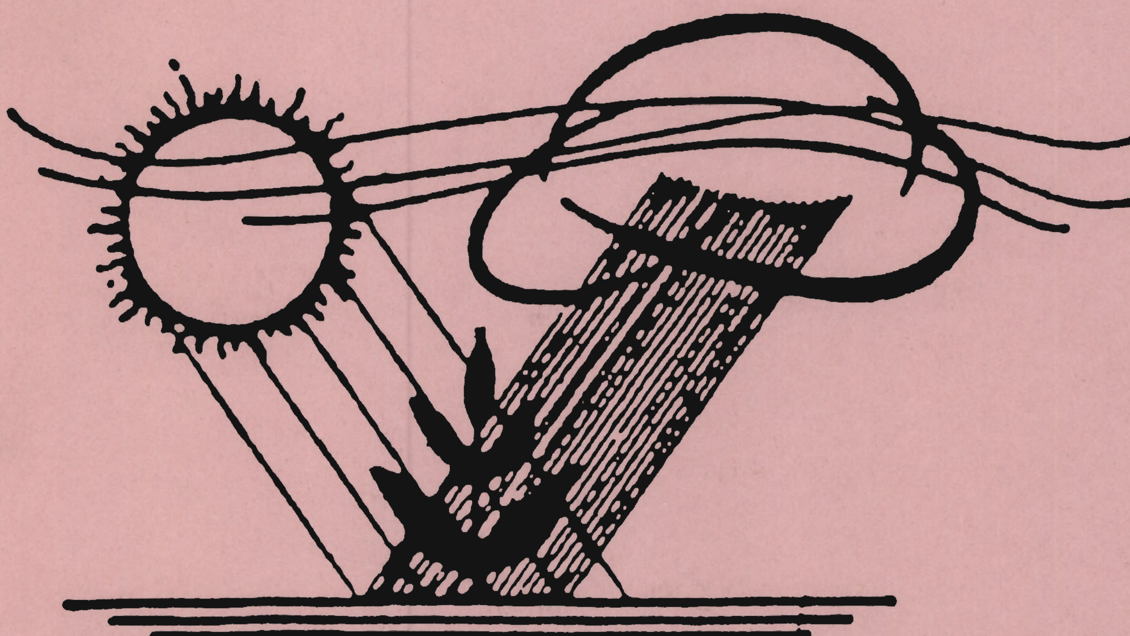
PROCEEDINGS
1998
CALIFORNIA PLANT AND SOIL CONFERENCE

AGRICULTURAL CHALLENGES IN AN URBANIZING STATE



CALIFORNIA CHAPTER OF AMERICAN SOCIETY OF AGRONOMY

AND

CALIFORNIA FERTILIZER ASSOCIATION

JANUARY 21 & 22, 1998

RADISSON HOTEL
500 LEISURE LANE
SACRAMENTO, CA 95815

PROCEEDINGS
1998
CALIFORNIA PLANT AND SOIL CONFERENCE

AGRICULTURAL CHALLENGES IN AN URBANIZING STATE

CALIFORNIA CHAPTER OF AMERICAN SOCIETY OF AGRONOMY

AND

CALIFORNIA FERTILIZER ASSOCIATION

JANUARY 21 & 22, 1998

RADISSON HOTEL
500 LEISURE LANE
SACRAMENTO, CA 95815

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. Lorenz
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
1994	Brock Taylor
1995	Jim Oster
1996	Dennis Westcot
1997	Terry Smith

CALIFORNIA CHAPTER
AMERICAN SOCIETY OF AGRONOMY
HONOREES

1973	J. Earl Coke	1991	Francis E. Broadbent
1974	W.B. Camp		Robert E. Whiting
1975	Milton D. Miller		Eduardo Apodoca
1976	Malcolm H. McVickar	1992	Robert S. Ayers
	Perry R. Stout		Richard M. Thorup
1977	Henry A. Jones	1993	Howard L. Carnahan
1978	Warren E. Schoonover		Tom W. Embleton
1979	R. Earl Storie		John L. Merriam
1980	Bertil A. Krantz	1994	George V. Ferry
1981	R.L. "Lucky" Lockhardt		John H. Turner
1982	R. Merton Love		James T. "Jim" Thorup
1983	Paul F. Knowles	1995	Leslie K. Stromberg
	Iver Johnson		Jack Stone
1984	Hans Jenny	1996	Henry Voss
	George R. Hawkes		Audy Bell
1985	Albert Ulrich		Frank Parsons
1986	Robert M. Hagan	1997	Jolly Batcheller
1987	Oscar A. Lorenz		Hubert B. Cooper, Jr.
1988	Duane S. Mikkelsen		Joseph Ronstadt Smith
1989	Donald L. Smith	1998	William H. Isom
	F. Jack Hills		George A. Johannessen
1990	Parker F. Pratt		Ichiro "Ike" Kawaguchi

1998 Honorees of the California Chapter of the American Society of Agronomy

William (Bill) H. Isom

George A. Johannessen

Ichiro "Ike" Kawaguchi

William (Bill) H. Isom

Bill received Emeritus status when he retired from the University of California Cooperative Extension Service in 1988. This honor exemplified a distinguished career in teaching and research that covered over 28 years. Besides carrying the role of regional extension specialist, Bill carried the statewide duties of Dry Bean Specialist. His contribution under both hats are widely recognized and remain a major contribution to the agricultural community and to the field of agronomy.

Born in Hurricane, Utah, Bill attended Hurricane Elementary and Hurricane High School. He graduated from Utah State Agricultural College (Utah State University) with a Bachelor of Science degree in Agronomy in 1940. Bill's education was interrupted by World War II where he advanced from private to 1st Lieutenant while serving in both the U.S. Army Infantry and the U.S. Army Corps of Engineers. After the war Bill continued his education at Utah State, graduating in 1951 with a Master of Science degree in Agronomy. He attended Cornell University where he received a Ph.D. degree in Plant Breeding and Genetics in 1955.

Following graduation from Cornell, Bill joined the USDA-ARS as an Agronomist-Plant Breeder on a Flax Improvement Project at the Southwest Irrigation Field Station in Brawley. In 1960, he began his 28-year career with the University of California. His first asignment was as a Field Crops and Weed Science Specialist with Cooperative Extension in Imperial County. Because of his many talents and his strong skills in education, Bill moved to the University of California at Riverside where he served as the Extension Agronomist for Field Crops and Weed Sciences for Southern California. Bill was always at the forefront in research and education programs in agronomy. His cooperation with U.C. Plant Breeders assisted in the release of new alfalfa and bean varieties. His weed control research helped to register several herbicides and to develop new weed control programs which enabled the agricultural industry in Southern California to be one of the strongest in the nation. During this period, Bill was awarded the Distinguished Service Award for Agronomic Contributions to Crop Production in Riverside County (1975) by Riverside County growers and Riverside Cooperative Extension.

In 1980, Bill was designated the Statewide Specialist in Dry Bean Production for the University of California and continued in this position until his retirement in 1988. In 1987, he received a California Dry Bean Advisory Board resolution of appreciation for service to the California Dry Bean growers and industry.

Bill's recognition was partly due to the ability to work well with everyone including growers and University personnel. He had a special talent of telling jokes and stories that made people want to be with him. He was a dedicated person that went the extra mile to complete research and education events. Because of this dedication, he was awarded in 1987, the Distinguished Teaching Award as the Outstanding University of California Specialist.

He has been a member of the American Society of Agronomy, Crop Science Society of ASA, Western Crop Science Society, California Chapter of ASA, Western Society of Weed Science, Southwest Alfalfa Group and the American Association for the Advancement of Science.

Bill is married to Helen Joyce. They will be celebrating their 50th wedding anniversary in March 1998. They have three children and 9 grandchildren.

George A. Johannessen

Just prior to retirement George was serving as director of both the California Agricultural Education Foundation and the California Tomato Research Institute. These posts exemplified George's dedication to research to better improve California agricultural production and to pass that information along through leadership training and teaching. His accomplishments under both hats are widely recognized and remain a major contribution to the agricultural and agronomy fields.

Born in Seattle, Washington, George received his Bachelor of Science degree in agriculture from Rutgers University in 1941 where he enjoyed four years on the varsity rowing team. George's education was interrupted by World War II where he served in the U.S. Army Medical Corps. He spent twenty-seven months overseas and rose from a private to a Captain. After the war George continued his education at Purdue University where he earned a Master of Science degree and Cornell University where he received a Ph.D. degree. He majored in vegetable crops and had minors in plant breeding, plant physiology, plant pathology and soil fertility.

After receiving his Ph.D., George served on the Cornell faculty as Assistant and Associate Professor of Vegetable Crops and Pomology. In 1953, George began a seven-year assignment as a Pacific Division Agronomist for the American Can Company. George then went on to become Head of the Plant Breeding Department at the Pineapple Research Institute of Hawaii and an Affiliate Member of the Graduate Faculty at the University of Hawaii. In 1964, he joined the Cal Can Company as the Director of Raw Product Research. George was appointed as Director of California Tomato Research Institute in 1968, where he represented California processing tomato growers on technical matters and directed the Institute's funded tomato research. Although he retired from the Institute in 1990, George continues to serve as Director Emeritus with the Institute.

George has served as Vice President of the American Society of Horticultural Science. He is also a member of the American Phytopathological Society; the Institute of Food Technologists; the Council for Agricultural Science and Technology; the Agricultural Research Institute, Washington, DC; and an honorary member of the scientific fraternity, Sigma Xi.

George has always had a special interest in working with young people and with others interested in learning about the field of agriculture, horticulture and agronomy. He has served continuously as a member of the California Agricultural Leadership Program's Selection Committee since Class II and is a member of the Board of the Agricultural Education Foundation where he has served since 1987. He also serves on the Cornell Alumni Admissions Ambassador's Committee, Emil Mrak Agricultural Student Loan Committee at UC Davis, Nissen Agricultural Student Loan Committee of Cal Poly, San Luis Obispo, and as a member of the Advisory Council to the College of Agriculture and Natural Resources at Cal Poly, San Luis Obispo.

In addition, he has served on numerous foreign horticultural assignments in Mexico, Ghana, Spain, Ivory Coast, Taiwan, Israel, and the People's Republic of China.

George is married to Patricia Martin of Tipton, Indiana. They have 4 children.

Ichiro "Ike" Kawaguchi

Ike passed away suddenly at his home in Davis in late June. We are all saddened by the loss of one of the great contributors to the plant breeding field, especially the alfalfa breeding program. Ike was a true friend, colleague and contributor to the agricultural community, especially the agronomy field.

Born in Roy, Utah, Ike attended Roy Elementary School and Weber High School. During those years, he spent many hours working on the family farm and learning agriculture from the "ground up". He graduated from Weber State University with an Associate degree and then attended Utah State University majoring in crop and soil science where he received both a Bachelor of Science and Master of Science degree.

While completing his Master of Science degree, a comprehensive study of the disease complex associated with alfalfa in Utah, Ike's major professor suggested that he consider a breeding position that was open at Waterman-Loomis Co. in Bakersfield. Waterman-Loomis had recently made the decision to start developing proprietary cultivars. Ike joined Waterman-Loomis in 1966 as the lead person breeding non-dormant cultivars and for seed production on breeding lines. During his eighteen-year tenure at what became W-L Research, Inc, Ike was either the principal developer or co-principal developer of 35 commercially successful cultivars. In 1983, Ike joined Plant Genetics in Davis and initiated a very successful alfalfa breeding program designed to complement the fledgling biotechnology industry. In the short term of six years, 15 more successful cultivars were developed and entered the market place. In 1989, he started his own company, I.K. Research, Inc, and continued to rapidly develop high yielding, multiple pest resistant cultivars. He was joined in this effort by his son Jeff.

Ike was an active member of a number of organizations including the Kiwanis Club in Bakersfield, American Society of Agronomy, California Seed Association, Pacific Seed Association, North American Alfalfa Improvement Conference, Western Alfalfa Improvement Conference and the California Statewide Alfalfa Workgroup. While a member of the Kiwanis Club, he was a prime mover in an effort to develop signs along the major California highways identifying crops that were under production. This was a public service project that promoted the agriculture of California and served a needed educational role. This pioneering effort has since been adopted by several other regions.

Ike was also a perennial contributor to the planing, an active participant, and frequent speaker at the Annual California Alfalfa Symposium and the California Chapter of the American Society of Agronomy. In 1995, he received the Alfalfa Industry Award from the California Alfalfa Symposium. The recent Alfalfa Industry Symposium was named in his honor. These honors are a tribute to his major contributions that have helped the success of alfalfa production in California and the Western United States.

Ike had a quiet, kind manner. His approach to alfalfa breeding was as academic as it was applied. He had a keen eye and feel for plant selection and his integrity was beyond reproach. He was a colleague and friend and his presence and contributions will be greatly missed, but his legacy will never be forgotten.

Ike is survived by his wife of 37 years, Chizuko Kawaguchi of Davis; children, Jeffrey Kawaguchi, and Kevin Kawaguchi both of Davis.

CALIFORNIA CHAPTER ASA
1997
BOARD MEMBERS

THE EXECUTIVE COMMITTEE

President: Terry Smith, Soil Science Department, Cal Poly State University, San Luis Obispo
First Vice-President: Shannon Mueller, Agronomy Farm Advisor, UC Cooperative Extension, Fresno
Second Vice-President: Bill Rains, Agronomy and Range Science Department, UC Davis
Past President: Dennis Westcot, California Regional Water Quality Control Board, Sacramento
Executive Secretary-Treasurer: Steve Oakley, CPCSD, Shafter

COUNCIL MEMBERS

One-Year Term:

Henry Carrasco, Western Farm Service, Salinas
Wes Mueller, Crop Science Department, Cal Poly State University, San Luis Obispo
Phil Osterli, University of California Cooperative Extension, Stanislaus County

Two-Year Term:

Casey Walsh-Cady, CA Department of Food and Agriculture Fertilizer Research and Education Program, Sacramento
Steve Kaffka, Agronomy and Range Science Department, UC Davis
Bob Dixon, Dixon Agronomics, Stockton

Three-Year Term:

Marsha Campbell Mathews, University of California Cooperative Extension, Stanislaus County
John Palmer, J.G. Boswell Cotton Breeding, Corcoran
Warren Bendixen, University of California Cooperative Extension, Santa Maria

TABLE OF CONTENTS

	Page
Past Presidents	i
List of Past Honorees	ii
Biographies of 1998 Honorees	iii
1998 Chapter Board Members	vii

GENERAL SESSION

Land Use Policies and Urban Growth: Can Agriculture Survive? 1
Mary E. Handel, Land Use Consultant, Napa, CA
Consumer Food Safety Priorities: Meeting the Challenge 4
Christine M. Bruhn, Director, Center for Consumer Research, UC Davis

CONCURRENT SESSIONS

I. SEWAGE SLUDGE IN CALIFORNIA AGRICULTURE: WHAT WE KNOW, WHERE WE STAND

California Biosolids Mineralization Research 10
David M. Crohn, Department of Soil and Environmental Sciences, University of California, Riverside
Fate of Pathogens During the Sewage Sludge Treatment Process and After Land Application 16
James E. Smith, Jr., Senior Environmental Engineer, USEPA, Center for Environmental Research Information, Cincinnati, OH and Joseph B. Farrell, Consultant, Cincinnati, OH
Fate and Transport of Pathogens From Land Application of Sewage Sludge: What We Know, What We Don't Know 22
Marylynn V. Yates, Department of Soil and Environmental Sciences, UC Riverside
Fate and Effects of Chemicals Applied to Agricultural Land from Municipal Sewage Sludge: Past Experiences and Present Status 27
A.L. Page and A.C. Chang, Department of Soil and Environmental Sciences, UC Riverside
Sludge, Sludge on the Range: Unresolved Science in the 503 Regulations 31
Albert G. Medvitz, Farmer/Rancher, Rio Vista, CA
Why the California Farm Bureau Federation Remains Cautious About the Use of Sewage Sludge on Agricultural Properties 41
Ron Liebert, Associate Counsel, California Farm Bureau Federation, Sacramento, CA

II. MANAGEMENT OF AGRICULTURAL DORMANT SPRAYS

Sources of Pesticides in Urban Stormwater 44
Valerie M. Connor, Central Valley Regional Water Quality Control Board, Sacramento, CA
Water Quality Impacts from Dormant Sprays 47
Chris Foe, Central Valley Regional Water Quality Control Board, Sacramento, CA
Use of Vegetation to Reduce Dormant Spray Runoff 50
Lisa J. Ross, Department of Pesticide Regulation, Sacramento, CA
The Bt Program to Reduce Dormant Insecticide Use 59
Carolyn Pickel, UC-IPM Area Advisor, Sacramento Valley
Impact of Pyrethroids on Beneficial Mite Predators 62
Frank G. Zalom, Department of Entomology and Statewide IPM Project, UC Davis
Dormant Sprays, Issues and Alternatives 66
Walt Bentley, IPM Entomologist, University of California and Carolyn Pickel, UC-IPM Area Advisor, Sacramento Valley

Page

III. ADVANCES IN NUTRIENT MANAGEMENT

Best Management Practices for Nutrient Management in Arizona 69
Charles A. Sanchez, Yuma Agricultural Center, University of Arizona

Evaluation of Pre-Sidedressing Soil Nitrate Testing to Determine N Requirements of Cool-Season Vegetables 71
T.K. Hartz, Extension Specialist, Department of Vegetable Crops, UC Davis

Controlled Release Fertilizers in Celery Production 78
Warren E. Bendixen, UC Cooperative Extension, Santa Maria

Developing Site-Specific Information For Cropping Systems in California 84
Stuart G. Pettygrove, LAWR, University of California, Davis; R.E. Plant, Department of Agronomy & Range Science, UC Davis; R.F. Denison, Department of Agronomy & Range Science, UC Davis; J.A. Young, Department of Agronomy & Range Science, UC Davis; S.K. Upadhyaya, Department of Biological and Agricultural Engineering, UC Davis; M.D. Cahn, UC Cooperative Extension, Sutter, Co.; E.M. Miyao, UC Cooperative Extension, Yolo Co.; T.E. Kearney, UC Cooperative Extension, Yolo Co.

Determining Best Nitrogen Management for Broccoli Production in the San Joaquin Valley 89
Michelle Le Strange, UC Cooperative Extension, Visalia; Jeffrey P. Mitchell, UC Kearney Agricultural Center, Parlier; and Louise E. Jackson, Vegetable Crops Department, U.C. Davis

IV. THE FARMSCAPE

Role of Noncrop Vegetation in Pest Management 91
L.E. Ehler, Department of Entomology, UC Davis

Wildlife and Agriculture 94
E. Lee Fitzhugh, Wildlife Extension, Department of Wildlife, Fish, and Conservation Biology, UC Davis

Rotational Wetland Systems in the Klamath Basin 102
Harry L. Carlson, Intermountain Research & Extension Center, Tulelake, CA

Assessing the Challenge for Waterfowl Habitat in the Rice Landscape of the Sacramento Valley 106
Frederic A. Reid, Richard G. Kempka and Michael A. Bias, Ducks Unlimited, Rancho Cordova, CA; James E. Hill and Sylvie M. Brouder, Agronomy and Range Science Department, UC Davis; and Glenn Wylie and John H. Day, Biological Resources-Division USGS, Dixon, CA

California Rangelands: Balancing Livestock Production and Water Quality 107
Kenneth W. Tate, UCCE Rangeland Watershed Specialist, Agronomy and Range Science, Davis, CA; Melvin R. George, UCCE Range and Pasture Specialist, Agronomy and Range Science, Davis, CA; Edward R. Atwill, UCCE Environmental Health Specialist, School of Veterinary Medicine, Veterinary Medicine Teaching and Research Center, Tulare; and Sheila Barry, Watershed Management Specialist, Alameda County Resource Conservation District, Livermore, CA

V. PEST MANAGEMENT

Federal Perspective on Pesticide Drift: Building on Interest 109
Karen Heisler, Pesticides Program, USEPA, Region 9, San Francisco, CA

California's Enforcement Policy on Pesticide Drift 112
Paul H. Gosselin, Assistant Director of Enforcement, Environmental Monitoring and Data Management, Department of Pesticide Regulation, Sacramento

Pest Management in Urban-Rural Agriculture in the Central Valley and Fresno County 115
Richard Molinar, Small Farms Advisor, UC Cooperative Extension, Fresno, CA

Page

VI. FARMING MARGINAL SOILS

Deep Ripping of Environmentally Sensitive Lands for Tree and Vine Development 119
Michael A. McElhiney, District Conservationist, USDA - Natural Resources Conservation Service, Modesto, CA
Conservation Farming and its Potential in California 122
Brent Rouppet, Soil and Plant Sciences, Merced College, Merced, CA
Culture, Capital, and Contours: A Socio-Economic Approach to Managing Marginal Agricultural Lands 126
Daniel C. Mountjoy, USDA - Natural Resources Conservation Service, Salinas, CA

SCHOLARSHIP WINNERS

Question: How can you, in your agricultural career, help to resolve the conflict between the need for natural resources required by production agriculture and the rapidly growing urbanizing society in California?

Joel G. Canestrino, Agricultural Systems in the Environment, University of California, Davis 131
Allison M. Bettencourt, Soils/Irrigation Production Management, Fresno State University 132
Jennifer Campos, Crop Science Department, Cal Poly, San Luis Obispo 133

POSTERS

Root Distribution of Cotton Under Drip Irrigation 134
R.B. Hutmacher, K.R. Davis, S.S. Vail, M.S. Peters, J. Covarrubias, USDA-ARS and University of California
Comparison of Nitrate Uptake and N-Use Efficiency of Acala and Pima Cotton 134
D.W. Raines, R. Travis and M. Aslam, University of California, Davis
Comparative Uptake and Assimilation of Nitrate in Intact Seedlings of C_3 (barley) and C_4 (corn) Plants Effect of Light and Exogenously Supplied Sucrose 134
S.S. Goyal and H.L. Sehtiya, University of California, Davis
The Contribution of Low Molecular Weight Organic Acids from Decomposing Rye to Reductions in Root-Knot Nematode Populations 135
R.G. McBride, R.L. Mikkelsen, and K.R. Barker, North Carolina State University
Effect of 15 Years of Biosolids Application on Crops and Soil Phosphorus 135
A.E. Peterson, R.P. Wolkowski, P.E. Speth, T.H. Wright, and P.L. Schlecht, University of Wisconsin-Madison and Milwaukee Metropolitan Sewerage District
Nonpoint Source Risk Assessment Using BASINS; Case study of Yolo County, CA 135
R. Favreau, M. Zhang, and S. Geng, University of California, Davis
Genetic Analysis of Root Architecture in Lettuce 136
L.E. Jackson, D.A. St. Clair, R.W. Michelmore, L.J. Wyland, and O. Ochoa, University of California, Davis
Morphology and Pedologic Processes in Weathered Granitic Bedrock, Southern California 136
C.S. Frazier and R.C. Graham, University of California, Riverside
Assessing the Fertility Status of Long-Term No-Tillage Cotton Soils; In-Row versus Between-Row Sampling 137
D.D. Howard, M.E. Essington, and D.D. Tayler, University of Tennessee

Page

Effect of Seeding Date on Male Sterility and Agronomic Traits of Rice Mutants 137
X. Lei and D.J. Mackill, University of California, Davis and USDA-ARS
Environmentally-Influenced Male Sterility in Rice 137
S. Han and D.J. Mackill, University of California, Davis and USDA-ARS
Seed Yield of Easy Tripping Alfalfa Under Honey Bee Pollination 138
K.L. Taggard, E.E. Knapp, L.K. Gibbs, S.C. Mueller, and L.R. Teuber, University of California, Davis and University of California Cooperative Extension, Fresno County
Allocation of Test Locations and Years for Alfalfa Seed Yield Trials 138
L.R. Teuber, K.L. Taggard, L.K. Gibbs, and S.C. Mueller, University of California, Davis and University of California Cooperative Extension, Fresno County
Screening Eucalyptus Clones for Salt Tolerance 138
C.M. Grieve, M.C. Shannon, and J.A. Poss, USDA-ARS, U.S. Salinity Laboratory, Riverside, CA
Can Lengthening the Harvest Interval Improve Alfalfa Hay Quality During the Summer? 139
R.L. Kallenbach and D.W. Cudney, University of California
Fatty Acid Analysis of Soil Microbial Communities - A Comparison of Two Methods 139
K.J. Graham and K.M. Scow, University of California, Davis
Modeling of Water Flow and Fertilizer Movement through the Root Zone to Minimize Leaching 140
F. Somma and J.W. Hopmans, University of California, Davis
Differences in Microbial Communities Due to Soil Depth and C Inputs in California Agricultural Soils 140
E.J. Lundquist, S. Uesugi, K.J. Graham, L.E. Jackson, and K.M. Scow, University of California, Davis
GIS-Based Analyses of Soil Quality Parameters From A Wetland/Cropland Rotation System 140
F. Costa, University of California, Santa Cruz; C. Bode, University of California, Berkeley; W. Jarrell, Oregon Graduate Institute; and C. Shennan, University of California, Santa Cruz

LAND USE POLICIES AND URBAN GROWTH: CAN AGRICULTURE SURVIVE?

Mary E. Handel
Land Use Consultant
7 Valley West Circle
Napa, California 94558
Phone (707) 253-2125

INTRODUCTION

Population growth and current land use patterns affect agriculture. If population growth occurs according to predictions and urban development patterns continue status quo, we can expect tremendous changes in our state's agriculture.

THE CHALLENGE FOR AGRICULTURE

Competition for resources and the conflict that arises from competing land uses are key issues These are closely related but need to be discussed separately in order to address potential solutions to diminish the competition and the conflict.

COMPETITION FOR RESOURCES

Basic agricultural needs include clean air, an affordable and adequate water supply, and land. Land use policies and patterns of urban growth affect all three basic needs. This presentation will focus on the competition for land, rather than air or water.

HOT SPOTS FOR URBAN DEVELOPMENT

Three kinds of development affect the competition for agricultural land:

(1) City Expansion

Many cities were founded as service centers for agriculture and they are located on or next to good soil where people could farm. The land characteristics that make agriculture successful also make urban development desirable--good soil drainage, good weather and climate conditions, and moderate topography. Cities have their reasons for wanting to expand and various policies affect how often, what kind of development will be allowed and the direction they will grow. Firm urban growth boundaries are rare.

(2) Unincorporated Community Expansion

This kind of expansion involves similar issues as city expansion, even though it is under the jurisdiction of the county, which usually does not have as stringent development standards. Septic systems and wells serve the parcels rather than a sewer or sanitation district and municipal water supply. Often residential development involves larger lot sizes, 1- to 2-acre parcels as opposed to more traditional city densities of 4 units/acre. Because growth and development tends to be less compact than that of the cities, land use is less efficient.

(3) Allowed Uses on Agricultural Land

In a 1994 study of the general plans of 16 counties in California, some of the allowed uses on agricultural land included golf courses, recreation facilities, bed and breakfast inns, churches, and day care centers. These uses required use permits so they aren't automatically granted, but the fact that they could be permitted uses shows that they are viewed as uses that could be conditioned and ultimately compatible with agricultural operations. Agricultural commissioners and farmers often argue they are not compatible, and many of these uses could be growth inducing.

Houses are allowed on agricultural parcels. Consequently, land divided into smaller parcels has the potential for more houses. Smaller agricultural parcels also attract non farm residents who want an estate in the country.

School districts, which don't have to conform to local planning and zoning laws, are notorious for locating schools in agricultural areas where the cost of land is less. They like agricultural land where the value of the land is in dollars per acre rather than dollars per square foot, which is the case inside city limits.

Because fewer people live in agricultural areas compared to cities, agricultural land becomes an acceptable dumping ground for uses that are offensive or inconvenient to accommodate in the city. Land fills are a good example.

PRESSURES TO CONVERT FARMLAND

Changes in the fiscal policies and conditions of state and local government can influence farmland conversion. How land use decisions are made, the lack of accountability, and the lack of a regional approach can result in the conversion of farmland to urban uses.

POLICIES AND TOOLS TO PROTECT FARMLAND

While written policies in general plans and zoning ordinances that support farmland preservation are important, implementation of the policies is equally important. Other tools besides general plans and zoning ordinances can be used to provide a variety of options for local government, landowners, and even developers.

THE URBAN/AGRICULTURAL CONFLICT

Because of the nature of California agriculture and the kind of urbanization occurring in agricultural areas many issues of conflict arise. The kind of crop, the rate of population growth, and the kind of urban development adjacent to agricultural operations influence the conflict. Each kind of growth hot spot brings a set of circumstances that also affects the conflicts. Every time a city expands, for example, a new set of farmers and urban folks are in conflict. Various viewpoints or perspectives on the purpose or value of farmland brings different expectations and different opinions on how to manage farmland and these often clash.

THE SIGNIFICANCE OF REDUCING THE CONFLICT
Potential solutions or ways to reduce the conflict must be explored and implemented if we are to break the cycle of farmland conversion. Buffers, larger parcel sizes in agricultural areas, the design of urban edges, and the use of conservation easements and firm urban growth boundaries are examples of potential solutions.

FINDING SOLUTIONS
Clearly the problems and risks of continuing current land use patterns need to be recognized before we can begin to look for solutions. In short, how important is agriculture to California? Assuming we think it is very important, our next step is to look for acceptable solutions. The longer we wait to develop more workable land use patterns, the more drastic the measures may need to be in order to make a difference. In any case, increased political will and participation by agriculture are necessary. Even then, can such awareness and action be organized in time, before we lose too much agriculture?

Some people think so and several groups and efforts are underway now to address these concerns. Examples of such efforts include the Great Valley Center in Modesto, the Agricultural Task Force for Resource Conservation and Economic Growth in the Central Valley, and the California Futures Network.

Consumer Food Safety Priorities: Meeting the Challenge

Dr. Christine M. Bruhn
Director, Center for Consumer Research
University of California
Davis, California

Many of today's consumers are not in touch with the agricultural issues, including food production, food handling and food preparation. Many are not aware that food crops and agricultural animals are developed for select traits, contributing to concern about newer techniques of production which use biotechnology. People also do not recognize the ubiquitous nature of microorganisms and are intolerant of food that contains microorganisms that can cause illness. Consumers want healthful food, yet to many healthy means fresh, natural, and unprocessed. At the same time, changing life-styles and consumer demographics increase the potential for food borne illness. These conditions present challenges and opportunities for the agricultural and food industry.

THE CONSUMER

Changing demographics increases the number of persons at highest risk for food borne illness. The 265 million U.S. population consists of 29% younger than 20 years, and about an equal proportion in the 20-34, 35-49, and 50 and older age brackets. [12] By the year 2050, the population will increase by 129 million, a 49% increase over 54 years. About one-third of the population (36%) will be 50 years or older, compared to the current 26%. Twenty percent of the population will be 65 years or older with 18 million people over 85 years. Since older people are at increased risk for food borne illness, this suggests a need to address food safety issues.

Consumers want to enjoy favorite foods without placing excessive demand on their limited time. Increased participation of United States women in the paid work force (30% in 1950 compared to 59% in 1994) is a key factor in consumer demand for partially or fully prepared items from the supermarket. Consumers want perishable products with a long shelf life. About half, 53%, of shoppers who buy convenience items rate a product's long-time storability as the most desirable product attribute.[21,12]

People have increased the number of meals purchased from restaurants. In 1970 about 33% of the U.S. food dollar went for food away from home; by 1995 that proportion increased to 47%. [3] The entire food service industry has experienced growth, but the greatest growth is in the fast food segment. This industry experiences rapid employee turn-over, many of whom have minimum food handling experience.

"Natural," "unprocessed," and "no additives" are appealing attributes to many. Fresh is seen as healthier or higher quality than processed. Since processing and specific food additives can be protective against food borne pathogens, these marketing trends can increase consumer risks.

FOOD SAFETY

Concern about pesticide residue was highest in 1989 at the time of the controversy over use of the growth regulator, Alar, on apples. Since that time confidence in the safety of produce and belief in the health-enhancing value of produce has increased due to concerted educational efforts by the produce industry and health professionals.[1] Some supermarkets advertise a certification system to verify that produce meets legal pesticide residue minimums or contains no residues detectable by test sensitivity. Many supermarkets also offer organic produce.

Similarly, concern about pesticide residues is high in Europe, where pesticide residues were considered a serious hazard by 79% of consumers in 1995.[23] This area of concern was second only to bacterial contamination, classified as serious by 85% of consumers.

Interest in organic production has grown in recent years. Although those with higher income purchase organic produce, attitude studies indicate interest in organic production is highest among those with less formal education and lower income.[9,19] Organic produce is perceived by consumers as a pesticide-free production method. The United States Department of Agriculture National Organic Standards Board clearly indicates that organic is a method of production, not a pesticide free claim.[11] The greatest appeal for organic products is the perception that it is environmentally beneficial; the greatest detriments are limited availability, high cost, potential to increase microbiological risks, and consumer misconception that organic produce is grown without the use of pesticides.[20] Care must be taken to accurately position the organic products to avoid the appearance of deception.

Consumer food safety concerns now focus on microbiological safety. This has been the most frequently volunteered concern in the U.S. for the last several years and reached 69% in 1997.[2] When specific food safety areas are identified, microbiological safety is described as a serious hazard by 82% of people surveyed. Similarly, bacteria contamination is classified as serious by 85% of Europeans and the greatest public health risk by 73% of Australians surveyed. [6,23]

These relative concerns reflect the media coverage given food borne illness outbreaks. In the past, most people associated food borne outbreaks with foods of animal origin. Today, however, *E. coli* 0157:H7, *Cyclospora*, and other pathogens have been associated with produce. *E. coli* O157:H7 apparently from radish sprouts was responsible for widespread illness in Japan. Alfalfa sprouts were implicated in an outbreak in Virginia. *Salmonella* has been associated with pre-cut tomatoes, cantaloupe, and watermelons. *Cyclospora* has been traced to raspberries from Guatemala, and fresh basil in the U.S. Frozen strawberries was the source of an Hepatitis A outbreak in the US in 1997.

Outbreaks have ramifications for the manufacturer as well as others in the industry. As scientists are better able to trace the cause of food borne illness, consumers will become aware of the link between consuming certain foods and becoming ill. When the source of a food borne illness is identified, consumers respond by avoiding the product. Care must be taken in production and processing to avoid or destroy potential pathogens.

When a national sample of consumers were asked on whom they rely to ensure the products they buy are safe, the percentage responding "myself as an individual" decreased from 48% in 1989 to 25% in 1996. [1] As self reliance decreased, consumer reliance on food manufacturers and supermarkets increased. This may be a response to the message that if raw food contains microorganisms it is contaminated. It suggests some consumers are shifting the responsibility for safe food to producers, manufacturers and retailers.

Newer methods of controlling food borne pathogens and extending shelf life of lightly processed food are being explored. These include probiotic sprays and food irradiation

THE PROMISE OF NEW TECHNOLOGIES

FOOD IRRADIATION Food irradiation is an effective quarantine treatment for some insects; it prevents sprouting of tubers like potatoes and onions; it extends the shelf life of some produce; at the appropriate treatment, it can serve as a pasteurization treatment against many food-borne pathogens.[7] The food appearance, flavor, and nutrient value is essentially comparable to fresh. This process has been approved by the appropriate regulatory bodies in over 30 countries and is endorsed for safety by health authorities such as the World Health Organization and the American Medical Association.

The Food Marketing Institute annual survey found about 60% of consumers indicated they are very or somewhat likely to buy strawberries irradiated to keep them fresh longer and 70% would buy poultry irradiated to destroy bacteria. [1] Other surveys indicate, on average, 60% would purchase irradiated produce, with the percentage increasing to 80% or more after an educational program, and to 90% or more after sampling irradiated food. [5] Irradiated produce, tropical fruit, and chicken have been well received, although the supermarkets offering these products are few. [4,25]

BIOTECHNOLOGY. As populations increase, efforts to maintain land, water and air quality will increase. Divergent views on the efficacy and appropriateness of products modified by biotechnology have highlighted the clash between those striving to preserve the traditional approaches to health and farming and those seeking to use new tools of science and technology to realize improved environmental stewardship and healthier food products.

Biotechnology can be used to create new varieties with improved quality or reduced pesticide need. Nearly 8 out of 10 (79%) Americans were aware of biotechnology, with more than half (54%) saying biotechnology has already provided benefits to them; 78% predicted they will benefit from biotechnology in the next five years.[15] Nearly half of survey respondents realized foods produced through biotechnology were already in supermarkets. Almost two-thirds, 62% indicated they are very or somewhat likely to buy a product modified to taste better or fresher with 17% of these very likely.[1] Additionally 74% were very or somewhat likely to buy a product modified to resist insect damage and require fewer pesticide applications.

Among Canadian consumers, about two-thirds expect society will receive benefits from biotechnology, and the same proportion believe that society will also be at increased risk.[24] Most Australians believe genetic engineering is a "good idea" with as many as 90% supporting medical and environmental applications and about two thirds supporting food and nutritional applications.[16] Almost all, 93%, Japanese consumers interviewed believed biotechnology will provide benefits to them or their family in the next five years, with the greatest interest in environmental applications. [13]

Concern about personal or environmental safety has led to opposition among some consumer and activist groups. Never-the-less, marketing experience in the United States with labeled tomatoes was positive, although the product was not widely available. Squash from plants modified to be virus resistant, potato naturally resistant to the potato beetle and oil crops resistant to herbicides are in U.S. markets. Potatoes specially marketed as bioengineered sold at a premium in the supermarket. Farmers' demand for seed have exceeded supply.

In other areas of the world, response is varied. China has embraced biotechnology for years. When asked about the severity of potential food risks, 44% of Europeans considered genetic engineering a serious risk.[14] This is about in the middle of potential food risks, with bacterial contamination at the top with 85% of consumers and sugar at the bottom with 12%. With the exception of Austria and Germany, half or more European consumers indicate they will purchase a product modified by genetic engineering.

Labeling of biotechnologically modified products in the European market is controversial at this time. In July 1997, the European Union Standard Committee on food accepted a proposal which calls for mandatory labeling on products which may come from genetically modified (GMO) sources, whether or not they are intended for human consumption. [17] The label statement "may contain GMOs" will be required when material of GMO origin can not be excluded but there is not evidence of its presence. Manufacturers may voluntarily label certified genetic modified organism-free items with the statement, "contain no GMOs." In contrast, in the United States, labeling is not required because the FDA is aware of no significant difference between foods derived from biotechnology and those modified conventionally.

It is unclear if mandatory labeling in Europe will have a negative or positive impact on consumers, although it does present a significant tracking problem for manufacturers. If consumers perceive use of biotechnology as a safe technique which increases quality or improves the environment, identification on the label could be positive. If they see biotechnology as an unnatural innovation in which they are exposed to increased risks while others get benefits, labeled products will be avoided. Acceptance depends on providing information to the public and consumer philosophic orientation. Researchers have concluded that generally those concerned about other food safety areas, will be concerned about genetic engineering. [16]

SUMMARY

Concerns about food safety will remain high as long as the challenge of controlling food borne pathogens is great. Growers will develop plans to reduce opportunities for pathogen contamination. Although people will always have an individual approach to style of life, if the industry wishes to have available the full breadth of technologies to address consumer demand, it is important to invest in consumer education. Technological advances can help achieve increased trade and enhanced environmental quality and human health.

References

1 Abt Associates Inc., 1996, Trends in the United States, Consumer Attitudes and the Supermarket, Food Marketing Institute, 88 p.
2. Abt Associates Inc., 1997, Trends in the United States, Consumer Attitudes and the Supermarket, Food Marketing Institute, pp 88.
3. Anonymous, 1995, Changing patterns of food spending, Agricultural Outlook. October p. 21-22.
4. Anonymous., 1995. The irradiation option. Food Safety Consortium 5(3):1, 5.
5. Bruhn, C. M., 1995, Consumer attitude sand market response to irradiated food J Food Protection 58:175-181.
6. Colmar Bruton Research, 1996, Food Safety Findings from Presentation on Consumer Monitor IV. Australian Supermarket Institute, pp 17.
7. Diehl, J. F. 1990, Safety of Irradiated Foods, Marcel Dekker, Inc. New York, p 345.
8. Dumagan, J. C. and Hackett, J. W., 1995, Almost half of the food budget is spent eating out, Food Review, 18(1), 37.
9. Eom, Y.S. 1992, Consumer Respond To Information About Pesticide Residues. Food Review. 15(3):6-10.
10. Find/SVP and Thomas Food Industry Register, 1995, FoodTRENDS'95. New York.
11. Food Chemical News, 1996, Organic Standards Backgrounder. CRC Press. p21.
12. Food Institute, 1996, Population Trends 1996-2050, pp. 31. Fair Lawn, NJ.
13. Hoban, T. J., 1996, How Japanese consumers view biotechnology. Food Technology 50:85-88.
14. Hoban, T.J., 1997, Consumer acceptance of biotechnology: An international perspective. Nature Biotechnology 15:232-234.
15. International Food Information Council (IFIC)., 1997. News release on consumer survey conducted by the Wirthlin Group.
16. Kelley, J., 1995, Public Perceptions of Genetic Engineering: Australia, 1994. International Social Science Survey/Australia.
17. Lew, S. 1997, EU to require labeling of genetically modified soybeans and maize beginning Nov. 1., Food Chemical News. Aug. 11:5-7.
18. The Packer, 1990, Fresh Trends, A profile of fresh produce consumers, Illinois.
19. The Packer, 1992, Fresh Trends, A profile of fresh produce consumers, Illinois.
20. The Packer, 1995, Fresh Trends, A profile of fresh produce consumers, Illinois.
21. Sloan, E., 1996, The top 10 trends to watch and work on, Food Technology 50(7):55-71.
21. Sloan, E., 1997, The Big Chill, Food Technology 51(4):26.
23. Tordjman, A., 1995, Trends in Europe, Food Marketing Institute, pp. 96.
24. Walter, R., 1994, Baseline Study of Public Attitudes to Biotechnology. Canadian Institute of Biotechnology, Ottawa, Ontario, Canada.
25. Wong, L. 1996, 1997, Personal communications. Dr. Wong is Plant Industry Administrator, Department of Agriculture, State of Hawaii, Honolulu, Hawaii.

CALIFORNIA BIOSOLIDS MINERALIZATION RESEARCH

DAVID M. CROHN
Department of Soil and Environmental Sciences
University of California, Riverside

INTRODUCTION

The Clean Water Act charges the United States Environmental Protection Agency (USEPA) with regulating the disposal of sewage sludges generated during wastewater processing. These sludges are formed by concentrating the inert and organic solids that are either collected with the wastewater or generated during treatment. To help communities dispose of them, the USEPA actively promotes land application of sludges as an economical alternative to landfilling or incineration. Because sludges contain large amounts of the nitrogen, phosphorus, and trace elements needed by growing plants, they are promoted as fertilizers. They also can improve soils as organic amendments in the same way as animal manures ("Standards" 1993). To encourage public acceptance of land application, the USEPA and the wastewater treatment industry often refer to sewage sludges as *biosolids* ("Biosolids" 1994, "Plain" 1994, Sorber 1994).

Due to their origin in wastewater, biosolids contain a number of pollutants that require special attention. Biosolids contain pathogens, heavy metals, and toxic organic chemicals, along with nutrients that, if over-applied, can harm both people and the environment ("Standards" 1993, "Process" 1995, Committee 1996, Crohn 1996, Harrison *et al.* 1997). In general, the relative presence of pathogens, metals, and toxic organics will determine if a product may be put to a particular use, such as forage fertilization or backyard gardening, while the quantity actually applied in a given year or growing season is constrained by the nutrient content, or fertilizer value, of the biosolids.

Because California depends heavily on groundwater, nitrogen limits most land application rates. Over-fertilization with nitrogen often pollutes groundwater with nitrate (Patrick *et al.* 1987, Follett *et al.* 1991). Biosolids contain one to ten percent nitrogen on (a dry weight basis) the majority of which is in organic form ("Process" 1995). The balance consists of inorganic nitrogen is in the form of ammonium (NH_4^+), much of which can volatilize to the atmosphere during the application process, or nitrate (NO_3^-), which leaches readily and can also be lost to the atmosphere through denitrification ("Process" 1995, Crohn 1996). Only inorganic forms are immediately plant-available, but some of the organic nitrogen is converted each year to ammonium in a process called *mineralization*. Designers add the expected mineralized nitrogen to the inorganic nitrogen contained in the incorporated biosolids to determine application rates appropriate for specific crops. Little information is available about the rate at which biosolids organic nitrogen is mineralized in California soils, however. To reliably meet the "agronomic rate" requirement of 40 CFR Part 503, more research will be needed.

MINERALIZATION AND RELATED PROCESSES

The organic fraction of biosolids nitrogen refers to that portion that is bound up with carbon compounds. Because plants cannot take it up, organic nitrogen is often referred to as *immobilized* nitrogen. To be used by plants, organic must be converted, or *mineralized*, to ammonium ions (NH_4^+) by soil microbes. Under aerobic, or oxygen rich, conditions, other bacteria may convert the ammonium to nitrate (NO_3^-), a process referred to as *nitrification*. Both nitrate and ammonium are plant available.

During mineralization, biosolids are used as food by bacteria and other microorganisms. Soil microbes use biosolids carbon as an energy source while biosolids nitrogen serves primarily as a nutrient for building proteins in new and growing cells. As carbon is used for energy, it is converted to CO_2 and released from the soil as a gas. This steadily depletes carbon from the soil. As carbon decomposes, any associated organic nitrogen is mineralized to ammonium. Different forms of carbon are metabolized at different rates, however. Carbohydrates and proteins are decomposed readily while more recalcitrant forms, such as lignin and cellulose, break down more slowly (Terry *et al.* 1979, Boyle 1990, Lerch *et al.* 1992).

Environmental conditions also affect mineralization rates which can vary considerably. The most important factors are biosolids type (Epstein *et al.* 1978, Parker and Sommers 1983, Garau *et al.* 1986, "Process" 1995), soil temperature (Terry *et al.* 1981), soil type (Tester *et al.* 1977, Magdoff and Amadon 1980, Garau *et al.* 1986, Dendooven *et al.* 1995), and moisture (Stanford and Epstein 1974). Other factors, such as application rate and soil pH are generally less important (Tester *et al.* 1977). Warm well-drained soils promote rapid mineralization rates. Such soils are common in California.

The USEPA has published a table of typical mineralization rates for biosolids (Table 1). Values found in Table 1 were loosely developed from a series of sixteen week laboratory incubations (Sommers *et al.* 1981), rather than from field studies. Although Sommers *et al.* (1981) maintained conditions they considered optimal for mineralization, conditions favoring mineralization can persist well beyond sixteen weeks in many parts of California. Sommers *et al.* (1981) recommended annual mineralization rates of 40% for aerobically digested biosolids, 15% for anaerobically digested biosolids, and 8% for composts. They did not specifically develop second year recommendations. The USEPA reduces mineralization rates by half for each additional year after application (Table 1). No justification is given for this approach, although a precedent similar to this began in California.

Table 1. USEPA Example Mineralization Rates ("Process" 1995)

Time	Biosolids type		
Years after application	Aerobically digested	Anaerobically digested	Composted
0-1	0.30	0.20	0.10
1-2	0.15	0.10	0.05
2-3	0.08	0.05	-
3-4	0.04	-	-

Pratt *et al.* (1973) invented the idea of the *decay series* to describe the decomposition of biosolids and manure in California soils. They predicted that biosolids from a source they were familiar with would release 35% of its organic nitrogen during the first year after application, 10% of the remaining organic nitrogen during the next year and 5% over the third. An application containing 1000 kg organic nitrogen would therefore mineralize 350 kg, 65 kg, and 29 kg during the first, second, and third years after application. The USEPA included this fundamental approach, which is simple, reasonable, and intuitive, in Table 1. Note that the biosolids product considered by Pratt *et al.* (1973) was anaerobically digested and that their California decay series is therefore significantly higher than the USEPA's ("Process" 1995). The particular values that make up the decay series are in doubt, however. Pratt *et al.* (1973) warn that their decay series "should not be considered appropriate for all municipal sludges." They admit freely that their values were never tested in the field and recommended long-term trials to validate them. Although the USEPA has not subjected the decay series described in Table 1 to rigorous field testing either, these values for the basis for many, and probably most, current designs.

Mathematical modeling presents a more conceptually coherent alternative to the decay series approach. Mathematical models attempt to summarize the many complex processes we call decay using tractable and measurable parameters. First-order models are most often used to predict decay. The simplest form of first order model lumps all organic nitrogen into a single compartment (Stanford and Smith 1972, Parker and Sommers 1983, Garau *et al.* 1986, Boyle and Paul, 1989, Federle *et al.* 1997),

$$N_m = N_o\left(1 - e^{-kt}\right), \quad (1)$$

where N_m is the nitrogen mineralized during year t (kg/ha/yr), N_o is the initial organic nitrogen mass (kg/ha), and k is the annual mineralization rate (yr^{-1}), a constant. Other investigators represent two compartments (Molina *et al.* 1980, Lindeman and Cardenas 1984, Lerch *et al.* 1992, Gilmour *et al.* 1996), one for a rapidly metabolized, or *labile*, fraction, and the other for more *recalcitrant* materials. Both compartments decompose as first order processes,

$$N_m = N_o S\left(1 - e^{-k_l t}\right) + N_o\left(1 - S\right)\left(1 - e^{-k_r t}\right), \quad (2)$$

where S is the biosolids labile fraction, and k_l and k_r are annual mineralization rates for the labile and recalcitrant fractions (yr^{-1}), respectively. Gilmour *et al.* (1996) favor a variation on (2) based on sequential, rather than simultaneous, decomposition of the labile and recalcitrant compartments, an approach similar to Crohn (1996).

FIELD STUDIES

Data from field studies are needed to develop parameter values suitable for California if (1), (2), or similar models are to be used to design application rates. Few such studies have appeared in the literature, however. Artiola and Pepper (1992) conducted a five-year study of land application to a sandy irrigated soil in Arizona. Laboratory tests suggested annual mineralization rates of 65% or greater. Accelerated mineralization was confirmed in the field where it was observed that applications failed to significantly increase the soil total nitrogen pool. Nitrate levels increased substantially, however, confirming that almost all of the applied biosolids had mineralized.

Barbarick *et al.* (1996) published a study of mineralization rates from biosolids applied to dryland wheat in Colorado. They applied 5 to 6 application during the 11 year study which was hampered since no record was made of the nitrogen present in the experimental plots before applications began. Mineralization rates varied greatly according to application rates and ranged from 13 to 67% during the first year. Experimental error and environmental variability account for much of the observed variability.

Chang *et al.* (1988) incorporated a biosolids compost and two anaerobically digested biosolids products into a sandy loam soil plots as well as a loam soil plots located at the University of California field station in Moreno Valley, California. Between 1975 and 1983, the investigators harvested three sorghum and eight barley crops. The study included control plots as well as the biosolids-amended plots. The uncomposted biosolids decomposed very rapidly (Decay series: 0.89, 0.30, 0.10, 0.05) while the compost mineralized more slowly (Decay series: 0.47, 0.20, 0.10, 0.05). The authors did not model decomposition as a first-order process.

DISCUSSION

Chang *et al.* (1988) developed the only scientifically rigorous mineralization values available for designing land application rates field tested in California. The hot irrigated desert climate of Moreno Valley strongly favors mineralization. The decay series reported by Chang *et al.* (1988) probably overestimates decay in dryland or cooler climates. Additional studies would help to validate or refute the Moreno Valley numbers.

REFERENCES

Artiola J. F., and Pepper I. L. (1992). "Longterm influence of liquid sewage sludge on the organic carbon and nitrogen content of a furrow-irrigated desert soil." *Biology and Fertility of Soils*, 14(1), 30-36.

Barbarick, K. A., Ippolito, J. A., and Westfall, D. G. (1996). "Distribution and mineralization of biosolids nitrogen applied to dryland wheat." *J. Environ. Qual.,* 25(4), 796-801.

"Biosolids recycling: beneficial technology for a better environment." (1994). EPA *832/R-94/009,* U.S. Envir. Protection Agency, Ofc. of Water, Washington, D.C.

Boyle, M. (1990). "Biodegradation of land-applied sludge." *J. Environ. Qual.* 19, 640-644.

Boyle, M. and Paul, E. A. (1989). "Nitrogen transformations in soils previously amended with sewage sludge." *Soil Sci. Soc. Am. J.,* 53(3), 740-744.

Chang, A. C., Page, A. L, Lund, L. J., Pratt, P. F. and Warneke, J. E. (1988). "Leaching of nitrate from freely drained-irrigated fields treated with municipal sludges." *Planning now for irrigation and drainage in the 21st century,* D. R. Hay, ed., American Society of Civil Engineers, New York, 455-467.

Committee on the Use of Treated Municipal Wastewater Effluents and Sludge in the Production of Crops for Human Consumption, Water Science and Technology Board, Commission on Geosciences, Environment, and Resources, National Research Council. (1996). "Use of reclaimed water and sludge in food crop production." National Academy Press, Washington, D.C. *http://www.epa.gov/owmitnet/pipes/sludmis.htm*

Crohn, D. M. (1996). "Planning land application rates for agricultural systems." *J. Envir. Engrg.,* 122(12), 1058-1066.

Dendooven, L. Merckx, R., and Vlasak, K. (1995). "Limitations of a calculated N mineralization potential in studies of the N mineralization process." *Plant and Soil,* 177, 175-181.

Epstein, E., Keane, D. B., Meisinger, J. J., and Legg, J. O. (1978). "Mineralization of nitrogen from sewage sludge and sludge compost." ." *J. Environ. Qual.,* 7(2), 217-221.

Federle, T. W., Gasior, S. D., Nuck, B. A. (1997). "Extrapolating mineralization rates from the Ready CO_2 screening test to activated sludge, river water, and soil." *Environmental Toxicology and Chemistry,* 16(2), 127-134.

Follett, R. F., Keeney, D. R., and Cruse, R. M. eds. (1991). *Managing nitrogen for groundwater quality and farm profitability,* Soil Sci. Soc. Am., Madison, Wisc.

Garau, M. A., Felipó, M. T., and Ruiz de Villa, M. C. (1986). "Nitrogen mineralization of sewage sludges in soils." *J. Environ. Qual.,* 15(3), 225-228.

Gilmour, J. T., Clark, M. D., and Daniel, S. M. (1996). "Predicting long-term decomposition of biosolids with a seven-day test." *J. Environ. Qual.,* 25(4), 766-770.

Harrison, E. Z., McBride, M. B., and Bouldin, D. R. (1997). "Case for caution: recommendations for land application of sewage sludges and an appraisal of the US EPA's Part 503 sludge rules." CWMI, Center for the Environment, Cornell University, Ithaca, NY. *http://www.cfe.cornell.edu/wmi/PDFS/PDFS.html*

Lerch, R. N., Barbarick, K. A., Sommers, L. E., Westfall, D. G. (1992). "Sewage sludge proteins as labile carbon and nitrogen sources." *Soil Sci. Soc. Am. J.,* 56, 1470-1476.

Lindeman, W. C. and Cardenas, M. "Nitrogen mineralization potential and nitrogen transformations of sludge-amended soil." *Soil Sci. Soc. Am. J.,* 48, 1072-1077.

Magdoff, F. R. and Amadon, J. F. (1980). "Nitrogen availability from sewage sludge." *J. Environ. Qual.,* 9(3), 451-455.

Molina, J. A. E., Clapp, C. E., and Larson, W. E. (1980). "Potentially mineralizable nitrogen in soil: the simple exponential model does not apply for the first 12 weeks of incubation." *Soil Sci. Soc. Am. J.,* 44, 442-443.

Parker, C. F. and Sommers, L. E. (1983). "Mineralization of nitrogen in sewage sludges." *J. Environ. Qual.*, 12, 150-156.

Patrick, R., Ford, E. and Quarles, J. (1987). *Groundwater contamination in the United States.* University of Pennsylvania Press, Philadelphia.

"Plain English guide to the EPA Part 503 Biosolids Rule" (1994). *EPA/832/R-93-003,* U.S. Envir. Protection Agency, Ofc. of Wastewater management, Washington D.C.

Pratt, P. F., Broadbent, F. E., and Martin, J. P. (1973). "Using organic wastes as nitrogen fertilizers." *California Agriculture,* 27(6), 10-13.

"Process design manual: surface disposal of sewage sludge and domestic septage" (1995). *EPA/625/R-95/001,* U.S. Envir. Protection Agency, Ofc. of Research and Development, Washington D.C.

Sommers, L. E., Parker, C. F., and Meyers, G. J. (1981). *Volatilization, plant uptake and mineralization of nitrogen in soils treated with sewage sludge.* Purdue University Water Resources Center, West Lafayette, Indiana.

Sorber, C. A. (1994). "Biosolids: a blueprint for public acceptance." *Water Environ. Technol.,* 6(5), 61-63.

"Standards for the use or disposal of sewage sludge: final rules." (1993). *Federal Register,* 58(32), 9248-9415.

Stanford, G. and Epstein, E. (1974). "Nitrogen mineralization-water relations in soils." *Soil Sci. Soc. Am. J.,* 38, 103-106.

Stanford, G. and Smith, G. (1972). "Nitrogen mineralization potentials of soils." *Soil Sci. Soc. Am. Proc.,* 36, 465-472.

Terry, R. E., Nelson, D. W., Sommers, L. E. (1979). "Carbon cycling during sewage sludge decomposition in soils." *Soil Sci. Soc. Am. J.,* 43, 494-499.

Terry, R. E., Nelson, D. W., Sommers, L. E. (1981). "Nitrogen transformations in sewage sludge-amended soils as affected by environmental factors." *Soil Sci. Soc. Am. J.,* 45, 506-513.

Tester, C. F., Sikora, L. J., Taylor, J. M., and Parr, J. F. (1977). "Decomposition of sewage sludge compost in soil: I. carbon and nitrogen transformation." *J. Environ. Qual.,* 6(4), 459-463.

FATE OF PATHOGENS DURING THE SEWAGE SLUDGE TREATMENT PROCESS AND AFTER LAND APPLICATION

James E. Smith, Jr., Senior Environmental Engineer
USEPA, Center for Environmental Research Information
Cincinnati, Ohio 45268
Phone (513) 569-7355; E-mail smith.james@epamail.epa.gov

Joseph B. Farrell, Consultant
1117 Stormy Way (Anderson Township)
Cincinnati, Ohio 45230
Phone (513) 231-0669; E-mail JBF44UND@TSO.CIN.IX.NET

Obligation

Federal, state, and local regulatory authorities are entrusted with a mandate to protect the public health and the environment. Wastewater contains the feces and urine from both humans and animals that carries many disease-causing organisms. Disease causing organisms or pathogens from humans can enter a community's wastewater from patients at hospitals, or from any sick person or individual carrying the organisms. Carriers may not have the symptoms or even know they have a disease. Animal wastes can enter the wastewater from farms, meat packing and processing facilities and from rats and other animals and/or vectors found in or around sewage or sewers. Humans come in contact with the pathogens and thus potentially disease by direct contact with sewage, by eating food or drinking water contaminated with sewage, or through contact with human, animal, or insect carriers. During the course of typical wastewater treatment, the microorganisms in sewage are reduced in number, becoming concentrated in the sewage sludge. Table 1 shows the principal pathogens of concern in municipal wastewater and sewage sludge and associated disease/symptoms (EPA 1985, 1989). You will note there the causes of typhoid, gastroenteritis, cholera, hepatitis A, polio, giardiasis, hook worms, cryptosporidiosis, and amebiasis. Table 2 gives typical pathogen levels in unstabilized/digested sludges (EPA 1979).

So there can be no doubt that pathogenic organisms are present in sewage/wastewater and that these organisms are accumulated or concentrated in the sewage sludge. A key question to answer, however, is what constitutes an infectious dose of a pathogenic organism? Unfortunately, the infectious dose varies with the organism and, particularly for bacteria and viruses, can vary widely. Table 3 gives some reported infective dose data, showing values as low as 100 for *Salmonella* (various species), < 1 PFU for Poliovirus, and 1 egg for helminths. This information coupled with what we know about the survival times of pathogens on soil and plants (see Table 4, after Kowal 1985) provide a framework or setting for 40 CFR 503, *Standards for the Use or Disposal of Sewage Sludge*. It shows that sludge, before it is applied to land, must have its vector attraction reduced and must be either disinfected before it is applied or is applied under restrictions that prevent it from being a risk to public health and the environment.

Table 1. Principal Pathogens of Concern in Municipal Wastewater and Sewage Sludge

Bacteria	Disease/Symptoms for Organism
Salmonella spp.	Salmonellosis (food poisoning), typhoid
Shigella spp.	Bacillary dysentery
Versinia spp.	Acute gastroenteritis (diarrhea, abdom. pain)
Vibrio cholerae	Cholera
Campylobacter jejuni	Gastroenteritis
Escherichia coli (pathogenic strains)	Gastroenteritis
Viruses	
Poliovirus	Poliomyelitis
Coxsackievirus	Meningitis, pneumonia, hepatitis, fever, etc.
Echovirus	Meningitis, paralysis, encephalitis, fever, etc.
Hepatitis A virus	infectious hepatitis
Rotavirus	Acute gastroenteritis with severe diarrhea
Norwalk Agents	Epidemic gastroenteritis with severe diarrhea
Reovirus	Respiratory infections, gastroenteritis
Protozoa	
Cryptosporidium	Gastroenteritis
Entamoeba histolytica	Acute enteritis
Giardia lamblia	Giardiasis (diarrhea & abdominal cramps)
Balantidium coli	Diarrhea and dysentery
Toxoplasma gondii	Toxoplasmosis
Helminth Worms	
Ascaris lumbricoides	Digestive disturbances, abdominal pain.
Ascaris suum	Can have symptoms: coughing, chest pain.
Trichuris trichiura	Abdom. pain, diarrhea, anemia, weight loss
Toxocara canis	Fever, abdominal discomfort & muscle aches
Taenia sasginata	Nervousness, insomnia, anorexia.
Taenia solium	Nervousness, insomnia, anorexia.
Necator americanus	Hookworm disease
Hymenolepis nana	Taeniasis

Table 2. Typical Pathogen Levels in Unstabilized/Digested Sewage Sludges

Pathogen	No./100 milliliters
Virus	2,500 - 70,000
Fecal Coliform Bacteria	1,000,000,000
Salmonella	8,000
Ascaris lumbricoides	200 - 1,000

The regulatory approach chosen by EPA was to require communities intending to use sewage sludge in agriculture to meet certain sewage sludge disinfection and vector attraction reduction conditions. Depending on the intended use of the sludge pathogen requirements can be met and one of ten vector attraction reduction options an be met. The intent of a Class A pathogen requirements is to reduce the level of pathogenic organisms in the sludge to *below detectable levels.* When the Class B requirements are met, it is recognized that the level of pathogenic organisms has *only* been *significantly* reduced. Pathogens are still present. As such, other precautionary measures must be exercised to insure that the risk to public health is no greater than it is with a Class A sludge. These measures restrict the public's access to the land application site, control animal grazing, and prevent crop harvesting for a period of time.

Table 3. Reported Infective Dose Data

Organism	Infective Dose	Range	Reference
Bacteria			
Clostridium perfringens	10^6	10^6 to 10^{10}	Kowal, 1985
Escherichia coli	10^4	10^4 to 10^{10}	Kowal, 1985; Keswick, 1984
Salmonella (various species)	10^2	10^2 to 10^{10}	Kowal, 1985; Metro, 1983
Shigella dysenteriae	10 to 10^2	10 to 10^9	Kowal, 1985; Keswick, 1984; Levine, 1973
Shigella flexneri	10^2	10^2 to 10^9	Kowal, 1985
Streptococcus faecalis	10^9	10^9 to 10^{10}	Kowal, 1985
Vibrio cholerae	10^3	10^3 to 10^{11}	Kowal, 1985; Keswick, 1984
Viruses			
Echovirus 12	HID50 919 PFU HID1 17 PFU est'd	17-919 PFU	Kowal, 1985
Poliovirus	1 TCID50, <1 PFU	4 x 10^7 TCID50 for infants 0.2 to 5.5 x 10^6 PFU for infants	Kowal, 1985
Rotavirus	HID50 10 ffu HID25 1 ffu est'd	0.9 to 9 x 10^4 ffu	Ward et al., 1986
Parasites			
Entamoeba coli	1-10 cysts	1-10 cysts	Kowal, 1985
Cryptosporidium	10 cysts	10-100 cysts	Casemore, 1991
Giardia lamblia	1 cyst estimated	NR	Kowal, 1985
Helminths	1 egg	NR	Kowal, 1985

Where: HID = human infective dose TCID50 = tissue culture infectious dose for 50 % response
PFU = plaque forming units ffu = focus forming units NR = not reported

Table 4. Survival Times of Pathogens on Soil and Plants

	Soil		Plants	
Pathogen	**Absolute Maximum**	**Common Maximum**	**Absolute Maximum**	**Common Maximum**
Bacteria	1 year	2 months	6 months	1 month
Viruses	6 months	3 months	2 months	1 month
Protozoa	10 days	2 days	5 days	2 days
Helminths	7 years	2 years	5 months	1 month

Present Methods for Meeting 40 CFR 503 Pathogen Requirements

CLASS A

Broadly speaking goals of these processes are to achieve the following pathogenic microorganism densities:

- *SALMONELLA* < 3 MPN / 4 g TS or fecal coliform < 1000 MPN/g
- ENTERIC VIRUSES < 1 PFU / 4 g TS
- VIABLE HELMINTH OVA < 1 / 4 g TS

Six alternatives exist for sewage sludge to be Class A with respect to pathogens:

1. **Time (D-days) temperature (t-°C)** related by : $D = \frac{131{,}700{,}000}{10^{0.14t}}$ or $\frac{50{,}070{,}000}{10^{0.14t}}$ The first equation applies when the total solids are ≥ 7%; t ≥ 50°C and time is ≥ 20 minutes. If the sludge particles are small and are heated by warmed gases or an immiscible liquid, the minimum time is 15 seconds. This equation also applies when the solids <7%, t >50°C and time is ≥ 15 sec to <30 min. The second equation applies for total solids < 7 %; t ≥ 50°C and D ≥ 30 minutes. *Salmonella* or fecal coliform density must be measured at the time of use or disposal to see if it is in conformance with criteria.
2. **Alkaline Treatment** - pH is raised to >12; pH is kept >12 for 72 hours, 12 of which the temperature is > 52°C; air dry sewage sludge to 50 % total solids concentration. *Salmonella* or fecal coliform levels indicated above must be met.
3. **Prior Testing for Enteric Virus & Viable Helminth Ova** - Check raw sewage sludge concentrations of enteric viruses and viable helminth ova. If in greater concentrations than set forth above, then analyze sewage sludge after treatment. If viruses and helminth ova are less than set forth above in either raw or treated sludges, then sludge is Class A. (Potential exists here for PFRP demonstration) Fecal coliform or *Salmonella* densities indicated above must be met in the processed sludges.
4. **Routine monitoring of each batch of treated sewage sludge.**
5. Use one of the **Processes to Further Reduce Pathogens (PFRP)**;
6. Use **PFRP Equivalent Process**.

PFRP processes include composting, heat drying, heat treatment, thermophilic aerobic digestion, beta ray irradiation, gamma ray irradiation, and pasteurization and are described in detail in the literature (EPA 1992).

CLASS B

Requirements for sewage sludge to be classified Class B with respect to pathogens can be satisfied by: 1) periodically monitoring the processed sludge for fecal coliform density - collect seven samples of treated sewage sludge at the time of use or disposal and show that the geometric mean fecal coliform density of these samples is < 2,000,000 MPN per gram of TS or CFU per gram of total solids; 2) using a Process to Significantly Reduce Pathogens (PSRP), or 3) using a PSRP Equivalent Process. PSRP processes include aerobic digestion, anaerobic digestion, composting, air drying, and lime stabilization. They are described in detail in the literature (EPA 1979).

VECTOR ATTRACTION REDUCTION (VAR)

Options prescribed for VAR are shown in Table 5. The descriptions of the VAR methods presented in the regulation are "bare-bones" descriptions. EPA has published guidance (1992) which expanded on these procedures. A recent paper (Farrell et. al. 1996) describes the development of EPA's new methods for quantifying vector attraction reduction (VAR) that are included in the Part 503 regulation. This paper explains why alternative methods were needed, describes the experimental methods and the limitations of the methods, and compares the various methods. The methods are not in total agreement. The SOUR (specific oxygen uptake rate) method and the % VSR (volatile solids reduction) method agree at 20°C, but the SOUR method is more conservative above 20°C and less conservative below 20°C. The AVSR (additional volatile solids reduction) method is more conservative than the other two methods. The authors prefer to use the SOUR and AVSR methods over the % VSR methods since they more directly measure residual biological activity.

Another recent paper (Smith et.al. 1994) discussed VAR methods or tests for measuring 38 % volatile solids' destruction, additional anaerobic digestion, SOUR, and additional aerobic digestion and raising the pH to 12. Some direction was also provided for determining sampling locations, timing, and numbers of samples to take.

Table 5. Summary of Requirements for Vector Attraction Reduction Options Under Part 503

Requirement	What is Required?
Option 1 503.33(b)(1)	At least 38% reduction in volatile solids during sewage sludge treatment
Option 2 503.33(b)(2)	Less than 17% additional volatile solids loss during bench-scale anaerobic batch digestion of the sewage sludge for 40 additional days at 30°C to 37°C (86°F to 99°F)
Option 3 503.33(b)(3)	Less than 15% additional volatile solids reduction during bench-scale aerobic batch digestion for 30 additional days at 20°C (68°F)
Option 4 503.33(b)(4)	SOUR at 20°C (68°F) is ≤1.5 mg oxygen/hr/g total sewage sludge solids
Option 5 503.33(b)(5)	Aerobic treatment of the sewage sludge for at least 14 days at over 40°C (104°F) with an average temperature of over 45°C (113°F)
Option 6 503.33(b)(6)	Addition of sufficient alkali to raise the pH to at least 12 at 25°C (77°F) and maintain a pH ≥ 12 for 2 hours and a pH >11.5 for 22 more hours
Option 7 503.33(b)(7)	Percent solids ≥ 75% prior to mixing with other materials
Option 8 503.33(b)(8)	Percent solids ≥ 90% prior to mixing with other materials
Option 9 503.33(b)(9)	Sewage sludge is injected into soil so that no significant amount of sewage sludge is present on the land surface 1 hour after injection, except Class A sewage sludge must be injected within 8 hours after the pathogen reduction process.
Option 10 503.33(b)(10)	Sewage sludge is incorporated into the soil within 6 hours after application to land or placement on a surface disposal site. If sewage sludge is Class A, it must be applied to or placed on the land surface within 8 hours after the pathogen reduction process.
Option 11 503.33(b)(11)	Sewage sludge placed on a surface disposal site must be covered with soil or other material at the end of each operating day.
Option 12 503.33(b)(12)	pH of domestic septage must be raised to ≥ 12 at 25°C (77°F) by alkali addition and maintained at ≥ 12 for 30 minutes without adding more alkali.

References

Casemore, D.P. 1991. The epidemiology of human cryptosporidiosis and the water route of infection. Wat. Sci. Tech. 24(2): 157-164.

EPA, 1992. Environmental regulations and technology - control of pathogens and vector attraction in sewage sludge, EPA Pub. No. 625/R-92/013, Center for Environmental Research Information, Cincinnati, OH 45268.

EPA, 1989. Environmental regulations and technology - control of pathogens in municipal wastewater sludge, EPA Pub. No. 625/10-89/006, Center for Environmental Research Information, Cincinnati, OH 45268.

EPA, 1989. Technical support document for pathogen reduction in sewage sludge. Publication no. PB 89-136618. National Technical Information Service, Springfield, Virginia.

EPA, 1985. Health effects of land application of municipal sludge. EPA Pub. No. 600/1-85/015. EPA Health Effects Research Laboratory, Research Triangle Park, North Carolina.

EPA, 1979. Technology Transfer Process Design Manual - Sludge Treatment and Disposal, EPA 625/1-79-011, Center for Environmental Research Information, Cincinnati, Ohio.

Farrell, J.B., V. Bhide, and J.E. Smith, Jr., 1996. Development of EPA's new methods to quantify vector attraction of wastewater sludges. Water Envir. Res. 68, No. 3, 286-294.

Keswick, B.H. 1984. Sources of groundwater pollution. In: Groundwater Pollution Microbiology. G. Bitton and G. Gerba, eds. John Wiley and Sons, New York. pp. 39-64.

Kowal, N.E.1985. Health effects of land application of municipal sludge. Health Effects Research Laboratory, US EPA, Cincinnati, OH. EPA/600/1-85/015.

Levine, M.M., H.L. DuPont, and S. B. Formal. 1973. Pathogenesis of Shigella dysenteriae (Shiga) dysentery. J. Infect. Dis. 127(3): 261-270.

Machno, P.S., R.C. King, and S.C. Hennig. 1995. Nationwide survey of enhanced low cost, low technology methods for going beyond class B. in Proceedings of Water Environment Federation and American Water Works Association's Conference on Biosolids & Residuals Management, Kansas City, Missouri. July 26, 1995.

Smith, J. E., Jr., and J. B. Farrell. 1994. Vector Attraction Reduction Issues Associated with the Part 503 Regulations and Supplemental Guidance. in Proceedings of the Water Environment Federation's Conference, "International management of water and wastewater solids for the 21st century: A global perspective," June 19-22, 1994, Washington, D.C., pp 1311-1330.

Ward, R.L., D. I. Berstein, E. C. Young, J.R. Sherwood, D.R. Knowlton, and G. M. Schiff. 1986. Human rotavirus studies in volunteers: Determination of infectious dose and serological response to infection. J. Infect. Dis. 154(5): 871-880.

FATE AND TRANSPORT OF PATHOGENS FROM LAND APPLICATION OF SEWAGE SLUDGE: WHAT WE KNOW, WHAT WE DON'T KNOW

Marylynn V. Yates
Department of Soil & Environmental Sciences
University of California
Riverside, CA 92521
phone: 909-787-5488, fax:909-787-2954, e-mail: marylynn.yates@ucr.edu

Introduction

On November 25, 1992, William K. Reilly, Administrator of the United States Environmental Protection Agency (EPA), signed into law the Standards for the Use or Disposal of Sewage Sludge (Code of Federal Regulations, Part 503). The regulations establish standards for the use or disposal of sewage sludge generated during the treatment of domestic sewage at a treatment works as well as domestic septage (i.e., from septic tanks, cesspools, etc.). Requirements were established for the application of sewage sludge to land, placement of sewage sludge on a surface disposal site, incineration of sewage sludge, and distribution and marketing of sewage sludge. The regulations establish pollutant limits for several inorganic compounds. The amount of sludge that can be applied to a given site is constrained by the concentration of the pollutants in the sludge, as limits are set on the annual pollutant loading rates.

In addition, the regulations established two classes of sludge, Class A and Class B, based on pathogen density requirements. Generally, Class A sludge must either be exposed to high temperatures and/or pH for an extended period of time or must be analyzed for the presence of viruses and helminth ova. Demonstration of acceptable levels of indicator organisms such as fecal coliforms or Salmonella is not sufficient for a sludge to be classified as Class A. For Class B sludge, however, it is sufficient to demonstrate that the number of indicator organisms is at or below a threshold level. Class A sludge is extensively treated to reduce pathogen concentrations, and thus the restrictions placed on the use of this material are fewer than for Class B sludge, which is not as extensively treated. The development of the pathogen reduction requirements for the two classes of sludge was not based on risk assessment (as were the metal loading rates); rather, best professional judgment and published information in the scientific literature were used.

Pathogens In Wastewater

There a number of different types of microorganisms that are typically found in untreated domestic wastewater. These, along with the diseases they cause, are summarized in Table 1.

Table 1. Microorganisms typically found in domestic wastewater (Gerba, 1996)

Organism	Disease(s) Caused	Concentration (per mL)
total coliform bacteria	indicator organism	10^5 - 10^6
fecal coliform bacteria	indicator organism	10^4 - 10^5
fecal streptococci	indicator organism	10^3 - 10^4
enterococci	indicator organism	10^2 - 10^3
Shigella	dysentery	present
Salmonella	typhoid, salmonellosis	10^0 - 10^2
Clostridium perfringens	indicator organism	10^1 - 10^3
Giardia cysts	diarrhea	10^{-1} - 10^2
Cryptosporidium oocysts	diarrhea	10^{-1} - 10^1
Helminth ova	ascariasis, anemia, diarrhea	10^{-2} - 10^1
Enteric viruses	hepatitis, meningitis, diarrhea	10^1 - 10^2

Pathogen Reduction During Sludge Treatment

During wastewater treatment, the number of microorganisms is reduced. The number of microorganisms remaining in the treated effluent depends on a number of factors, including the initial concentration in the raw wastewater and the type of wastewater treatment process(es) used. Typical concentrations of microorganisms in the sludge produced during secondary wastewater treatment (i.e., biological treatment such as activated sludge) are shown in Table 2. Treatment of sludge further reduces the concentrations of microorganisms in sludge; concentrations of microorganisms in sludge after typical reduction by various types of sludge treatment are shown in Table 3.

Table 2. Typical concentrations of microorganisms in secondary sludges (Straub et al., 1993)

Organism	Concentration (no./g dry wt)
Total coliform bacteria	7×10^8
Fecal coliform bacteria	8×10^6
Fecal streptococci	2×10^2
Salmonella	9×10^2
Giardia	10^2 - 10^3
Ascaris	1×10^3
Trichuris	$<10^2$
Toxocara	3×10^2
Enteric viruses	3×10^2

Table 3. Microbial concentrations after reduction by sludge treatment (adapted from Straub et al., 1993)

Organism	Sludge Treatment Process				
	Anaerobic digestion	Aerobic digestion	Composting	Air drying	Lime stabilization
Total coliform bacteria	10^5 - 10^8	10^5 - 10^8	<10^4 - 10^6	<10^4 - 10^6	<10^4 - 10^6
Fecal coliform bacteria	10^3 - 10^6	10^3 - 10^6	<10^2 - 10^4	<10^2 - 10^4	<10^2 - 10^4
Fecal streptococci	10^{-1} - 10^2	10^{-1} - 10^2	<10^{-2} - 10^0	<10^{-2} - 10^0	<10^{-2} - 10^0
Salmonella	10^{-1} - 10^2	10^{-1} - 10^2	<10^{-2} - 10^0	<10^{-2} - 10^0	<10^{-2} - 10^0
Giardia	10^2 - 10^3	10^2 - 10^3	<10^{-2} - 10^1	<10^{-2} - 10^2	10^2 - 10^3
Ascaris	10^3	10^3	<10^{-1} - 10^1	<10^{-1} - 10^3	10^3
Trichuris	<10^2	<10^2	<10^{-2} - 10^0	<10^{-2} - 10^2	<10^2
Toxocara	10^2	10^2	<10^{-2} - 10^0	<10^{-2} - 10^2	10^2
Enteric viruses	10^2 - 10^0	10^2 - 10^0	<10^{-2} - 10^0	<10^{-2} - 10^2	<10^{-2}

Fate of Pathogens during Land Application

The potential hazards from pathogenic microorganisms associated with land application sludge will vary based on a variety of factors, including the sludge application method, the microbiological quality of the sludge at the time of application, environmental factors, and the management of the site.

The number of pathogens is reduced during each stage of sewage treatment, and reduced further during sludge treatment, as shown in Tables 2 and 3. However, even composted sludge can not be guaranteed to be free of all pathogens. One issue that must be considered is that for human pathogenic viruses (such as hepatitis A virus and poliovirus) and some pathogenic parasites (such as *Giardia* and *Cryptosporidium*) the number of microorganisms that must be ingested to cause disease is very small - in some cases only one particle may cause disease. In addition, it is important to remember that the absence of indicator bacteria such as fecal coliforms or fecal streptococci in sludge does not guarantee the absence of pathogenic microorganisms. Many pathogens are much more resistant to inactivation by sewage and sludge treatment processes than are the so-called indicator bacteria.

Pathogens (especially parasites and, to a lesser extent, viruses) can survive in the environment for a considerable period of time (months to years). According to published research results, parasite eggs appear to be the most resistant to inactivation once the sludge has been applied to land (Meyer et al., 1978). *Ascaris* eggs have been found to survive for up to four years in soil, while eggs of *Trichuris* have been found to remain infective for six years (Griffiths, 1978). Viruses have been found to remain infective in soils for several months, especially at low temperatures (Straub et al., 1993).

The movement of microorganisms through the soil at sludge-amended sites has not received much study, especially at the field scale. Coliform bacteria have been found to migrate up to 200 cm at a site in Arizona (Pepper et al.,1991). Studies of parasite movement have generally shown that none of the parasites could be recovered below 2 - 60 cm (Straub et al., 1993). Because of their small size (25 nm), viruses are the most likely of the three groups of microorganisms to pose a threat to ground water quality. In one study, viruses were detected in a 3-m-deep well at a site where anaerobically digested sludge was applied to a sandy soil 11 weeks after sludge application (Jorgensen and Lund, 1985).

As stated previously, there have been very few field studies to assess the fate of pathogenic microorganisms in sludge-amended soils. One problem in performing studies of this nature is the cost of the analyses. Analyzing soil samples for enteric viruses costs hundreds of dollars per sample. Confounding the problem is inhibition of the analytical procedures by other components of the sludge and soil. Another problem is related to the differences in behaviors of the various microorganisms: even among related viruses, such as the enteroviruses, behavior can vary considerably, so it is not always possible to extrapolate from one study to another. Variability in the environment also makes performing field studies difficult: considerably spatial heterogeneity exists in a single field. Predicting behavior in one field based on behavior in another field is extremely difficult to do. However, some generalizations are possible. For example, most microorganisms will persist for longer periods of time in cooler temperatures than warm ones. The rate and amount of water applied to the soil surface will also affect the extent of microbial movement: the more water applied, and the greater the rate of application, the more extensive the movement. Soils with a coarser texture generally will permit more movement of microorganisms. The clay content of the soil is important in that many microorganisms adsorb onto these charged particles, and thus are restricted in their movement.

In summary, the current federal regulations specify treatment processes to reduce the numbers of pathogenic microorganisms in the sludge prior to land application. These regulations are based on best professional judgment and published scientific information rather than a formal risk assessment process. Based on what is known about the survival and transport of microorganisms in the environment, parasites have the ability to persist in soils for several years. However, their large size is an impediment to transport through the subsurface. Viruses, however, are small enough to be transported if they survive for a long enough periods and are not solid-associated. Little field information is available to allow confident predictions about the potential for microbial contamination at specific sites, although generalizations can be made.

References

Gerba, C.P. Municipal waste and drinking water treatment. 1996. In: Pollution Science, Pepper, Gerba, and Brousseau, eds. Academic Press, San Diego, Ch. 20.

Griffiths, H.J. 1978. A handbook of veterinary parasitology of domestic animals of North America. Univ. of Minnesota, Minneapolis, MN.

Jorgensen, P.H. and E. Lund. 1985. Detection and stability of enteric viruses in sludge, soil, and ground water. Wat. Sci. Technol. 17:185-195.

Meyer, R.B., K.D. Miller, and E.S. Kaneshiro. 1978. Recovery of *Ascaris* eggs from sludge. J. Parasitol. 64:380-383.

Pepper, I.L., C.P. Gerba, K.L. Josephson, and T. M. Straub. 1991. Agricultural sludge reclamation study yearly report for 1991. Pima County Wastewater Management Department, Tucson, AZ.

Straub, T.M., I.L. Pepper, and C.P. Gerba. 1993. Hazards from pathogenic microorganisms in land-disposed sewage sludge. Rev. Env. Contam. and Toxicol. 132:55-91.

Fate and Effects of Chemicals Applied to Agricultural Land from Municipal Sewage Sludge: Past Experiences and Present Status

A.L. Page and A.C. Chang.
University of California, Riverside, CA.

Phone (909) 787-3433 and (909) 787-5325 respectively
e-mail albert.page@ucr.edu and andrew.chang@ucr.edu

One of the present day major problems facing municipalities is finding environmentally sound means to disposal/reuse sewage sludges collected during the course of wastewater treatment. Sewage sludges are the residues remaining following the treatment of municipal wastewater prior to its discharge or reuse. As such they consist of unwanted and undesirable constituents of wastewater. Their composition is highly variable and related to the composition of the domestic wastewater supply and to materials added from commercial and industrial sources. In addition to biodegradable organic matter, sewage sludges contain pathogens, essential plant nutrients, and potentially toxic chemical constituents. The constituents of greatest concern are the harmful trace elements, toxic organic compounds and pathogens.

Present methods of ultimate disposal of sewage sludge include landfilling, incineration followed by landfilling of the ash, dedicated land disposal, land reclamation, and beneficial use on agricultural land. Of the above the most ideal options are land reclamation and beneficial use on agricultural land because these not only serve to dispose of the waste but also utilize their soil conditioning properties and conserve their plant nutrients.

Although municipal sewage sludges have been applied to land since the advent of wastewater treatment some 100 years ago, only within the past 25-30 years have public health officials and environmentalist expressed concern over possible adverse effects on public health and the environment. During the early 1970's information on the fate and effects of contaminants in municipal sludge when applied to land was largely unavailable. Information to access the transfer of harmful chemicals from sludge through the food chain, to surface and ground water and to access their effects on the growth and quality of crops was either inadequate or totally lacking. Through an extensive and aggressive program of research initiated in the 1970's and sponsored largely by the federal government, our knowledge of the kinds and concentrations of chemicals in municipal sludge, their transfer to the food chain, their fate when applied to land and their phytotoxicity has greatly expanded.

The stage for the direction of research on land application of municipal sludge was set at a Research Needs Workshop sponsored by a sub-committee of US Environmental Protection Agency, US Department of Agriculture and the National Land Grant Colleges and held in 1973 (National Association of State Universities and Land Grant Colleges, 1974). The purpose of the workshop was to identify what is known about liquid effluent and sludge application to land, and what research was needed for successful utilization of land as a soils treatment system from economic, engineering, health and aesthetic points of view. Workshop participants were in agreement that sludges are a valuable soil conditioner and source of plant nutrients (nitrogen, phosphorus and micronutrients) but that additional information was needed to properly access potential hazards associated with its application to land.

In general the workshop concluded that where sludges are applied to land additional information was needed on methods to control leaching of nitrates and trace elements to groundwater, on the transfer of harmful trace elements to consumers via the food chain, and on the toxicity of trace elements to crops grown on sludge amended soils. Elements most important in terms of transfer to the human food chain were identified as arsenic, cadmium, mercury,lead, selenium and zinc. Those most important in terms of phytotoxicity were identified as boron, cadmium, copper, nickel and zinc. The workgroup also concluded that there was an immediate need for rapid laboratory and greenhouse methods to evaluate the suitability of various combinations of sludge, crops and soils for land use.

In an effort to simulate effects of levels of trace elements in sludge amended soils early research involved the growth of plants in the greenhouse with the elements added to soils as inorganic salts and sludges amended with inorganic salts. Field studies which followed showed that the results of these greenhouse studies grossly over estimated trace elements uptake and phytotoxicity. Field studies also demonstrated that crops grown on sludge amended soils would not accumulate either arsenic, chromium, copper, lead, mercury, nickel or zinc in amounts sufficient to harm consumers. However, depending upon soil conditions, research showed there is a potential for cadmium, molybdenum and selenium to be taken up by certain crops in amounts harmful to humans(cadmium) and animals (cadmium, molybdenum and selenium). Except possibly on very acid soils ($pH<5.5$), there are no documented cases of copper, nickel and zinc toxicities to plants grown on sludge amended soils.

Where sludge is used on land to prevent nitrogen leaching it is essential that the input of nitrogen is balanced by output by crops and loss by volatilization (ammonia volatilization and denitrification). Through research over the past 20 years we greatly improved our understanding of the processes controlling the rate of nitrogen transformation in relation to soil and sludge properties. This knowledge has provided us with the tools to plan, design, and operate sludge land application systems such that nitrogen leaching is minimized.

Almost without exception sludges contain higher concentrations of the trace elements of concern than do soils and consequently concern was expressed of the fate of these trace elements in sludge following their application to soil. Numerous laboratory and field studies have demonstrated that most trace elements are immobile in soils and once added will remain essentially within the depth of incorporation. Therefore, except for boron , problems associated with trace elements entering ground water beneath lands where sludge have been applied are unlikely. Very sandy soils, and soils where the water table is near the surface, however, may be exceptions.

The research conducted over the past twenty five years has provided the US Environmental Protection Agency with much of the information needed to define upper boundary pollutant limits for sludge application to land. The agency engaged in an extensive and exhaustive review of the findings of research designed to assess potential problems encountered in operations involving agricultural use of municipal sewage sludge. These findings were incorporated into a comprehensive exposure assessment/risk assessment model to arrive at scientifically based levels of pollutants in soil protective of public health and the environment. The exposure assessment/risk assessment model traced the flow of 10 inorganic and 12 organic chemicals in sewage sludge through 14 pathways from soil to a target organism. Upper limits for sludge use on agricultural land were established for 10 elements; arsenic, cadmium, chromium, copper,lead, mercury, molybdenum, nickel, selenium and zinc (US Environmental Protection Agency, 1993). Chromium was later dropped from the regulation and levels for molybdenum are presently under review. Organic chemicals screened for regulation were not regulated by the agency because they were either: 1) banned from production, 2) normally found in sludges at low or trace concentrations, 3) commonly degrade rapidly in soil and 4) not generally taken up by plants.

In the US over the past twenty five years research conducted by many scientist across the nation has provided adequate technical information for waste management specialist to plan and design systems for the reuse of municipal sewage sludge in agricultural operations. This effort has culminated in the promulgation of Standards and Best Management Practices for the Disposal and Utilization of Sewage Sludge by the US Environmental Protection Agency mentioned in the previous paragraph. While no reuse practice can guarantee complete safety, current available scientific information indicates that the use of sewage sludge in agricultural operations, when practice in accordance with existing federal guidelines and regulations presents negligible risk to the consumer, to crop production, and to the environment. However, enforcement of regulations governing beneficial use of sewage sludge in agriculture is self regulating and largely the responsibility of the responsible parties. Municipal wastewater treatment plants, private processors, distributors and applicators must act responsibly and not only comply with all regulatory requirements and management practices, but also take extra steps to demonstrate to neighbors, farmers, food processors and consumers that such compliance is occurring. Finally, aside from human health and environmental concerns, institutional barriers such as public confidence in the adequacy of the regulatory system, concerns over liability, property values and nuisance aspects will play a major role in the acceptance of the use of sewage sludge in the production of crops.

Literature Cited

National Association of State Universities and Land Grant Colleges. 1974. Proceedings of the Joint Conference on Recycling Municipal Sludges and Effluents on Land. NASULGU, Washington, D.C.

U.S. Environmental Protection Agency. 1993. Standards for the use or disposal of sewage sludge. Federal Register 58(32):9248-9415. U.S. Gov. Print. Office, Washington, D.C.

Sludge, Sludge on the Range: Unresolved Science in the 503 Regulations

Albert G. Medvitz

P.O. Box 565
Rio Vista, CA 94571
email: amedvitz@wco.com

Abstract

The USEPA 40CFR part 503 regulations are problematic for the safe regulation of the land application of sewage sludge on grazing land. In several instances significant science is lacking about the long term (4 to 6 year) risks posed to livestock producers by using sewage sludge as an amendment to grazing land. Both explicit and implicit assumptions in the 503 risk assessments and associated science compromise the conservative nature of the regulations in protecting the agricultural viability of many livestock production enterprises.

Assumptions about animal exposure to the pollutants in sludge

In considering the potential dangers of sludge pollutants on livestock, the makers of the 503 sludge rule eliminated pollutants from consideration on the basis of estimates of toxicity, carcinogenic characteristics, and estimates of the exposure dose a highly exposed individual would likely encounter when exposed to sludge. This last probability was computed from a National Sewage Sludge Survey (NSSS) of publicly owned wastewater treatment works (POTWs). The survey, among other things, determined prevalence and concentrations of pollutants in sludge produced by these works.

To determine allowable concentrations of pollutants to be applied and to be accumulated in the nation's soils, the rulemakers relied on the existing base of scientific research to assess the potency of pollutants and estimate the doses of these pollutants to which people and animals and plants in the environment would be exposed.

As is to be expected of the science of a complex material, the knowledge of toxicity and the environmental interactions of sludge borne pollutants (including those with people) is incomplete, as is the behavior and fate of these pollutants after they are land applied. Furthermore, the behavior of environmental organisms which govern their interactions with sludge (and hence doses of pollutants ingested, inhaled, or absorbed) vary widely depending on exposed species and environmental conditions or are poorly understood in themselves. To compensate, the rule-makers relied heavily on simplifying assumptions and best guess estimates about the interaction of pollutants with organisms in untested conditions. In some instances they did not consider important but subtle long term effects on breeding behavior and thus overlooked important potential deleterious outcomes of the use of sludge on agricultural lands.

In the case of sheep, sludge pollutant exposure is achieved through eating forage grown on sludge as well as ingesting soils as they graze. Estimates of soil ingestion by grazing animals vary from about 0.5% to as much as 24% of total diet depending on grazing conditions. When grazing lands are rich and fresh, animals are likely to consume little soil, when grazing conditions are such that forage is scarce, more soil is consumed. Soil ingestion also varies by species and animal and range management practices. (Animals may also acquire pollutants from ephemeral streams and standing water from vernal pools on sludge amended ground, but this will not be discussed in this paper.)

The EPA considered domestic animal exposure to sludge pollutants in four of the fourteen pathways by which sludge borne pollutants and pathogens could be encountered in the environment. These are:

> human toxicity from the consumption of animal products produced from animals which are fed forages grown on sludge amended soils (pathway 4);
>
> human toxicity from the consumption of animal products produced from animals that incidentally ingest sewage sludge (pathway 5);
>
> toxicity to animals from feeding on forage grown on sludge amended lands (pathway 6);
>
> toxicity to animals themselves through direct ingestion of soil (pathway 7).

This paper considers these pathways, including pathways 4 and 5, only as they are relevant to livestock health and production.

In considering sludge toxicity to animals which might feed on forages and ingest soil amended with sludge, the EPA eliminated organic pollutants, including dioxins and furans, from consideration and considered only 9 inorganic elements: Arsenic, Cadmium, Chromium, Copper, Lead, Molybdenum, Nickel, Selenium, and Zinc. (The consequences of this omission of important organic compounds will be discussed below). After identifying the pollutants to be considered the rulemakers then considered them one by one. First they reviewed the literature to identify the most sensitive animal species for each pollutant (since sensitivity varies by species), they then, using the same literature, estimated the maximum intake of each pollutant which would not cause a toxic effect to a highly exposed animal of the most sensitive species. In the case of ingesting sludge grown plants, once having estimated the maximum allowable intake level of the trace metal, the rulemakers then estimated how much forage (pathway 6) animals ingest as well as the uptake of pollutants by plants grown in sludge amended soils. They also estimated background levels of pollutants in soils. From all of these estimates they calculated concentrations of pollutants in the soils which would produce concentrations in plant material such that animals eating these plants would consume trace metals below a level which would produce an observable adverse impact.

The process was similar for soil ingestion except it was not necessary to estimate pollutant uptake by plants. Rather, the EPA estimated levels of soil ingestion by grazing animals. The end result is an estimate of allowable concentrations of pollutants in sludge itself as well as maximum safe soil concentrations accumulating in the soil.

Problematic assumptions

Unfortunately, the 503 rules are compromised by several important assumptions. First, in calculating allowable concentrations of pollutants in sludge, the EPA rulemakers considered pollutants individually. But pollutants in sludge do not occur singly: they exist and act in concert with all of the pollutants found in the particular urban waste stream where the sludge is produced. In some instances, for example in noting the interaction of zinc and copper, the rulemakers did consider the toxicity of interactions of pollutants, but did not develop risk assessment algorithms for interacting pollutants. In the particular instance of copper and zinc, high levels of both Zinc and Copper would do no damage. But the consequences of high concentrations of Cadmium and Zinc, in animal diets for example, are not considered. Cadmium also interacts with the metabolic action of Copper and inhibits the accumulation of Copper by the developing fetus. Nor do the EPA analyses consider the consequences of interactions between inorganic and organic pollutants.

The EPA also did not take into account the combined effects of animal ingestion of sludge amended soils at the same time as the effects of animals feeding on crops grown on these soils. In other words, they did not consider near endpoint conditions where animals might be grazing on forage produced with near maximum allowable soil concentrations of pollutants and ingesting newly applied sludge in the soil itself. The sum of the two pathways was not considered, nor were accumulated sludge concentrations considered in background estimates. Nor did they consider animal consumption of standing water on sludge amended lands. (This last consideration may be of considerable importance to California and other Western states where winter and spring wet seasons produce ephemeral streams and vernal pools on grazing land. Since little or no data exist about ingestion through surface water runoff from sludge amended lands, the problem is not considered in this paper.)

Soil ingestion estimates used in pathway 7 are inconsistent with assumptions made about sensitive species and conditions of sheep production in California. As noted above estimates of soil ingestion vary depending on grazing conditions. Even if one assumes the legitimacy of Fries contention that estimates of soil ingestion are overstated, then soil ingestion rates will vary between near zero and 10% of animals daily diet. High end estimates would be particularly appropriate to sheep in California. Typical sheep grazing patterns in California are of flocks of sheep grazing the summer on cultivated fallow land or on post harvest stubble of a variety of crops, or on desert lands. Although precise data on levels of ingested soil are not available, it is not uncommon in ranch necropsies to find substantial residue of soil in sheep digestive systems. The upper estimates for soil ingestion seem not unreasonable for many California conditions.

It is worth noting that in developing pathway 7 the EPA estimates on soil ingestion violate it's own criteria of consideration of most sensitive species. In this pathway, soil ingestion was assumed to be 1.5% of animal diets. The estimate is based on soil ingestion of cattle, not the most sensitive species for, say, Copper. Furthermore, the estimate is based on the geometric mean of data obtained from cattle grazing in rotation on sludge amended pasture, only one third of which is sludge amended. Thus, while sheep are clearly identified as the most sensitive species when ingesting Copper, data on soil ingestion by cattle were used to calculate ingestion rates rather than dryland grazing data appropriate to sheep. Given other estimates, this assumption leads to an underestimate of soil ingestion by a factor of 4 or 5 for the most sensitive species to Copper toxicity. Furthermore, the assumption that animals rotate through pastures of which only one third have been treated with sludge is based on observations of a particular set of management practices at a particular time and is arbitrary.

The 503 rules thus allow the concentration of pollutants in sludge to be a factor of 4 or 5 times the amount prescribed under the criteria of maximum usable with no toxic effects when pollutants are considered individually.

Limitations of the research base

More subtle faults with the 503 regulations emerge from the inadequacies of the research base available to adequately assess risks over time frames of more than a year or so. The overwhelming majority of research on sludge borne pollutants are experimental studies of a few months to a year of feeding animals sludge amended diets or grazing animals on pastures to which sludge has been applied. In the EPA discussion of toxic levels of Copper, for example, the relevant data are from observations made over one season. The majority of studies are concerned with the safety of animal products for human food. The dependent variables in these studies are generally concentrations of pollutants in animal tissue which arise from ingestion of pollutants added to feed, ingestion of sludge, or forage grown on sludge in experimental diets. Except for a few instances, observations of animal breeding behavior and performance tend to be incidental asides.

For sheep, the production lifetime of a healthy ewe is on the order of seven years. Yet there are very few long term studies of the effects of sludge borne pollutants on health and productivity of breeding flocks over this period of time. In the early eighties Baxter et al conducted several studies on cattle, in which they studied pollutant accumulation in animal tissues. One study examined such effects after nine months of grazing, the other compared tissue concentrations in a herd which grazed a sludge disposal site for approximately 6 years with concentrations of herd on a nearby cattle ranch. In both studies, cattle were slaughtered and pollutants in tissues measured. In the longer more extensive study, significant increases in Cd in kidney tissues and decreases in liver Cu were noted as well as elevated levels of organics in fat tissue. Other than noting that the animals appear in good health with no apparent problems, the authors did not investigate effects on production or breeding effects. Also, while the "herd" had grazed the range for some time, it is not clear how long the sampled animals had been exposed to the sludge amended range.

In the early 1980's Hudgens, Hallford and others produced a series of studies of effects of a sludge amended diet on the productivity of breeding sheep. These ranged in length from a breeding season to four years and compared the effects of a control diet with those of a diet enhanced with cottonseed meal and another enhanced with 7% sewage solids.

In these studies, the authors declare there are no significant or meaningful differences between experimental and control groups in terms of lambing and weaning performance (12), blood, milk and tissue elemental composition (15), reproductive performance (13), or adverse toxicological effects (14).

However the characteristics of the Las Cruces, New Mexico sludges used in these experiments are vastly different than the characteristics of sludges permitted under the 503 rules. Table one compares the concentrations of heavy metals in the long-term diet fed to ewes by Hudgens and Hallford (13) with concentrations in a diet from soil ingestion of land applied sludge with maximum concentrations of heavy metal pollutants permitted under the 503 regulations, assuming 7% soil ingestion in the animal diet. The table shows two conditions: maximum allowable concentrations applied to the soil surface and not incorporated, and maximum allowable soil concentrations. The comparison does not take into account ingestion of pollutants in forage. The differences in trace metal ingestion are readily apparent. For example, the Pb in the experimental diet is nearly a factor of 2 less than that which would arise if animals ingested 7% of their diet from soils with maximum allowable sludge pollutant concentrations. The experimental dietary Pb is a factor of 10 less than would be consumed if surface applied sludge with maximum permitted levels were ingested. Similar ratios apply to other elemental pollutants.

Comparison of Metal Concentrations in Hudgens and Hallford Experimental Diet with Those in a Diet Composed of 7% Ingested Soil at Maximum 503 Concentrations.

Pollutant	Maximum 503 concentration allowed in applied sludge (mg/Kg)	Maximum 503 concentration allowed in soil (Kg/Ha)	(mg/kg)[1]	Concentration in diet when soil with 503 maxima is 7% of diet[4] (mg/kg) sludge on surface	sludge incor-porated	Concentration in sludge amended diet in Hudgens and Hallford.[2] (mg/kg)
Arsenic	75	41	25	5.25	1.8	not reported
Cadmium	85	39	24	6.2	2.0	0.5
Chromium	3000	3000	1852	216	135	25.8
Copper	4300	1500	926	307	71	26.4
Lead	840	300	185	60	14	6.9
Mercury	57	17	10.5	4	0.7	<0.04
Molybdenum[3]	75	18	11	5	0.8	not reported
Nickel	420	420	259	31	20	2.7
Selenium	100	100	62	7	4	not reported
Zinc	7500	2800	1728	547	143	55.6

1 calculated using soil density of 1.08 kg/liter of ayar clay soil from Montezuma Hills, a principal dryland agriculture area in California where sheep are rotated with small grains, assuming mixing to a depth of 15 cm (6 in).

2 In addition to reporting values for tabulated pollutants, Hudgens and Hallford reported values for the following pollutants/nutrients (ug/g): Ag (6.0), Ca (2014.0), Fe (601.7), K (5,066.3), Mg (1,045.7), Mn (35.8), Na (1,300), P (2,378.7).

3 Since the publications of the 503 regulations, limits to Mo have been deleted from the rule pending EPA reconsideration.

4 Calculated adding background concentrations in basal (unamended) diet, (i.e. $C_{tot} = .07C_{sludge} + .93C_{basal}$)

A further characteristic of the Hudgens and Hallford experiment compromises its relevance: the sludge was irradiated and presumably sterilized before being incorporated into the experiment. The 503 regulations do not require sterilization, but treatments to reduce pathogens are required for Class A sludges. Class B sludges, without additional pathogen treatment after wastewater treatment are allowed on grazing lands with a 30 day grazing restriction. The sterilization process in the Hudgens and Hallford experiment omits the possibility of observing effects on sheep from sludge borne pathogens, particularly if immune systems are stressed from elevated sludge exposure over five or six years.

Two other long term (3 year) studies by Bray et al and Dowdy, Bray, et al using goats and lambs show no or negligible effects on animals fed silage produced from sludge amended soils. Examination of the dietary concentrations in the studies show that, except for Zinc, they are even less than those reported in the New Mexico studies of Hudgens, Hallford and others cited above.

It should be emphasized at this point that these and the New Mexico studies of Hudgens, Hallford, and others do lend credence to the idea that sewage sludge with modestly elevated levels of pollutants may serve as a beneficial and safe soil amendment for California grazing lands. But the few studies investigating the long term effects of sludge on the breeding health of livestock do not lend credence to the 503 regulations as protecting the long term health of grazing animals.

The only study for cattle which I have found which at least in part addresses the issue was reported by Fitzgerald in 1980. In this long term study of cattle and swine grazing on sludge amended soils, Fitzgerald reports that "In general, the calf crops have been from 90% to 95% in the control herd and 80 to 85% in the experimental herd." (19, p. 36). This difference, however may also be an experimental artifact in that the ratio of bulls to cows in the experimental herd was 1 to 30 but 1 to 20 in the control herd. Nevertheless, the observation warrants caution in the long term use of sludge on grazing land.

Organic Pollutants

The seriousness of the gaps in the research about the longer term (five to ten year) impacts of sludge borne pollutants on livestock is made more apparent by the lack of research on the impacts of organic pollutants. The EPA conducted initial screening of pollutants using a national survey of POTWs, the so called National Sewage Sludge Survey. Before conducting the survey, the rulemakers *a priori* eliminated significant organic pollutants on the basis that their use has been banned in the United States. As the National Research Council notes in its report on sludge, the exclusion was an error and the survey was flawed. Possible exposures are underestimated.

Despite the sludge survey issues, the EPA included selected organic pollutants in its analysis of pathways 4 and 5 which are about the accumulation of toxic substances in animal tissues as they effect humans who consume animals. In considering these pollutants, the EPA rulemakers did not include organic pollutants as having possible impacts on animals as evidenced by their absence from the relevant pathways (6 and 7). Furthermore, in considering the health impacts of organic pollutants they used the existing research base on the cancer causing character of these chemicals.

Again, organic pollutants, when they were considered, were considered individually and not in synergy with other organic or inorganic pollutants.

The research bias towards human carcinogens is important because it excludes other important effects of organic pollutants, most notably their effects as endocrine disrupters. Such effects may have important consequences for immune responses and reproduction in domestic food animals. Even in recent publications on organic pollutants in sludge, the research is directed to assessing the safety of human consumption of animal tissues and not the long breeding viability of the animals.

The absence of research on both the organic and inorganic chemical species on long term breeding health of animal herds and flocks leaves open serious questions for producers about the protectiveness of the 503 regulations for their enterprises. Anyone close to the sheep and cattle production systems in California knows that they have been operating under difficult economic circumstances for close to a decade. Further they understand that lowered conception rates of a percentage point or two, increased abortions or a fraction of earlier deaths of animals resulting from sludge applications would be hard to identify and trace, yet could have a substantial economic and management impact on livestock enterprises.

The absence of research could be readily addressed by relatively modest experimental studies and epidemiological studies on the order of five to ten years where sludge has been used at the levels specified in the 503 regulations and where significant soil ingestion is likely to occur.

We must keep in mind that the issue is not whether or not sludge can be of benefit, but what are the conditions under which it can be used safely. In terms of breeding flocks of animals, the 503 rules are not based on a sufficiently firm scientific base to support trust in their use as a standard.

Other issues

This paper has focused on the problem of the lack of a sufficient research base on the long term effects of pollutants on breeding flocks to justify the USEPA 40CFR part 503 rules as a standard for the protection of livestock industries, particularly sheep production, in California. Besides concern for animals, the 503 regulations also must be analyzed in terms of the long term well being of range lands and on the ranchers ability to adapt his or her practices to changing crop production.

It should be noted that the research base on soil ecology usable to assess risks of the land application of sludge at the levels specified in the 503 regulations suffers a sparsity of data similar to that described above for breeding animals. McBride, Bouldin and others at Cornell question the EPA's risk assessment of phytotoxicity, partly as a result of data biased towards specific experimental species. Thus, for those who wish to pursue sludge use on California grazing lands, caution and independent analysis should be used. Further research under specific conditions reflecting the diversity of California's ecologies and crops needs to be accomplished before standards can be accepted with confidence.

References

1. Smith, S.R. (1996), Agricultural Recycling of Sewage Sludge and the Environment, CAB International, p. 90.

2. Fries, George F. (1995), "Transport of Organic Environmental Contaminants to Animal Products", Reviews of Environmental Contamination and Toxicology, vol. 41, p. 71-109. Fries suggests that high end estimates may substantially overestimate soil ingestion when plants are mature.

3. EPA (Prepared by Eastern Research Group) (1992), Technical Support Document for Land Application of Sewage Sludge, Vol. 1, USEPA, pp. 5-171 to 5-171; 5-172 to 5-182; 5-183 to 5-191.

4. EPA (Prepared by Eastern Research Group) (1992), Technical Support Document for Land Application of Sewage Sludge, Vol. 1, USEPA, p. 5-175.

5. Campbell, J.K. and Mills, C.F. (1979). "The Toxicity of Zinc to Pregnant Sheep." Environmental Research 20, p. 1.

6. Fries, George F. (1995), Ibid.

7. EPA (Prepared by Eastern Research Group) (1992), Technical Support Document for Land Application of Sewage Sludge, Vol. 1, USEPA, p. 5-175, 176.

8. EPA (Prepared by Eastern Research Group) (1992), Technical Support Document for Land Application of Sewage Sludge, Vol. 1, USEPA, p. 5-177.

9. Baxter, John C. et al (1982). Heavy Metal Retention in Cattle Tissues From Ingestion of Sewage Sludge. J. Environ. Qual., (11,4) p. 616-620.

10. Baxter, et al (1983). Heavy Metals and Persistent Organics at a Sewage Sludge Disposal Site. J. Environ. Qual. 12: 311-316.

11. Baxter, J.C., et al (1983). Heavy Metal and Persistent Organics Content in Cattle Exposed to Sewage Sludge. J. Environ. Qual. (12,3) p. 316-319.

12. Hallford, D.M. et al (1982). Influence of Short Term Consumption of Sewage Solids on Productivity of Fall-Lambing Ewes and Performance of Their Offspring. J. Anim. Sci. (54,5) 922-932.

13. Hudgens, R.E. and Hallford, D.M., Effects of Long-Term Consumption of Sewage Solids on Reproductive Performance and Serum Progesterone and Estradiol-17beta in Mature Fine Wool Ewes. Theriogenology, Feb. 1983 (19,2) pp. 349-256.

14. Smith, G.S., et al (1985). Toxicological Effects of Gamma Irradiated Sewage Solids Fed as Seven Percent of Diet to Sheep for Four Years. J. Anim. Sci. 61:4 p. 931-941.

15. Swanson, D.W. et al (1984). Effects of Long-Term Consumption of Sewage Solids on Blood, Milk and Tissue Elemental Composition of Breeding Ewes. J. Anim. Sci. (59,2) 416-424.

16. EPA. A Plain English Guide to the EPA Part 503 Biosolids Rule, EPA, Sept 1994, p. 29.

17. Bray, B. J. et al (1985). Trace Metal Accumulations in Tissues of Goats Fed Silage Produced on Sewage Sludge-Amended Soil. J. Environ. Qual. (14,1) p. 114-118.

18. Dowdy, R.H., et al (1983a). Performance of Goats and Lambs Fed Silage Produced on Sludge-Amended Soil. J. Eniron. Qual. (12,4) p. 467-472.

19. Fitzgerald, Paul R. (1980). An Evaluation of the Health of Livestock Exposed to Anaerobically Digested Sludge From A Large Community. *In*: Proc. Nat. Conf. on Municipal and Industrial Sludge Utilization and Disposal. Information Transfer, Inc. Silver Spring, Md. p 32-36.

20. NRC, Committee on the Use of Treated Municipal Wastewater Effluents and Sludge in the Production of Crops for Human Consumption (1996). Use of Reclaimed Water and Sludge in Food Crop Production. National Academy Press. p. 7.

21. Fries, George F. (1995). "A Review of the Significance of Animal Food Products as Potential Pathways of Human Exposures to Dioxins". J. of Anim. Sci. 13 p. 1639-1650.

22. Fries, George F. "Ingestion of Sludge Applied Organic Chemicals By Animals", The Science of the Total Environment, 185 (1996) p. 93-108.

23. Harrison, Ellen Z. McBride, Murray B., Bouldin, David R. (1997). Recommendations for Land Application of Sewage Sludges and an Appraisal of the US EPA's Part 503 Sludge Rules: Working Paper, August 1997. Cornell Waste Management Institute. p. 28 ff.

WHY THE CALIFORNIA FARM BUREAU FEDERATION REMAINS CAUTIOUS ABOUT THE USE OF SEWAGE SLUDGE ON AGRICULTURAL PROPERTIES

By: Ron Liebert, Associate Counsel
California Farm Bureau Federation (CFBF)
2300 River Plaza Drive
Sacramento, California 95833
Ph: (916) 561-5691 Fax: (916)561-5691
rliebert@cfbf.com

I. INTRODUCTION.

A. **CFBF's policy regarding the use of sewage sludge on agricultural properties is one of CAUTION.** This caution is the result of, among others:

1. The conflicting scientific evidence about the safety and long-term consequences of sewage sludge use;

2. The potential environmental consequences and associated liabilities resulting from sewage sludge use; and

3. The economic issues involved with its use, such as public perception and the refusal of food processors to purchase crops grown using sewage sludge.

B. **What does it take to ameliorate our concerns?**

1. Independent monitoring and testing to ensure sludge quality. For example, are the metals and pathogen levels correct and moreover, consistent over time?

2. Sufficient local oversight of sewage sludge applications to ensure agronomic rates are properly determined and not exceeded; and

3. Locally controlled monitoring and tracking to ensure water and soil contamination do not and are not occurring.

4. Exceptional Quality (EQ) sewage sludge should not be exempt from the monitoring, tracking and administrative requirements that pertain to non-EQ sewage sludge.

II. WIDE SPREAD USE OF SEWAGE SLUDGE ON AGRICULTURAL PROPERTIES IS NOT A LONG-STANDING PRACTICE.

A. The USEPA's Part 503 regulations were not officially published and put into use until February of 1993 and the "wide spread" application of sewage sludge on agricultural lands not owned by treatment facilities has slowly developed only since that time.

B. Prior to 1993, most sewage sludges in CA were considered hazardous wastes and subject to significant regulation regarding their manner of disposal, usually in landfills or pursuant to POTW waste disposal permits.

III. THERE IS NOT A LOT OF SCIENTIFIC DATA AVAILABLE ABOUT THE LONG-TERM BENEFITS OR RISKS OF USING SEWAGE SLUDGE ON THE VARIETY OF CROPS AND SOIL TYPES IN CALIFORNIA.

A. Most of the USEPA's studies regarding sewage sludge, in particular the few available long-term studies, focussed on a limited number of crops and soil types, yet the EPA's regulations are intended for use for a huge variety of crops and soils

B. The USEPA's 1995 Process Design Manual "Land Application of Sewage and Domestic Septage" notes that metal uptake rates vary by plant species and soil pH and type and that mineralization rates for the nitrogen content of sewage sludge vary by treatment process and soil conditions.

C. We do know that eventually, applications must stop because heavy metals concentrations will reach levels potentially posing health risks to the farmer and the public.

1. We are told this fear is unwarranted because it could be decades before such problems arise. However, many of our members are 3rd, 4th or more generation farmers, who intend to pass their farms to their children. So long-term issues are of concern to us today.

IV. THERE IS A LEGITIMATE AND SIGNIFICANT SCIENTIFIC DEBATE ABOUT THE SAFETY OF SEWAGE SLUDGE. For example:

A. In other parts of the world, limits for heavy metals allowed in soils are substantially more restrictive than in the U.S.

B. Cornell University Cooperative Extension's "1997 Cornell Recommends for Integrated Field Crop Management" recommends limiting total cumulative metals concentrations in soils **to no more than 1/10** that permitted by the EPA's Part 503 regulations and recommends soil testing for background metal levels prior to sludge applications.

C. The National Academy of Sciences (NAS) study "Use of Reclaimed Water and Sludge in Food Crop Production" contains significant and troubling criticisms of the Part 503 regulations that have yet to be addressed, including the reliability of approved pathogen testing methods and the validity of the 1990 National Sewage Sludge Survey, which the USEPA relied on in deciding not to regulate organic pollutants in sewage sludge.

V. THE PROBLEM OF PERCEPTION.

A. CFBF is just as concerned about negative public perception of its products as the sewage sludge industry is of its product. But we must listen to our customers in order to operate and survive. We cannot dictate to our customers that they must buy our products regardless of their fears (e.g., Alar, strawberries, CNN reports, etc)

B. Banks and insurance companies are concerned about sewage sludge use because of potential environmental pollution and long-term effects on property values.

C. One way to counter these concerns is to have a strong commitment to independent monitoring, testing and tracking previously discussed. In particular, local oversight and involvement is essential.

SOURCES OF PESTICIDES IN URBAN STORMWATER

Valerie M. Connor
Central Valley Regional Water Quality Control Board
3443 Routier Rd.
Sacramento, CA 95827
Phone (916) 255-3111; Fax (916) 255-3015
E-mail connorv@gwgate.swrcb.ca.gov

SUMMARY

Urban storm runoff flows into rivers and creeks without any treatment to improve water quality. To ensure protection of the beneficial uses of these receiving waters, Regional Board staff have been evaluating the water quality and toxicity of urban runoff since 1988. Hundreds of samples have been collected in the Sacramento and Stockton urban areas and analyzed for toxicity using standard US EPA bioassay protocols. These toxicity tests indicate widespread toxicity (acute mortality) to the invertebrate toxicity test species, *Ceriodaphnia dubia*. The organophosphate pesticides, diazinon and chlorpyrifos, have been identified as the toxicants. Follow up chemical monitoring suggests these pesticides are present in all urban creeks at toxic concentrations (Figures 1 and 2). Additional monitoring suggests the pesticides originate from both urban and agricultural sources (Figures 3 and 4). Urban sources include professional applications by structural pest control and landscape maintenance companies. In addition, individual homeowners contribute to the problem in residential areas. It is not known if these sources are the result of proper or improper use and/or disposal practices. Urban areas also are impacted by the application of diazinon and chlorpyrifos as orchard dormant sprays and chlorpyrifos applications on alfalfa. Volatilization of pesticides occurs following agricultural applications. The pesticides enter urban areas when they are naturally scavenged by precipitation events, as evidenced by toxic levels of both pesticides being detected in rain samples collected throughout the Central Valley (Figure 4).

CONTROL STRATEGY

Organophosphate pesticide toxicity is not restricted to the Central Valley. It has been reported to occur throughout California, Arizona, Texas and Florida. In response to this widespread toxicity, the San Francisco Bay and Central Valley Regional Water Quality Control Boards have formed a coordinating committee to develop and implement an urban pesticide toxicity control strategy. The mission of the committee is to provide a forum for information exchange, coordination and collaboration on the development and implementation of an urban pesticide control strategy with recognition that the best solutions will be based on partnership among federal, state, and local agencies, industry, businesses and the public. Participants include Regional Board staff and representatives from the Department of Pesticide Regulation, EPA, the pesticide manufacturers, stormwater agencies, county sanitation districts, county agricultural commissions, environmental groups and other interested parties. The group has developed a control strategy with two main components: one which focuses on control of problematic products (in terms of formulation or use); and another which will promote integrated pest management in urban areas through general and focussed outreach and education. Several stormwater agencies are beginning to implement education programs.

Figure - 1. Diazinon Concentrations in Urban Creeks and Rain Samples in Sacramento and Stockton, California

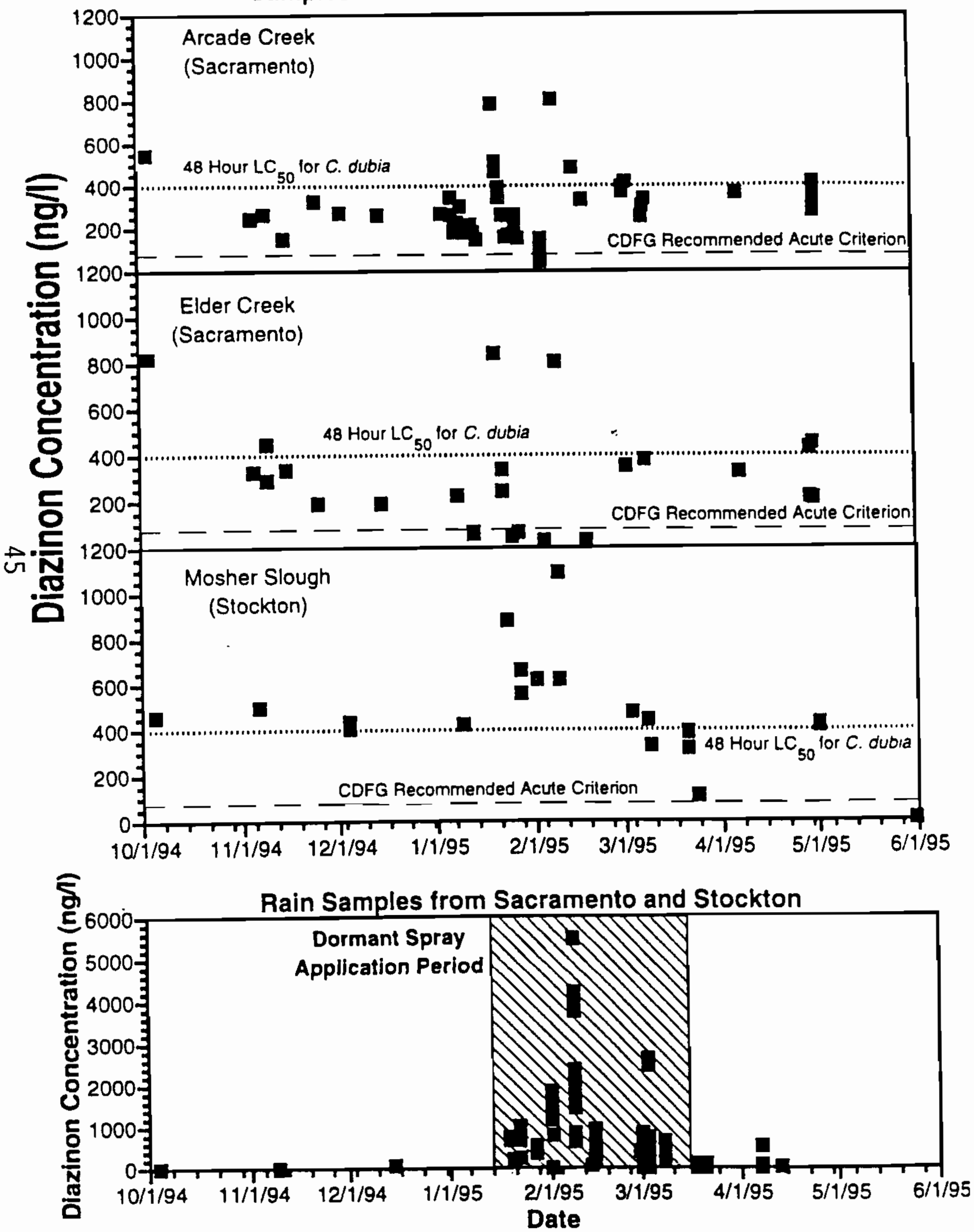


Figure 2. Summary of Chlorpyrifos Concentrations

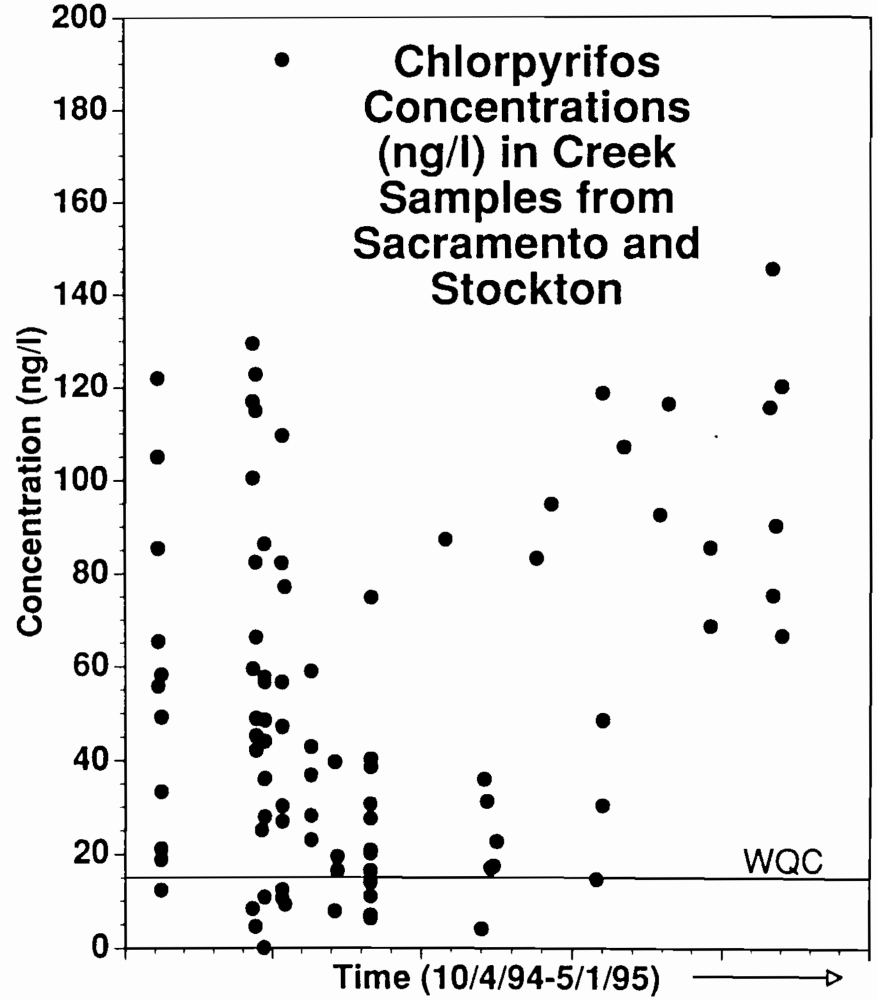
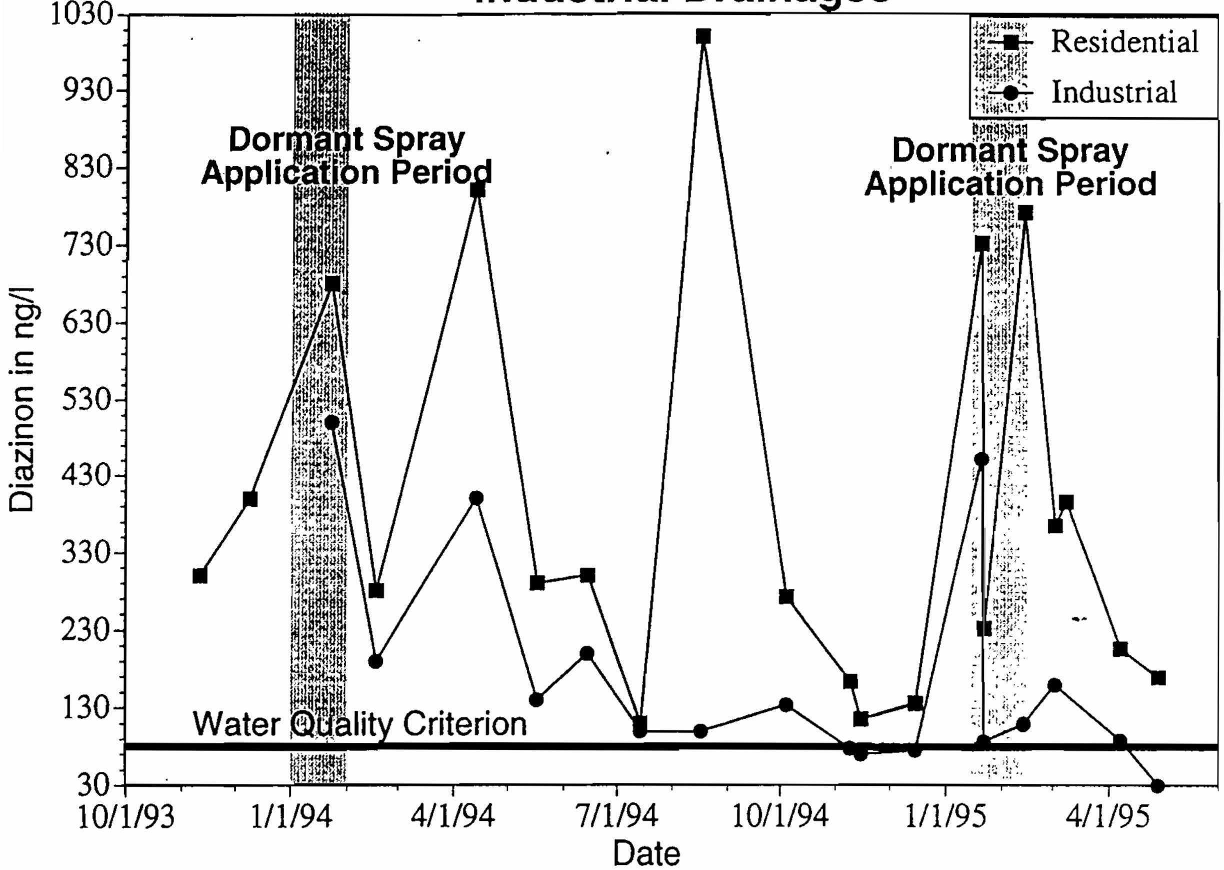


Figure 3. **Diazinon Concentrations in Residential and Industrial Drainages**



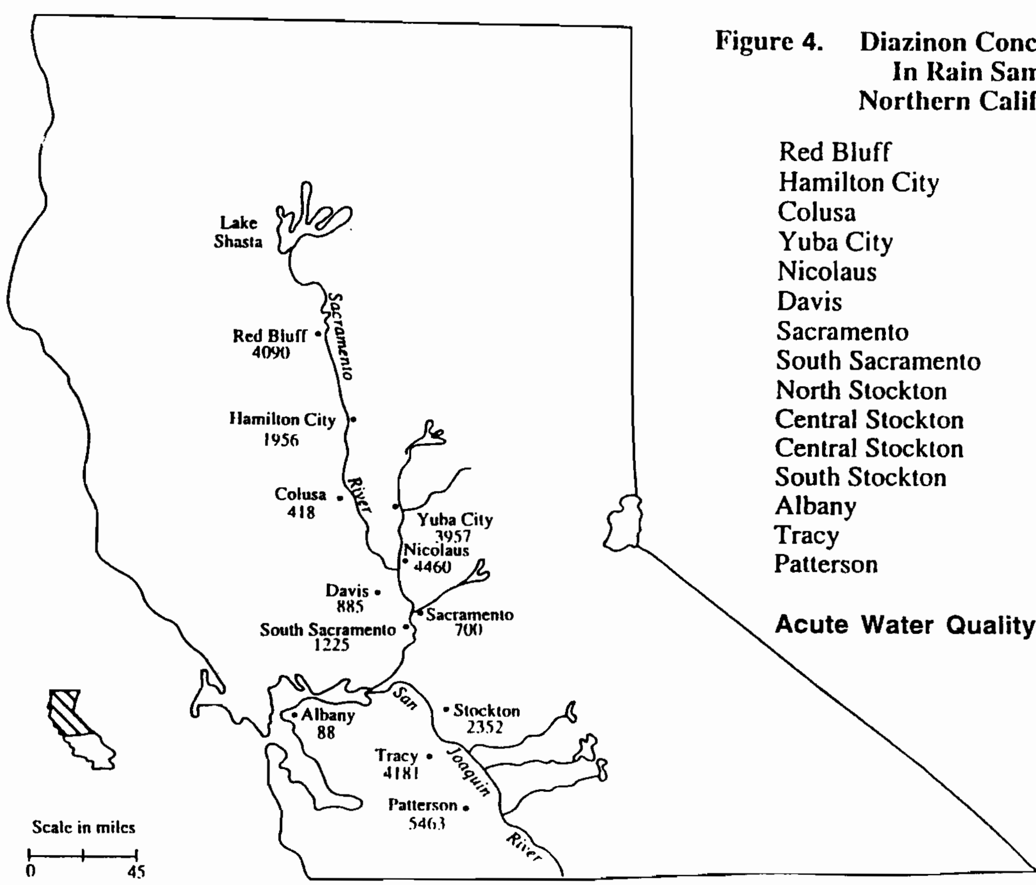


Figure 4. Diazinon Concentrations (ng/l) In Rain Samples From Northern California - 2/8/95

Red Bluff	4090
Hamilton City	1956
Colusa	418
Yuba City	3957
Nicolaus	4460
Davis	885
Sacramento	700
South Sacramento	1225
North Stockton	842
Central Stockton	2352
Central Stockton	1300
South Stockton	3729
Albany	88
Tracy	4181
Patterson	5463

Acute Water Quality Criterion = 80

Each number is the diazinon concentration detected in a single composite sample collected over the entire storm event on 2/8/95.

Water Quality Impacts From Dormant Sprays

Chris Foe
Central Valley Regional Water Quality Control Board
3443 Routier Rd
Sacramento, CA 95827
Phone (916) 255-3113 Fax (916) 255-3015

Each January and February approximately a million pounds of orchard spray insecticides are applied to about half a million acres of orchards in California's Central Valley for control of wood boring insects. Diazinon is the most commonly used dormant spray insecticide. In most winters diazinon is detected in the Sacramento and San Joaquin Rivers following rainfall in January and February. However, not known is the fate of the chemical once transported into the Estuary nor the biological consequences.

In February 1994 the U.S. Geological Survey and Regional Board collected water samples daily from the Sacramento River at the City of Sacramento and from the San Joaquin River at Vernalis for bioassay and pesticide analysis. In addition, water was collected during the first storm from key locations along the principal paths of water movement across the Estuary. Water samples for pesticide analysis were filtered through a 0.7 micron filter, extracted on C_8 solid phase extraction cartridge and eluted with hexane ether for analysis by GC/MS (Crepeau *et al.*, 1994). Chronic seven day *Ceriodaphnia* bioassays were conducted according to U.S. EPA (1994).

Three storms dropped five inches of rain in the City of Sacramento in February (Kuivila and Foe, 1995). On each occasion the flow rate of the Sacramento River increased and a sharp well defined pesticide pulse was observed one to two days later. Baseline pesticide concentrations before storms ranged between 30 and 60 ng/l. Peak concentration during each of the three storms was 393, 193 and 80 ng/l, respectively. Similarly, on the San Joaquin the flow rate of the River rose rapidly after each storm and was also accompanied by a diazinon peak. Prestorm diazinon levels were between 25 and 50 ng/l while storm peaks were 1,070, 375, and 200 ng/l.

During the first storm a pulse of diazinon was followed for 75 miles into the tidal Sacramento San Joaquin Delta Estuary from the City of Sacramento to the City of Martinez. The peak concentration at Sacramento was 393 ng/l and about a week later at Martinez was 120 ng/l. During the same storm a pulse of diazinon was followed in the San Joaquin River from Vernalis to Stockton, some 45 miles. The peak concentration at Vernalis was 1,070 ng/l and about 2 days later at Stockton was 810 ng/l. In both cases as the diazinon pulse moved seaward, the maximum concentration decreased and the pulse dispersed over time because of tidal dispersion.

Bioassays were used to determine the toxicity of pesticide contaminated water. Complete *Ceriodaphnia* mortality was observed in the Sacramento River at the City of Sacramento for three days during the highest diazinon concentrations. No toxicity was noted at any other time. In the San Joaquin River at Vernalis complete mortality was observed in water samples collected for 12 consecutive days. Again, the mortality corresponded with the highest diazinon concentrations. No toxicity was observed in water with diazinon concentrations less than 84 ng/l. These results are consistent with laboratory studies suggesting that diazinon was the primary toxicant.

Diazinon concentrations observed in this and other studies in the Central Valley during the dormant spray season are compared in Table 1 to recommended water quality criteria to protect freshwater aquatic life and to concentrations reported in the literature to kill sensitive freshwater organisms. Diazinon concentrations in surface water often exceed by at least an order of magnitude recommended criteria to protect aquatic life. The concentrations also exceed values reported in the literature to kill a variety of sensitive aquatic organisms present in the Central Valley and Delta suggesting that the runoff may cause impacts to native invertebrates communities. Sites most at risk appear to be water courses in small watersheds near orchards.

Literature cited

Crepeau,K.L, J.L.Domagalski, and K.M. Kuivila. 1994. Methods of analysis and quality assurance practices of the U.S. Geological Survey Organic Laboratory, Sacramento, California--Determination of pesticides in water by solid phase extraction and capillary column gas chromatography/mass spectrometry. OFR-94-362. U.S. Geological Survey, Sacramento, CA..

Kuivila, K.M.and C.G. Foe. 1995. Concentration, transport and biological impact of dormant spray pesticides in the San Francisco Estuary, California. Env. Toxicol. and Chem. 14:1141-1150

U.S. EPA 1994. Short-term methods for estimating the chronic toxicity of effluents and receiving water to freshwater organisms. Third edition. Research and Development (MD-591). EPA-600-4-91-002.

Table 1. Comparison of diazinon concentrations (ng/l) reported in the Central Valley, concentrations reported to be acutely toxic to aquatic life, and recommended criteria to protect freshwater aquatic organisms.

Diazinon Concentrations in Central Valley

Rainfall	Range=100-6,000
Water courses in small watersheds	Mean = 1,000 Peak = 7,000
Sacramento River	Background = 25-40 Peak = 400
San Joaquin River	Background = 30-60 Peak =800-1200

Diazinon Acute Toxicity Data (96 hr LC_{50}) Concentrations[1]

Amphipods (*Gammarus pseudolimnaeus*)	2,000
Water flea (*Sinocephalus serrulatus*)	1,400
Oppossum shrimp (*Neomysis mercedis*)	1,200
Water flea (*Ceriodaphnia dubia*)	400
Water flea (*Daphnia magna*)	210
Amphipod (*Gammarus fasciatus*)	200
Midge (*Chironomus tentens*)	30

Recommended Diazinon Criteria To Protect Freshwater Aquatic Life

Great Lakes Research Council	Maxima=8
National Academy of Sciences	Maxima=9
California Department of Fish & Game	Chronic=40
	Acute=80

---

[1] The 96 hour LC_{50} value is the concentration causing 50 percent mortality in the laboratory within four days.

USE OF VEGETATION TO REDUCE DORMANT SPRAY RUNOFF

Lisa J. Ross
Department of Pesticide Regulation
1020 'N' Street, Room 161
Sacramento, CA 95814
Phone (916) 324-4116; E-mail lross@cdpr.ca.gov

INTRODUCTION

During winter months, many growers in California apply dormant spray insecticides to stone fruit and nut crops to control over-wintering peach twig borer (*Anarsia lineatella*), San Jose scale (*Quadraspidiotus perniciousus*), and mites. Chlorpyrifos (phosphorothioic acid O,O-diethyl O-(3,5,6-trichloro-2-pyridinyl) ester), diazinon (phosphorothioic acid O,O-diethyl O-[6-methyl-2-(1-methylethyl)-4-pyrimidinyl] ester), and methidathion (phosphorodithioic acid S-[(5-methoxy-2-oxo-1,3,4-thiadiazol-3(2H)-yl)methyl] O,O-dimethyl ester), along with weed oil, are the predominant insecticides used to control these pests. The dormant spray season usually occurs from December to February, with the highest applications typically occurring in January.

During the winter of 1991-92, water samples collected in the SJR watershed were found toxic to the water flea, *Ceriodaphnia dubia*, and chlorpyrifos and diazinon were implicated as a potential cause of toxicity. During the winters of 1991-92 and 1992-93, the California Department of Pesticide Regulation conducted monitoring in the watershed and determined that 10, 72, and 18% of the 108 samples collected contained chlorpyrifos, diazinon, and methidathion, respectively. In addition, 2, 13, and 1% of these samples exceeded the *C. dubia* 96-hour LC_{50} for chlorpyrifos, diazinon, and methidathion, respectively. In addition to potential acute toxicity, concentrations measured in between rain events were near the chronic criterion for diazinon, 0.04 μg/L, established by the California Department of Fish and Game to protect freshwater aquatic life.

The predominant source of pesticides in streams and rivers is generally believed to originate from surface runoff. In-field cover crops may be an effective tool for controlling pesticide runoff since they have been employed to decrease soil erosion, improve water infiltration, prevent surface sealing of the soil, and consequently reduce water and sediment runoff. With a decrease in water and sediment runoff, a decrease in the mass of pesticide lost in surface runoff would also be expected. Given the potential for plants to retain pesticides on field, the use of cover crops for reducing dormant spray runoff in orchards was investigated in this study. Cover crops are already in use in California, such as grains to promote water infiltration and clover to promote nitrogen fixation. Therefore, differences in the mass runoff of chlorpyrifos, diazinon, and methidathion were investigated in a peach orchard using three treatments: 1. no seed (bare soil), 2. a clover seed mix and 3. oats (*Avena sativa* L).

METHODS

This study was conducted in a peach orchard, planted in February of 1990, located at the

University of California's Wolfskill Ranch in Winters. Prior to planting, the field was disced and land planed. In the no-seed treatment rows, Roundup®, Surflan®, and Goal® were applied at 2.3, 9.4, and 9.4 L ha^{-1}, respectively, to keep the soil free of vegetation. The clover mix (Table 1) was applied at a rate of 84 kg ha^{-1} and oats at a rate of 106 kg ha^{-1}. The three insecticides were applied together at a rate of 1120 g a.i. ha^{-1}, sprayed with 1,870 L ha^{-1} of water and 3.78 L ha^{-1} of Volk Supreme oil. Applied formulations were: diazinon 50 WP, chlorpyrifos EC, and methidathion 25 WP.

Treatments were assigned to the peach plot in a randomized complete block (RCB) design with three treatments: no seed, clover, and oats (Figure 1). The field was blocked from south to north, along a tree height gradient which resulted from a prior study. Treatment rows used for sampling were surrounded on either side by "buffer" rows treated in a similar manner. "Buffer" rows were not sampled, they simply served as protection against cross contamination between treatment rows.

The concentration of each insecticide deposited in the tree canopy was measured and converted to mass. Mass was analyzed with a RCB analysis of variance, to assure that any row to row differences in runoff were not due to differences in application rates. Results from soil and vegetation analyses were also used in this manner.

Soil and vegetation were collected from each treatment row one week prior to application, on the day of application (day 0), and days 3, 7, 13, 20, 28, and 35 after application. Concentrations were converted to mass and analyzed using a repeated measures RCB design conducted for each insecticide in each medium. Results were examined for significance of block, treatment, and day by treatment terms. Since significant interactions, block, and treatment effects were not found, a model of the change in mass over time for the entire plot was examined for the significance of linear, quadratic, and higher order terms using a lack-of-fit regression analysis.

Rain-runoff water was collected from each treatment row in each block. Water was collected at 30-min intervals during the first two storm events from 0 to 3 hours, and analyzed for all three insecticides. Runoff concentrations and volume were measured in each treatment row. The total mass of insecticide and runoff volume leaving each treatment row was calculated and analyzed with a RCB analysis of variance.

RESULTS

Soil half-lives were 15, 6.4 and 9.6 d for chlorpyrifos, diazinon, and methidathion, respectively (Figure 2). Vegetation half-lives were 8.5 d, 5.7 d, and 4.4 d for chlorpyrifos, diazinon, and methidathion, respectively (Figure 3). Runoff concentrations and mass were highest in no seed, followed by oats, then clover treated rows (Figures 4 and 5). Mass runoff of insecticides in vegetated rows was reduced by as much as 73% over non-vegetated rows (Figure 6). In addition, analysis of variance results showed mass runoff of each insecticide from vegetated rows was significantly lower than runoff from non-vegetated rows. Highest concentrations and mass lost were found in non-vegetated rows, followed by oats then clover. Analysis of filtered vs. unfiltered runoff water indicated that 10%, 44%, and 59% of the chlorpyrifos, diazinon, and methidathion lost from the field was in the dissolved phase, respectively (Figure 6).

Potential mechanisms involved in cover crop reduction of insecticide runoff include reduction in runoff volume, shorter half-lives on vegetation than soil, decrease in insecticide mass with soil borne runoff, and insecticide sorption to plant surfaces. These results should not be extrapolated to other fields and cover crops since partitioning of these insecticides between water and soil and water and plant surfaces may depend on specific soil and plant characteristics. Additional research should focus on the relative importance of each potential mechanism and the partitioning between water and plant surfaces to better define the ideal cover-crop:insecticide combination most effective for reducing runoff.

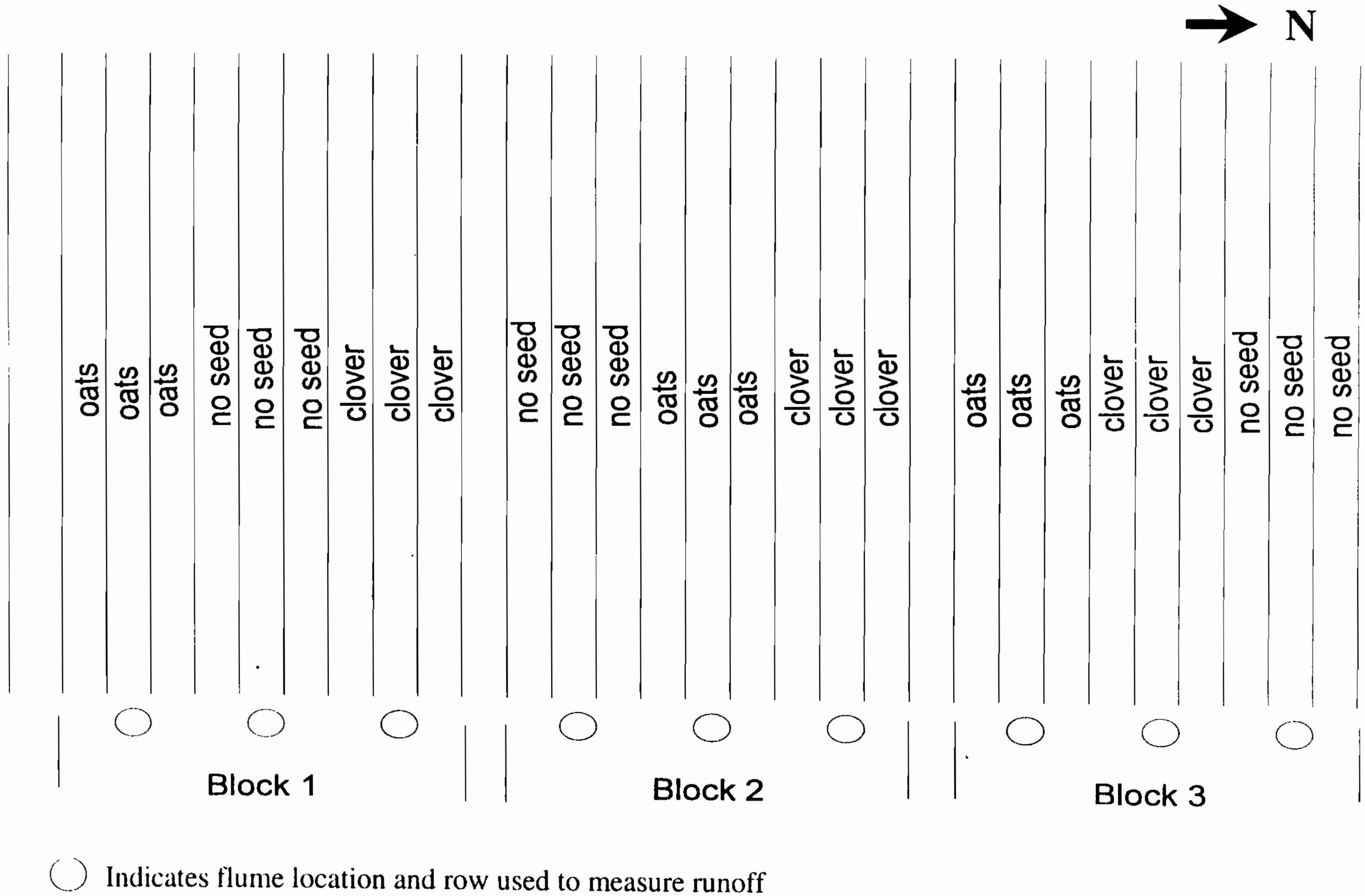


Figure 1. Randomized complete block layout in the peach orchard located in Winters, California.

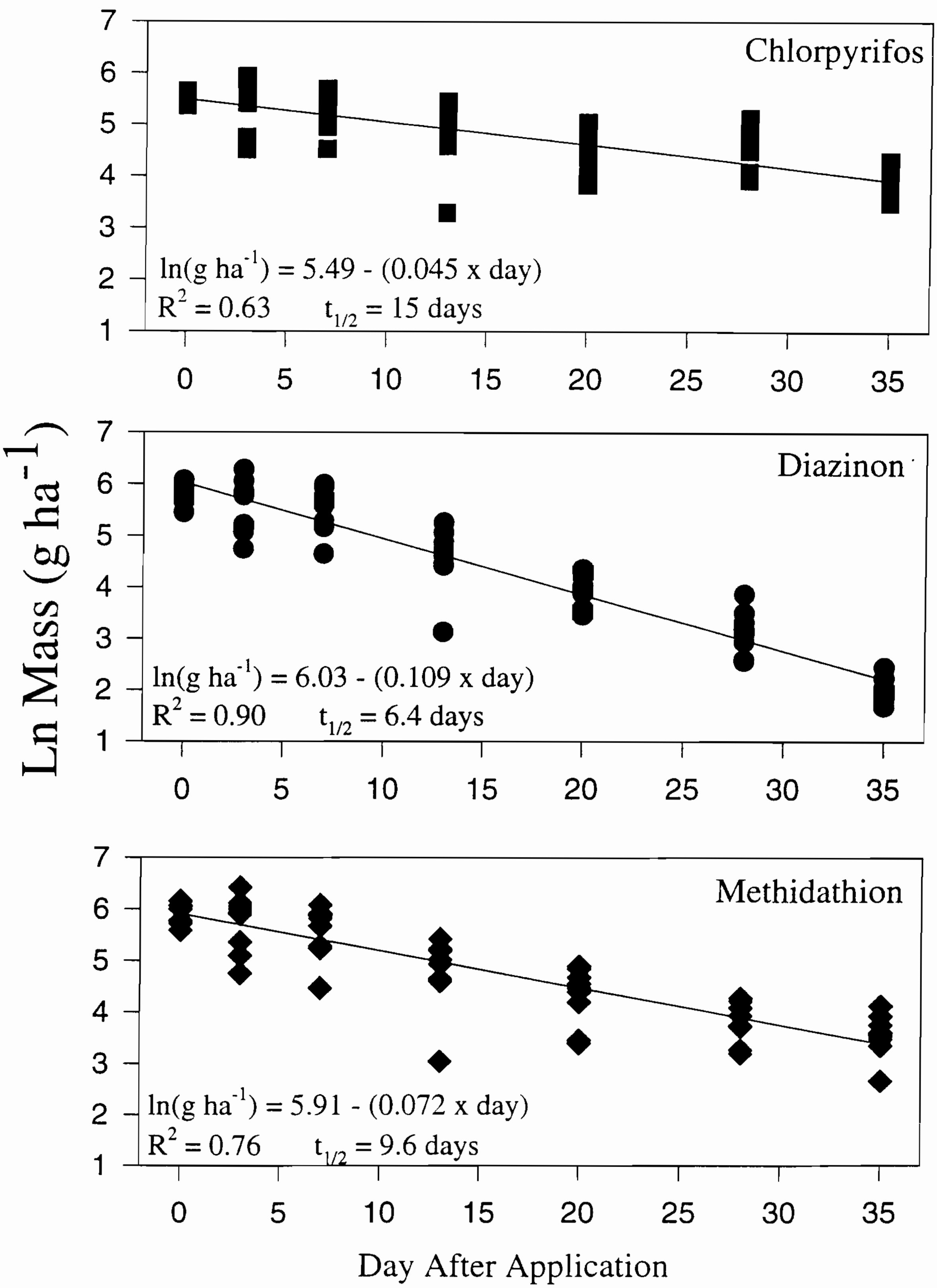


Figure 2. Dissipation of chlorpyrifos, diazinon, and methidathion from soil of the peach orchard.

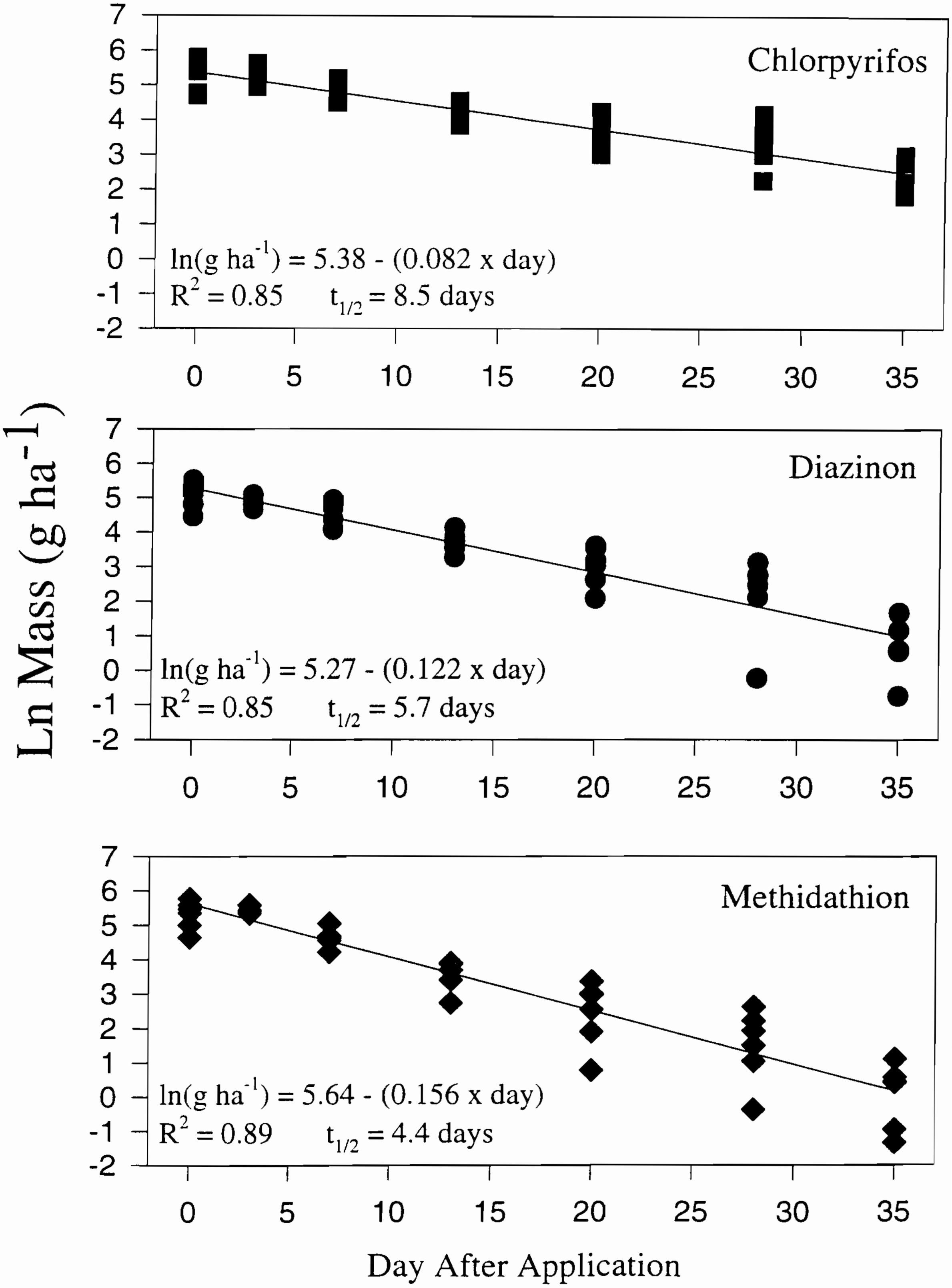


Figure 3. Dissipation of chlorpyrifos, diazinon, and methidathion from vegetation planted on the orchard floor.

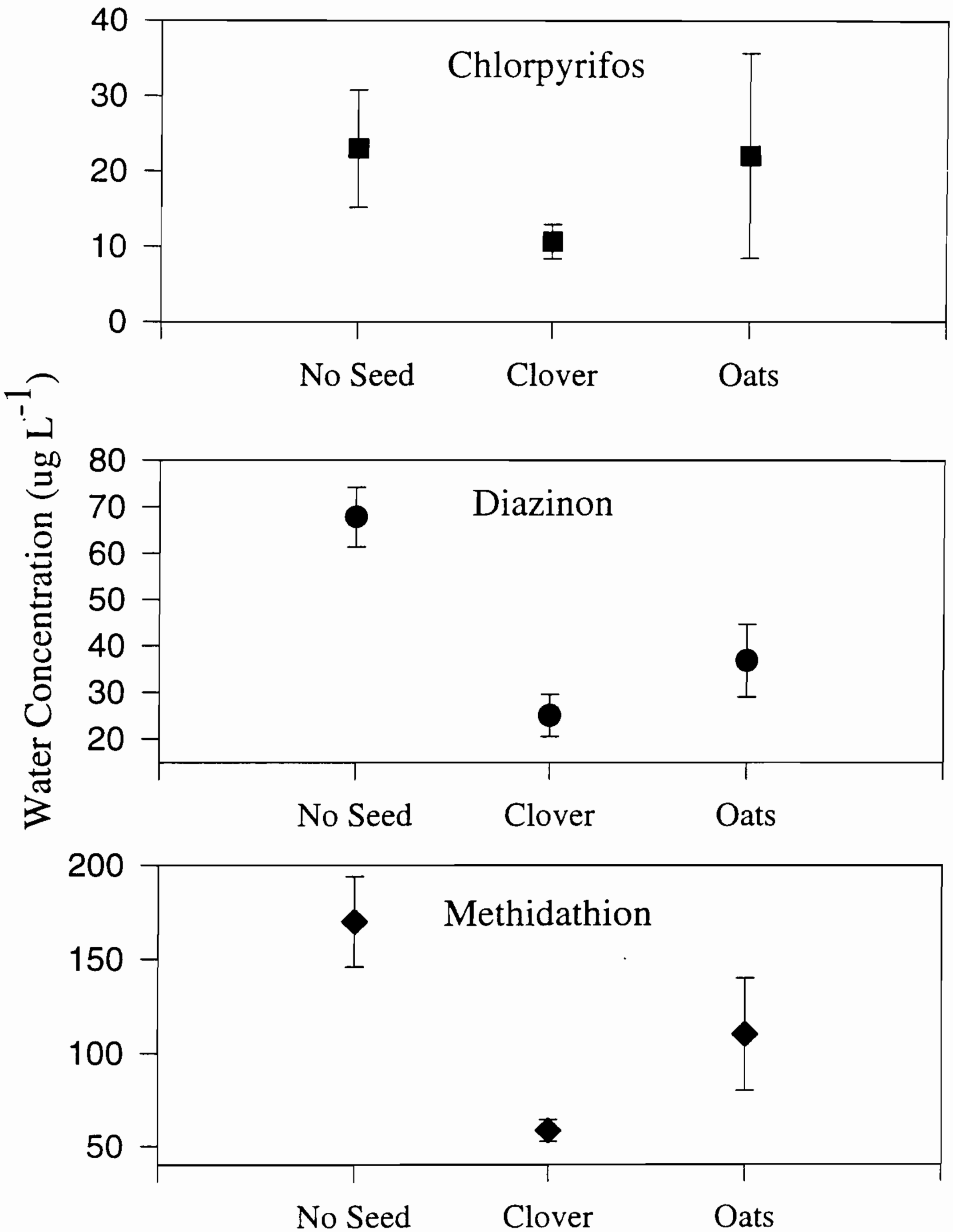


Figure 4 . Runoff concentrations from the first storm. Due to flooding, only data from the first interval are are shown. Each data point is a mean and standard deviation of two blocks.

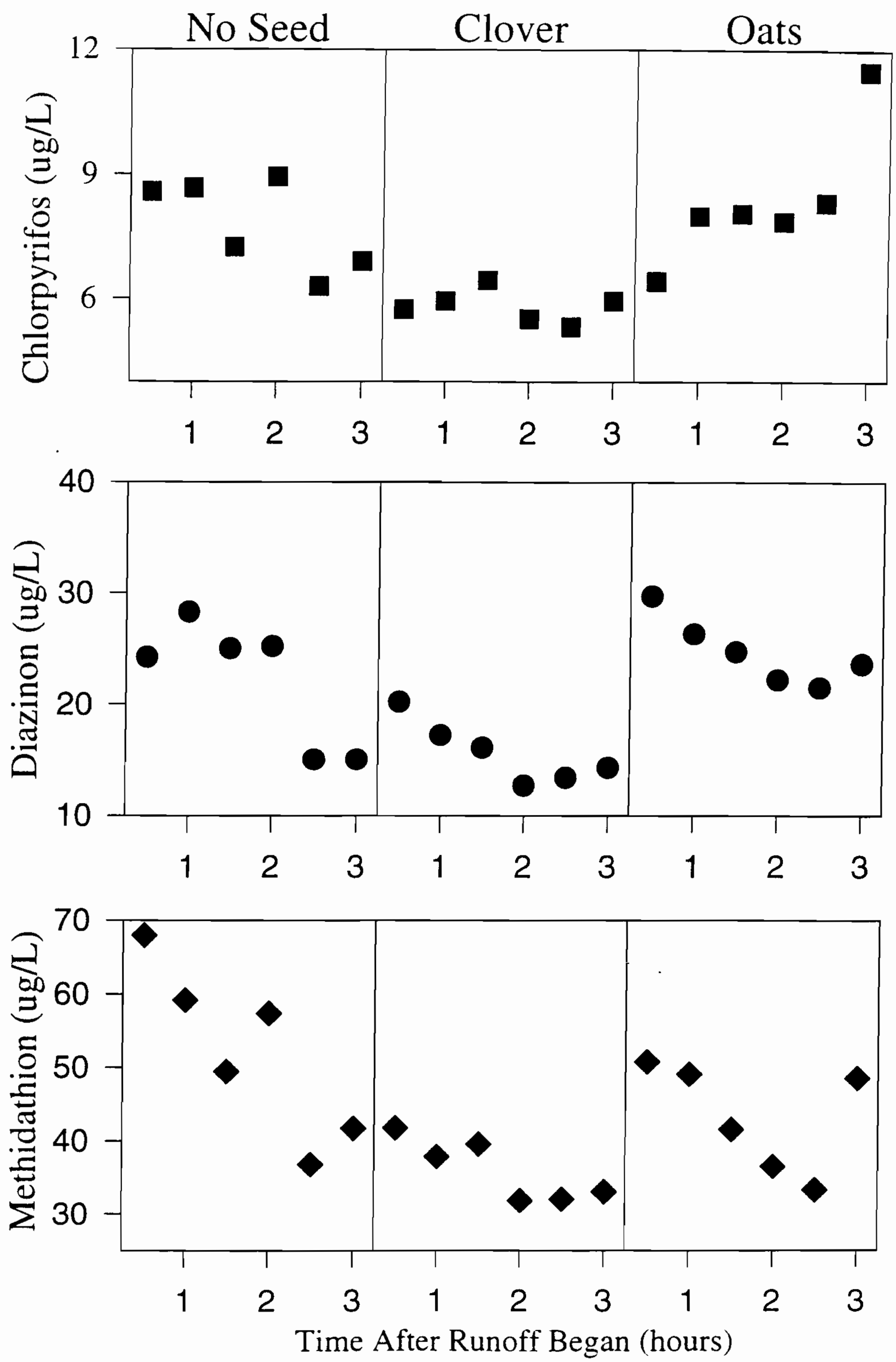


Figure 5. Mean concentration (n=3) of chlorpyrifos, diazinon, and and methidathion in runoff generated during the second storm.

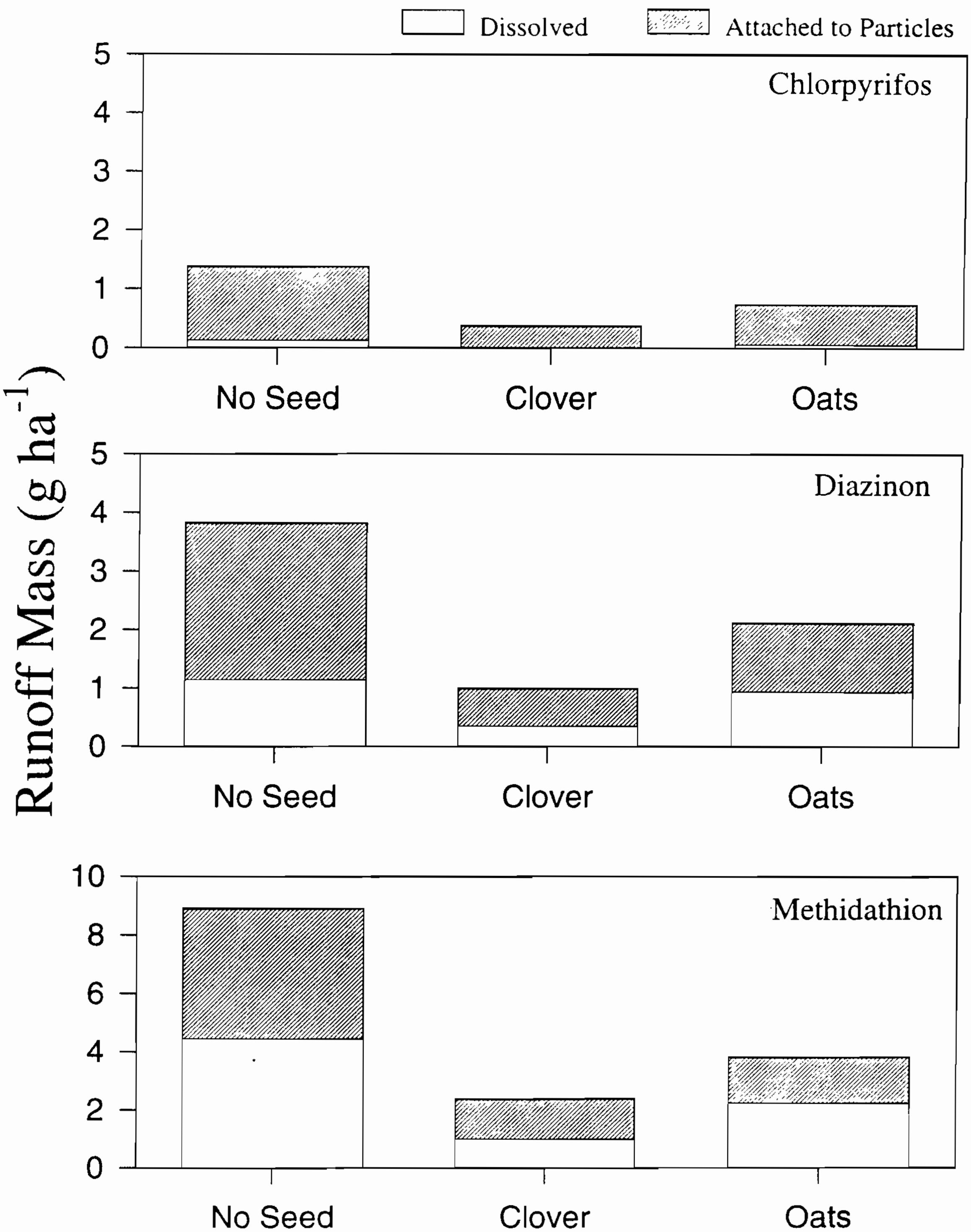


Figure 6. Mass of chlorpyrifos, diazinon, and methidathion dissolved and attached to particles in runoff water generated during the second storm.

The Bt Program to Reduce Dormant Insecticide Use

Carolyn Pickel
UC-IPM Area Advisor, Sacramento Valley
142-A Garden Highway
Yuba City, CA 95991
Phone: (530) 822-7515; E-mail: cxpickel@ucdavis.edu

Introduction

For many years, dormant sprays have been considered the mainstay of an IPM program. They are applied at a time when they target key pests while minimizing the effects on beneficial organisms that are overwintering. Dormant sprays are key to controlling peach twig borer, San Jose scale, overwintering eggs of European red mite, brown mite, mealy plum aphid and leaf curl plum aphid. Typically, the dormant spray includes an oil to provide control of the mite eggs by suffocating them and acting as a carrier for an organo-phosphate to control peach twig borer and San Jose scale, and aphid eggs. Typical insecticides used were parathion (while still registered), diazinon, supracide, lorsban and, more recently, asana, pounce, ambush. Synthetic pyrethroids like asana, pounce, and ambush did not provide as good control of scales as organo-phosphates, although PCA's are not seeing a scale buildup when using these materials over the last few years. Missing a dormant spray can sometimes equate to the application of three or more in-season sprays to control these pests. Applying three or four in-season broad spectrum sprays is detrimental to biological control of mites and other pests that are more active in the growing season.

In the early 1990's, growers and consultants reported dormant treatments were less effective for peach twig borer (PTB) control than in the past. Dormant organo-phosphates have also been implicated in killing raptors, including hawks, overwintering from Canada, in orchards at the time of application. More recently, organo-phosphates have been found in surface water monitoring studies in the Sacramento and San Joaquin River watersheds. Diazinon, lorsban and supracide had been found in concentrations believed to be high enough to cause acute toxicity to some aquatic organisms. Growers have been asked to voluntarily reduce these pesticides from their dormant program.

Methods

The University of California started a research program to develop dormant spray alternatives in the early 1990's. Research conducted in replicated trials on field stations showed that the insect bacteria, <u>Bacillus</u> <u>thuringiensis</u> (Bt), less harmful to the environment and beneficial insects, provided control for peach twig borer. All the commercial Bt products that were the Kurstaki strain provided control when tested in replicated field trials.

A long-term study to document the impact on PTB, other pests and beneficials in commercial orchards was started in 1991 on almonds, peaches and prunes. There was particular concern that once the insecticide treatment was eliminated from the dormant spray, growers would see more problems with San Jose scale, a serious scale pest. Demonstration sites throughout the California Central Valley were followed for three years in 24 to 28 grower applied plots including seven almond, 11 to 14 fresh or cling peach, and six to eight prune orchards, depending on the year. Three treatments were used in each orchard plot. The first treatment was the grower standard organo-phosphate and dormant oil spray. The new treatment applied to five acres was oil without an organo-phosphate plus Bt treatments at popcorn and ten days later. This was usually between full bloom and petal fall. The control treatment was treated by oil only and was between 25 and 100 trees in the corner of the block, away from drift. Bt was applied two times during bloom at the rate of one lb. per acre, generally in combination with fungicides. Three formulations of Bt were evaluated with different products assigned to orchards randomly. Several organic fresh peach blocks did not receive the organo-phosphates and had only two treatments. If treatments for other pests such as disease treatments were necessary, these were applied to all three treatments.

Efficacy data was collected on each treatment for PTB by recording shoot strikes by block for each generation and evaluating 500 to 1000 fruit at harvest. Secondary pests such as San Jose scale, bloom damage from leafrollers, cutworms, and green fruitworms, katydids, and stink bug damage were recorded at harvest. Dormant spur samples were taken from prune orchards to determine the San Jose scale, their parasitism, and prune aphid populations.

Results

The most convincing PTB efficacy data was in 1992 from overwinter shoot strikes counts in six almond blocks. Side-by-side comparison blocks of grower standard dormant, Bt blocks, and untreated showed the Bt blocks had a 64% reduction in shoot strikes compared to a 79% reduction in the grower standards. At harvest, there was no difference in percent PTB damage in either the Bt, which averaged 0.97%, or the standard dormant blocks with 0.76%. During the demonstration project, several growers observed shoot strikes and thought the Bt program was not working. On examination of the strikes it was determined most of these strikes were Oriental fruit moth (OFM), which is not controlled by Bt applications. It is important to monitor shoot strikes and determine species causing damage.

The first year of the Bt program saw an increase in San Jose scale. In most cases, by the second year the scale parasites increased providing no in-season insecticides were applied, then the scales decreased to low numbers. This was determined by taking dormant spur counts from each block and determining the percent infested with scales and the percent parasitized. This sample can be used by all almond, prune and peach growers when using the Bt program. It helps growers make their pest management decision for each block. Collect 100 dormant spurs making sure to get some older wood where the parasitized scale is found and look for the emergence hole on previous summer's scales. Record percent of infested mite eggs, San Jose scale, San Jose scale parasitism and aphid eggs. Compare these records to previous years to plan your pest management decisions for the dormant spray.

In the peach orchards, including fresh and processed, it was found that the Bt provided control for the overwintered generation and, in some orchards, into the next generation. But in many orchards, subsequent generations required a broad spectrum application to PTB. Once in-season sprays are applied, the block loses the benefit of building natural enemies populations. This could create future San Jose scale problems. However, in 1995, PTB pheromone became commercially available, creating a new alternative to use with the Bt program. Putting the two practices together improves control and allows an environment for beneficials to build in the orchard.

For the three years of the demonstration, prune orchards had no problems with PTB, however in the third year, 30% of the orchards began to have severe aphid problems. Research since that time has focused on developing sampling methodology to predict aphid problems that helps growers determine the need for a dormant insecticide. This method could also be used to delineate problem areas in the orchard, allowing spot sprays with dormant insecticides that help reduce dormant insecticides. Preliminary results have found it successful to monitor prune orchards at 75% leaf fall by looking for the aphids returning from alternate hosts. They lay the overwintering eggs that are the target of the dormant insecticide. These aphids are more easily found when there are fewer leaves on the tree since they continue to move to the remaining leaves as they drop.

In both peach and prune orchards the Bt treatments also had less bloom damage. This damage can be caused by five different worm species that feed during bloom that are also killed by Bt. In several orchards, there was 50% less bloom damage with the Bt treatment than with the dormant insecticide treatment which was predominately diazinon and oil.

Conclusion

All of the growers in the demonstration program applied two Bt sprays with their fungicide program, starting with popcorn. But more recent work has shown three Bt sprays are more effective, pointing out that timing Bt sprays on almonds is trickier that other stonefruit crops. This is because it is the first orchard tree to bloom in the spring, and the emergence of PTB from the overwintering hibernaculum may not be as early as popcorn each year when the first fungicide spray is applied. If you are interested in using the Bt sprays and keeping cost down by using only two Bt sprays, timing is critical. The Bt sprays need to be tied to emergence. This can be done by watching hibernaculum and observing when emergence occurs. Some PCAs and Bt companies help growers monitor emergence. Another method, although not as good as monitoring, is to watch the weather at popcorn. If it is cold at the time of the first fungicide, it is highly likely that PTB may not have started emergence. It is than best to wait to apply the first Bt with the second fungicide spray and then the second Bt ten days later. Since peaches and prunes bloom later, the PTB is ready to start emergence as the tree leafs out, making timing less critical. This makes it easy for the grower to add the Bt to their fungicide program.

From our results we found that the Bt program is viable for almond and peach orchards, and many almond growers are using the Bt program when they are unable to get their dormant spray on because of bad weather. Cling peach growers are testing the combination of a Bt bloom program with commercial PTB and OFM pheromone products for mating disruption. Prune growers can sample for aphids during leaf fall each year to determine if they can use the Bt program and be free of aphid problems. Lastly, using the Bt program will help reduce organo-phosphate insecticides in the central valley watershed.

IMPACT OF PYRETHROIDS ON BENEFICIAL MITE PREDATORS

Frank G. Zalom
Department of Entomology and
Statewide IPM Project
University of California
One Shields Ave.
Davis, CA 95616
Phone (530) 752-8350

Douglas Walsh, Dept. of Entomology, UC Davis
Michael Stimmann, Dept of Environmental Toxicology, UC Davis
Carolyn Pickel, UC Cooperative Extension, Yuba City, CA
William Krueger, UC Cooperative Extension, Orland, CA
Richard Buchner, UC Cooperative Extension, Red Bluff, CA
James Brazzle, UC Cooperative Extension, Bakersfield, CA

INTRODUCTION

Several mite species have the potential to cause economic damage in almond orchards. Of special concern are the web-spinning mites which include both the two-spotted spider mite and the Pacific spider mite. Two other spider mite species, the European red mite and the brown almond mite are occasionally present in large numbers, but they are adequately controlled by dormant sprays of Superior type oil. Phytophagous mites can be chronic problems for growers in some areas of the state - even when predatory mites are present - if conditions such as dust or water-stress are favorable for their development. However, spider mite outbreaks often result from the build-up of mites previously kept under control by natural enemies or in some other way induced to increase in abundance. It has been demonstrated that applying in-season sprays for key almond pests such as the peach twig borer or the navel orangeworm with certain pesticides (e.g. carbaryl and permethrin) can cause secondary outbreaks of mites later in the season (Bentley, et al. 1987). If not carefully monitored and treated, spider mites can defoliate trees and reduce the following season's growth and yield.

An integrated mite management program developed by Hoy and others (e.g. Headley and Hoy, 1987), has been successful in reducing acaricide use in many California orchards. This program requires the preservation or release of the western orchard predator mite, *Galandromus (=Metaseiulus) occidentalis* Nesbitt, and combines use of a sampling program and (population) thresholds for predators and spider mites with cautious use of selected insecticides and reduced rates of acaricides as needed. The success of this program can be severely constrained by the introduction of new insecticides which might disrupt the balance of predators and phytophagous mites.

Most dormant season insecticides applied to California almond and stone fruit orchards are for two Lepidoptera pests, the peach twig borer and the San Jose scale. A dormant season application of an oil and an organophosphate insecticide (historically either parathion, diazinon, chlorpyriphos or methidathion) has been the recommended control for peach twig borer and San Jose scale for over 20 years. This tactic was thought to be a nondisruptive practice because it is applied at the time of the year when the natural enemies of other insects are not injured by the spray, and has therefore been considered an important integrated pest management tactic. Virtually all producers of almonds and stone fruits apply an oil and organophosphate dormant spray. Recently, because of concerns for various environmental effects of dormant sprays, many growers have been implementing alternative control tactics including the use of pyrethroid insecticides applied at that time. The relatively lower cost of pyrethroids than other potential controls is also a factor in their use.

METHODS

The residual effect of dormant season applications of esfenvalerate (Asana XL) and permethrin (Ambush 3.2 EC), was determined in an almond orchard in Glenn County. Treatments consisted of current dormant season applications of esfenvalerate, permethrin, and diazinon (Diazinon 4E), and previous year dormant and in-season esfenvalerate treatments and previous year dormant and in-season applications of permethrin. Untreated control trees were also maintained in the completely randomized block. There were 10 treatments total of 8 single tree replicates applied by handgun with buffer trees between each treatment replicate. The trees were sampled for spider mites and predators every 2 weeks beginning in May. Treatments in the plots were applied February 3, 1995, and February 6, 1996, and hull split sprays on July 21, 1995. Treatments consisted of:

1. Asana (Dormant 95)
2. Ambush (Dormant 95)
3. Organophosphate (Dormant 95 & 96)
4. Untreated
5. Asana (Dormant 95) + Asana (Hull split 95)
6. Ambush (Dormant 95) + Ambush (Hull split 95)
7. Asana (Dormant 96)
8. Ambush (Dormant 96)

Sampling was conducted monthly for spider mites and mite predators in the orchard. Cardboard bands were placed around all trees in each treatment before larval emergence, and removed before adult emergence to determine peach twig borer abundance. No subsequent treatments were made in these plots.

Small branches and twigs were cut from all 8 trees in each treatment present on August 24, 1995, and placed into clean mason jars by treatment replicate. The wood was stored at -21C until residue tests and bioassays could be run. The twigs were thawed, and cut into sections about 2 cm long which were chosen from the internodal portion of the twigs to enable more accurate determination of surface area than is possible with buds and nodes. Each section was then immersed in hexane, then placed in a sonic dismembrator and sonicated for 2 minutes to extract the pyrethroids from the plant cuticle. The extracted material was cleaned using solid phase extraction (SPE) chromatography, yielding samples that are almost free of unwanted chemicals such as other pesticides, oils, and waxes. An HP Gas Chromatograph equipped with a robotic autosampler was used for analysis. Using this method, permethrin and esfenvalerate residues could be detected at levels as low as 0.1 ng/mm sq. of bark surface. Bioassays were conducted using the predator mite *G. occidentalis* from a colony established from mites collected in Sacramento Valley orchards. Twigs taken from the samples used for residue analysis were split in half, and placed in Petri dishes lined with water moistened filter paper. *Tetranychus* sp. mites and mite eggs removed from a laboratory colony were brushed onto each twig to serve as a food source for the predator mites. Two adult female predator mites where transferred using a fine paint brush onto each twig. There were 5 twigs per dish and 4 dishes per replicate (40 predator mites total), with 4 replicates of each treatment. Predator mite survival was determined after 48 hours.

On February 9, 1996, small branches and twigs were cut from all eight replicates of each treatment, and residue tests and bioassays conducted as previously described except that the number of *G. occidentalis* eggs was determined in addition to survivorship of the adult females.

RESULTS AND DISCUSSION

Results of the pyrethroid extractions indicated very good efficiency as extraction techniques rarely entirely remove the pesticide residue, especially if it is bound in the plant's waxes or oils. Over 92% extraction efficiency was achieved for permethrin and over 94% from esfenvalerate. We then determined whether the pyrethroid residues were located on bark and/or woody tissue. Location of residues on and within the twigs is important as only the residues that would be exposed to organisms should have biological activity. Our results showed that the residues are almost exclusively associated with the bark, and therefore the surface of the twig. Penetration of the material into the wood does not appear to be a problem. We then attempted to determine the amount of pyrethroid residues in relation to location on twig. Our results indicated some difference in residue between node and internode parts of twigs. However, because the node (bud) parts of twigs probably have more surface area, it was difficult to accurately determine the surface area, and therefore to make comparisons. If greater concentration of residue is present in the node (bud) parts, predator mites (which overwinter in this region) could have greater exposure to the residue. We then attempted to determine whether the pyrethroid residues could easily be washed from bark, as might occur during rain events in winter following the dormant application. In general, pesticides may be extracted with either water alone, water plus a surfactant, or with an organic solvent. Pyrethroid extraction from twigs in our study required an organic solvent. From these data, we can assume that water does not remove significant amounts of the pyrethroids from twigs, and therefore that rainfall including the record amounts obtained this past year would not remove all residue.

Pyrethroid residues from dormant and from hullsplit and dormant applications made earlier in 1995 were present on twigs collected on August 24, 1995. Bioassays on these twigs using the predatory mite, *Galendromus (=Metaseiulus) occidentalis*, to determine survival indicated the amount of both permethrin and esfenvalerate residues present on almond twigs were sufficient to kill the predatory mites placed on the bark.

Results from the February, 1996 samples indicated that residues of both esfenvalerate and permethrin had persisted the entire year since the previous dormant season application (Table 1), and that there remained biological activity during this time. Residues remaining from the one year old dormant spray and a hullsplit spray applied to the same trees was not significantly different from that remaining from the one year old dormant spray alone. By comparison, residue analysis of small branches collected less than 1 day following application yielded higher residues of esfenvalerate and permethrin. In the bioassay of the small twigs collected from these treatments, all esfenvalerate and permethrin treatments resulted in significantly higher predator mite mortality than was observed on the untreated control twigs (Table 2). The diazinon applications resulted in some mortality of predator mites (~15%), but this was not as great as that observed for the various esfenvalerate and permethrin treatments which varied from 24% to 38% for esfenvalerate and from 19% to 42% for permethrin. Similarly, the number of eggs per treatment replicate were also significantly affected relative to the untreated control, and somewhat more by the esfenvalerate treatments than by the permethrin treatments.

Field data collected from these trees indicated that there was a significant effect of the 1996 esfenvalerate and permethrin dormant treatments on spider mites and eggs in early April, but that these differences became less pronounced as the season progressed and mite populations declined.

The residual effect from the prior season was less apparent for the esfenvalerate treatments than for the permethrin treatments. Field data from Kern County (where residues were not taken) clearly showed increased abundance of spider mites during the season in trees treated with either pyrethroid in the dormant season than in trees treated with an organophosphate, *Bacillus thuringiensis* or remaining untreated.

These results indicate that the pyrethroid insecticides esfenvalerate (Asana) and permethrin (Ambush or Pounce), while providing an effective option for control of overwintering peach twig borer, can have long term negative residual effects on predaceous mites on bark where they overwinter and disperse within trees, and short term negative effects resulting from residues on leaves. This effect may persist into the next season and could result in increased spider mite abundance. Therefore, orchards which are treated with pyrethroids, even in the dormant season, should be carefully monitored for spider mites during the subsequent season as there appears to be a greater risk of increased abundance following their application.

Table 1. Mean±SE residues (ng/mm^2) from field applications to almond in February, 1996.

Treatment	cis-permethrin[a]	trans-permethrin[b]	esfenvalerate[c]
Untreated	0.000±0.000 a	0.000±0.000 a	0.000±0.000 a
Diazinon (W95+96)	0.000±0.000 a	0.000±0.000 a	0.000±0.000 a
Asana (W95)	0.000±0.000 a	0.000±0.000 a	0.089±0.036 a
Asana (W95+S95)	0.000±0.000 a	0.000±0.000 a	0.119±0.036 a
Asana (W96)	0.001±0.001 a	0.000±0.000 a	0.610±0.112 b
Ambush (W95)	0.095±0.032 a	0.134±0.047 a	0.000±0.000 a
Ambush (W95+S95)	0.110±0.043 a	0.116±0.022 a	0.000±0.000 a
Ambush (W96)	1.867±0.275 b	1.603±0.184 b	0.000±0.000 a

[a] F=7.938; P<0.0001.
[b] F=32.984; P<0.0001.
[c] F=14.928; P<0.0001.
[d] column means followed by the same letter are not significantly different (P>0.05) by Fishers Protected LSD.

Table 2. Mean±SE number of predator mite adult females and eggs remaining on almond twigs after 48 hours, February, 1996.

Treatment	Adult females [a, c]	Eggs [b]
Untreated	7.96±0.227 a	8.16±0.967 a
Diazinon (W95+W96)	6.52±0.232 b	4.68±0.415 bc
Asana (W95)	6.04±0.313 bc	2.84±0.373 d
Asana (W95+S95)	5.32±0.395 cd	3.28±0.467 cd
Asana (W96)	5.40±0.332 cd	3.40±0.551 bcd
Ambush (W95)	5.04±0.426 d	4.44±0.592 bcd
Ambush (W95 + S95)	6.20±0.306 bc	4.96±0.495 b
Ambush (W96)	5.48±0.448 cd	3.96±0.677 bcd

[a] F=7.590; P<0.0001; n=25.
[b] F=8.212; P<0.0001; n=25.
[c] No sign. difference (P>0.05) in treatment x assay date interaction by 2 way ANOV.
Column means followed by the same letter are not sign. different (P>0.05) by Fishers Protected LSD.

LITERATURE CITED

Bentley, W., F.G. Zalom, W.W. Barnett, and J.P. Sanderson. 1987. Population densities of *Tetranychus* spp. (Acari: Tetranychidae) after treatment with insecticides for *Amyelois transitella* (Lepidoptera: Pyralidae). J. Econ. Entomol. 80: 193-200.

Headley, J.C. and M.A. Hoy. 1987. Benefit/cost analysis of an integrated mite management program for almonds. J. Econ. Entomol. 80: 555-59.

Dormant Sprays, Issues and Alternatives

Walt Bentley and Carolyn Pickel[1]

The traditional dormant spray of an organophosphate insecticide and oil is being closely scrutinized by the California Department of Pesticide Regulation (CDPR) and the State of California Water Resources Control Board. During the past decade problems associated with organophosphate residues being found in fog and in reduced cholinesterase levels in red-tailed hawks have been documented. More recently scientists have been testing water quality in the watersheds of the San Joaquin and Sacramento Rivers. The results of these toxicity tests indicate that residues of chlorpyrifos, diazinon, and methidathion are causing mortality to a key aquatic indicator, the water flea (*Ceridaphnia dubia*). It appears that these residues are related to runoff from orchards treated with dormant sprays. These findings are of major concern to the agriculture industry which must develop measures that mitigate the problems. The CDPR has the authority to regulate the pesticides in question but has instead decided on a voluntary approach to reducing movement of pesticides to surface water.

The application of a dormant spray has long been one of the key pest management strategies for deciduous fruit and nut crops. Its purpose is to manage a number of key pests with a single application, at a time when there is minimal harm to beneficial arthropods, there is no edible fruit on the tree, and worker reentry is at a minimum. The four key pests managed with this spray are peach twig borer (PTB), San Jose scale (SJS), European red mite (ERM), and brown almond mite (BAM). In the case of plums and prunes, the leafcurl plum aphid and the mealyplum aphid are also controlled. Minor pests which are reduced with this spray include fruittree leafroller and soft scales, particularly European fruit lecanium. Are there mitigating measures and alternatives to this very important pesticide timing?

If the application is continued there are some steps that can be used to reduce the potential for contaminated runoff to surface waterways. First of all don't mix and load sprayers near streams, drainage areas or near wells. This is a key point because accidents with the concentrated material can magnify the amount of pesticide found in surface water. Also recent research (Ross et. al.), funded by CDPR, has shown that concentrations in runoff water of the three organophosphates in question, when they were applied in a peach orchard, was lowest where clover cover crops were present during the winter. This was followed by oat cover crop, with the greatest amount of runoff found where no cover existed. The trial did not include resident vegetation. Total runoff of insecticides from the vegetated rows was reduced by as much as 74% in comparison to the rows without vegetation. Other cultural recommendations include providing a 20 foot minimum strip of vegetation along property bordering rivers and streams although the type of vegetation is not specified.

---

[1] IPM Entomologists, University of California; Statewide IPM Project and Cooperative Extension Sutter-Yuba counties, respectively.

A few growers, particularly almond, prune, and peach, are monitoring SJS and PTB to make decisions on whether to spray or not spray. They are not making strictly preventative decisions to spray. Monitoring involves examining the dormant wood and blossoms as well as the use of pheromone traps for each pest. Recent research in almonds and prunes has shown, where disruptive sprays are not applied during the growing season, that SJS parasitism becomes quite high after a two year period and treatments for scale are not always necessary. Similar research has shown that the dormant PTB spray is often not needed although predicting this is not always possible. In the case of PTB, monitoring of bloom strikes in the early spring or twig strikes during late May can be a good general guide to the need for treatment.

Consideration should be given to alternative sprays with less disruptive materials. One of these alternatives is to rely on oil alone during the dormant season for scale and mite egg control. This is possible when no broad spectrum materials are sprayed during the growing season. These sprays reduce natural enemies. This approach may be best for almonds in that less effective control provided by the oil would not result in unmarketable fruit. Dropping the dormant organophosphate will probably not work for apples, plums, pears, or late harvested nectarines, apricots, and peaches. The oil application will do nothing to reduce PTB numbers in these crops or aphids on apples, plums and prunes. For control of PTB applications of *Bacillus thuringiensis* (Bt) would be required during the emergence period in the spring. This approach requires a minimum of two sprays and, in years of prolonged PTB emergence, three sprays. These sprays can best be timed by monitoring spring emergence of PTB from the hibernaculum. Monitoring of fall aphid eggs is necessary to determine if organophosphate should be included for them.

New classes of chemistry are also becoming available. One of these has been the registration of spinosad (Success®) which is a natural metabolite of a soil bacterium. Numerous trials have demonstrated the activity of this material against PTB when applied during the dormant season. It also possesses low environmental risk. Unfortunately this pesticide is not active against SJS or ERM. There are newer materials known as synthesized insect growth regulators which have shown excellent SJS control in field experiments. Although not currently registered in California they should be available soon. Two of these are buprofezin (Applaud®) and CGA 59205 (Arbor®). Besides excellent efficacy against SJS these materials are not likely to be cross resistant to the organophosphate or carbamate insecticides.

Although not a traditional insecticide, mating disruption (also known as mating confusion) for PTB has become more and more common. Best results have been achieved with this technique in stonefruit orchards which are isolated from other orchards hosting great numbers of PTB. In particular mature and nonsprayed almond orchards provide sources of moths which mate and then fly into stonefruit orchards resulting in infested fruit. Also, where PTB populations are historically high, the inclusion of either a dormant oil and organophosphate or the application of Bt is necessary. Either of these sprays will reduce PTB numbers giving disruption a better chance of success. Mating disruption requires the hanging of dispensers containing the pheromone when moths first fly in the spring and again 90 days later. To be effective manufactures guidelines must be strictly followed. It is more costly than applying the dormant spray. Also monitoring of twig strikes in May and pheromone monitoring during the season must be accomplished to evaluate efficacy of the technique. This approach will not help in the management of aphids in crops such as plums, prunes, and apples.

Another alternative is not applying the organophosphate and oil dormant spray but to treat for these pests during the growing season. This does have obvious disadvantages in that multiple sprays are required, coverage is more difficult, timing is more critical, and these treatments result in the disruption of biological control. This alternative does allow you to judge the need of the spray through monitoring for pests during the spring. As described above, blossom and twig strikes can be counted and pheromone traps used to monitor both male PTB and male scale in effort to judge the need for treatment. Care must be taken to evaluate leaf curling by aphids.

There are workable alternatives to the dormant spray and workable methods of reducing contaminated runoff water to surface streams. To make these techniques work careful monitoring, application and timing are required. This does take time and money but the results can be as effective as those achieved by traditional dormant sprays.

Publications are available which describe monitoring techniques and spray timing methods. The first is the *IPM Pest Management Guidelines* produced by the State Wide IPM Program. Is available on the Internet <http://www.ipm.ucdavis.edu/>. The second is Publication 3308, *Integrated Pest Management For Almonds* produced by the University of California Statewide Integrated Pest Management Project. A third is California Agriculture, Volume 47 (5), September-October 1993 entitled *Insect Pathogen "Bt" controls peach twig borer in fruits and almonds.*

BEST MANAGEMENT PRACTICES FOR NUTRIENT MANAGEMENT IN ARIZONA

Charles A. Sanchez
Yuma Agricultural Center
The University of Arizona
6425 W. 8th Street
Yuma, Arizona 85364
Phone (520)-782-3836; E-mail sanchez@ag.arizona.edu

A large portion of the leafy salad vegetables produced in the United States during the winter months are grown in the low desert region of southern Arizona and southern California. The area of land cropped to vegetables in Arizona has increased over the past 15 years. For example, in Yuma county, Arizona, vegetables harvested from 13,000 hectares in 1980 had a farm gate value of 130 million dollars. By 1995, vegetables were produced on 27,000 hectares and had a farm gate value exceeding 500 million dollars. However, with this increased production of salad vegetables, concerns about nitrate contamination of groundwater have also increased. Land cropped to vegetables often receives more N fertilizer than land cropped to agronomic crops because of rigid produce quality standards enforced by the market, more frequent cropping, inadequately calibrated soil and plant tissue tests, and generally poorer irrigation efficiencies.

The Arizona Legislature has mandated the implementation of Best Management Practices (BMP's) by Arizona growers to reduce the potential risks of N fertilization to ground water. (ADEQ). This program involves a "General Permit" issued by the State Attorney General to all regulated agricultural activities in Arizona which implement BMP's. The general permit does not require an application, fees, or reporting, and is valid as long as there is compliance with BMP's. Growers found to be in violation of the general permit are subject to enforcement, including possible revocation of the general permit. If the general permit is revoked, a grower will be required to apply for an individual permit under the Arizona Aquifer Protection Program. These statutes enacted in 1986 are enforced by the Arizona Department of Environmental Quality. However, limited information was available on suitable BMP's for vegetable production in the desert.

Over the past seven years, we have been conducting research programs aimed at 1.understanding the potential for nitrate-N contamination associated with vegetable production in the desert, and 2. developing and testing BMP's for desert vegetables. The first component of the research program involved water quality monitoring to obtain an understanding of the scope and magnitude of nitrate-N ground water contamination. This component also involved studies of solute transport using biologically conserved tracers (such as Br) and ^{15}N to assess potential for N leaching. The second component of the research program involves a number of studies aimed at developing management practices that achieve efficient N utilization. This program includes evaluation and calibration of soil and plant testing criteria for low desert vegetables. This program also includes evaluation of alternative N management strategies involving variables of rate, placement, timing, and source. Additionally, we are evaluating the impact of irrigation practices on N utilization efficiency.

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

Project title:
Evaluation of pre-sidedressing soil nitrate testing (PSNT) to determine N requirements of cool-season vegetables

Project location:
Commercial farms in the Salinas and Santa Maria Valleys

Project Leader:
T.K. Hartz. Extension Specialist, Department of Vegetable Crops, University of California, Davis, CA 95616, (916) 752-1738)

Cooperators:
Craig Reade and Lynn Wierdsma, Betteravia Farms, Santa Maria

Bob Martin, Rio Farms, King City

Warren Bendixen, Farm Advisor, UCCE Santa Barbara County, Santa Maria

Objectives:
a) Evaluate the use of pre-sidedress soil nitrate testing (PSNT) to estimate sidedress N requirement of cool-season vegetables.
b) Document the accuracy of an on-farm soil 'quick test' for NO_3-N determination.
c) Survey commercial vegetable fields in the Salinas and Santa Maria Valleys to determine the range of soil NO_3-N concentrations common at the time of first sidedressing.
d) Conduct outreach efforts to disseminate results.

Summary:

It is generally acknowledged that intensive vegetable production as practiced along California's central coast contributes to nitrate pollution of groundwater. Heavy fertilization of two or more crops per year is the norm; annual fertilizer N input is commonly twice as high as N removal in harvested product. Soils in vegetable rotations also tend to be quite active in cycling organic N into mineral forms (NH_4-N and NO_3-N) available for plant growth. In vegetable fields it is common to find high soil NO_3-N concentration persist throughout the cropping season. In-season soil NO_3-N testing could identify fields with high residual soil NO_3-N levels, helping growers determine field-specific sidedress N requirements. This approach has been researched extensively in the Midwest for corn production; called the pre-sidedressing soil nitrate test (PSNT), it is now in widespread commercial use. This project proposed to adapt the PSNT technique to coastal vegetable production, and to refine a simple analytical technique for on-farm soil NO_3-N analysis.

A total of 10 field trials were conducted in commercial vegetable fields in the 1996 season; 4 were planted in head lettuce, 2 each in cauliflower, celery, and broccoli. Planting dates were staggered from late March to mid-August. All fields were sprinkler irrigated to establish the crop, then switched to furrow irrigation to complete the season. Fields were chosen that had soil NO_3-

N at or above 20 PPM NO_3-N prior to the first sidedress N application, as measured by an on-farm 'quick test' procedure; the test procedure is described in Appendix 1.

The nitrogen fertilization program in each field was determined solely by the participating growers. In each field two levels of reduced N application were established by skipping one or more sidedress N applications. These reduced N treatments, with replicate 4 bed wide by 100 ft long plots in each quadrant of the field, were compared with adjacent plots receiving the growers' full N program.

Periodic plant and soil sampling was done to document N status throughout the season. Soil samples (2-12 inches) were collected at each sidedressing and at harvest; NO_3-N concentration in 2N KCl extracts was determined by conventional laboratory analysis. Petiole (broccoli and celery) or midrib (cauliflower and lettuce) samples, as well as whole plant samples, were collected prior to the second sidedress N application and at harvest. After oven drying, the petioles and midribs were analyzed for NO_3-N concentration, the whole plant samples for total biomass and total N content.

Plots were harvested by experienced personnel from commercial harvest crews. Harvested plants were evaluated for size and condition based on established market standards. Celery and lettuce fields were harvested once, broccoli and cauliflower either once or twice, depending upon the percentage of plants ready for harvest on the first evaluation date.

A survey of commercial vegetable fields was conducted to determine typical soil NO_3-N concentration at the time of first sidedress application. More than 20 fields in the Salinas, Santa Maria and Oxnard areas were sampled from May through August, 1996. Composite soil samples (2-12 inches depth) were collected by field quadrant immediately prior to the first scheduled sidedress N application. NO_3-N concentration, in 2N KCl extracts of moist soil, was determined by standard laboratory technique. Some of these soil samples, plus others from the field trials, were also analyzed for NO_3-N by the quick test technique. The results of the two analytical methods were compared to document the accuracy of the quick test technique.

Eliminating one or both sidedress N applications had no effect on marketable lettuce yield in any field (Table 1); in each field the no sidedress N treatment received a seasonal total of no more than 110 lb N/acre. The very low fertilizer N total of the no sidedress treatment in field 1 (40 lb N/acre) may be misleading, since the irrigation water used on that field contained substantial NO_3-N, adding a seasonal total of approximately 60 lb N/acre. In field 3 the plots receiving no sidedress N could be visually distinguished by lighter color at harvest; late season soil NO_3-N was also low (< 5 PPM), yet yield was unaffected.

In both celery trials the grower fertilization program, somewhat higher than the industry norm, featured 4 sidedress applications; to ensure that an N regime far below industry standards was evaluated the reduced N treatments skipped 2, 3, or all 4 sidedress applications. Even in the lowest N treatments, which received only 206 (Field 1) or 114 lb N/acre (Field 2), crop yield (expressed either as mean plant weight or plant size distribution) was unaffected (Table 2). Similarly, N treatment had no effect on leaf color or degree of pithiness of the stalks.

Skipping the first sidedress N application did not reduce crop productivity in any broccoli or cauliflower trial (Tables 3 and 4). For each crop, one of the field trials showed no adverse effects from skipping 2 sidedress applications, while in the other trial this lowest N treatment did reduce crop yield. In the cauliflower (Field 2) trial this yield reduction cannot be attributed directly to lack of N application, since even the low N treatment received more than 250 lb

N/acre; rather, aggressive irrigation on the light textured soil undoubtedly reduced N availability through leaching. The modest yield reduction in the broccoli (Field 2) trial may have been more directly related to limited N supply, but even here it would be wrong to interpret these results to suggest that the 108 lb N/acre was insufficient for maximum productivity. In this trial all N was applied either preplant or just after emergence, more than 60 days before harvest. Repeated irrigation, and several fall rains, provided ample opportunity to leach NO_3-N before the period of peak N demand (just prior to harvest). The same seasonal N rate, applied later in the season, may have performed better.

Taken together, these trials clearly demonstrate that, in fields with substantial residual soil NO_3-N concentration (> 20 ppm), early season sidedressing is not required for optimum crop performance. The agronomic success achieved in most fields in treatments where several sidedress applications were eliminated is further corroboration that there is substantial opportunity for reducing fertilizer input in coastal production of cool-season vegetables.

Maintaining high productivity with seasonal N applications of 100 lb/acre or less may seem unlikely, but a rough N budget analysis can be instructive. Soil NO_3-N concentration of 25 ppm represents approximately 100 lb N/acre in the top foot, 150 lb N/acre in the top 18 inches. Net N mineralization rates of 1.0-1.5 lb N/acre per day have been documented in medium texture coastal vegetable soils; in a 70 day crop mineralization of organic N could add 70-100 lb of available N/acre. Given the NO_3-N concentration common in irrigation water, between 15-30 lb N/acre could be added during a cropping season. Clearly, a crop such as lettuce, which normally contains less than 120 lb N/acre in its total biomass at harvest, could be well supplied at very modest N fertilization rates provided that irrigation was efficiently applied, minimizing leaching losses.

The commercial field survey documented that high levels of soil NO_3-N at the time of the first sidedress N application is common. Of the 21 fields sampled, only 3 had soil NO_3-N less than 20 PPM; eight fields were 40 PPM or more. Caution is appropriate in interpreting these results. This survey concentrated on late spring-summer planted fields; fields planted in early spring would typically have much lower NO_3-N soil levels due to the effects of leaching winter rains. Also, a substantial portion of the soil NO_3-N measured in this survey undoubtedly represented N fertilizer applied preplant or through sprinklers following crop emergence. However, the main point to emphasize is that, at the time the growers were preparing to make large sidedress N applications, the majority of these fields did not need additional N, and would not for weeks to come; as the field trials demonstrated, a number of these fields would not require any additional N to achieve maximum yield and quality. In-season soil sampling is a crucial part of efficient N management. The soil NO_3-N quick test proved to be a valuable tool for assessing soil NO_3-N status. Across a wide range of NO_3-N concentrations the quick test was closely correlated with conventional laboratory analysis ($r^2 = 0.82$). Accuracy may be further improved by the use of a battery-operated colorimeter which eliminates the error associated with visually estimating the intensity of color of the test strip..

Additional field trials are underway in Oxnard, Santa Maria, and the Salinas Valley. By the end of the 1997 season a total of at least 18 separate field trials will have been conducted evaluating the PSNT approach to N management.

Table 1. Response of head lettuce to varying nitrogen regimes.

	N treatment	Total N (lb/acre)	% of plants[z] 24's	30's	Culls	Average head wt. (lb)	Leaf color [y]
Field 1	grower practice	240	94	2	4	2.3	18.6
	skip sidedress 1	140	95	2	3	2.3	19.2
	skip sidedress 1 and 2	40	95	1	4	2.2	18.7
			ns	ns	ns	ns	ns
Field 2	grower practice	210	92	5	3	2.5	18.7
	skip sidedress 1	160	94	4	2	2.4	19.3
	skip sidedress 1 and 2	100	93	4	3	2.5	18.9
			ns	ns	ns	ns	ns
Field 3	grower practice	232	93		7	2.1	18.1
	skip sidedress 2	165	93		7	2.1	18.1
	skip sidedress 1 and 2	102	94		6	2.1	16.0
			ns		ns	ns	*
Field 4	grower practice	277	82	11	7	2.0	23.3
	skip sidedress 1	210	83	11	6	2.0	22.6
	skip sidedress 1 and 2	110	85	11	4	2.1	23.0
			ns	ns	ns	ns	ns

[z] sized by standard commercial categories, in head count per 50 lb net wt. box

[ns] treatment means not significantly different at p = .10

* no sidedress treatment mean significantly different at p = .10

Field 1. Loam texture, seeded March 12. Sprinkler irrigated, final irrigation delivered by furrow; 40 lb N/acre (as AN-20) applied through sprinklers after emergence. 2 sidedressings of 100 lb N/acre each (as UN-32). Harvested 6/7/96. Soil NO_3-N at first sidedress = 21 ppm.

Field 2. Sandy loam texture, seeded March 28. Germinated with sprinklers, furrow irrigated; 60 lb N/acre preplant, 40 lb N/acre (as AN-20) applied through sprinklers. 2 sidedressings of a total of 110 lb N/acre (as AN-20). Harvested 6/14/96. Soil NO_3-N at first sidedress = 29 ppm.

Field 3. Sandy loam texture, seeded April 23. Germinated with sprinklers, furrow irrigated; 60 lb N/acre preplant, 40 lb N/acre (as AN-20) applied through sprinklers. 2 sidedressings of a total of 130 lb N/acre. Harvested on 7/10/96. Soil NO_3-N at first sidedress = 28 ppm.

Field 4. Loam texture, seeded April 27. Germinated with sprinklers, furrow irrigated; 70 lb N/acre preplant, 40 lb N/acre (as AN-20) applied through sprinklers. 2 sidedressings of a total of 170 lb N/acre. Harvested on 7/16/96. Soil NO_3-N at first sidedress = 47 ppm.

Table 2. Response of celery to varying nitrogen regimes.

	N treatment	Total N (lb/acre)	% of plants[z] 18's	24's	30's	36's	48's	Small	Average head wt. (lb)	Leaf color[y]
Field 1	grower practice	517	2	51	26	16	3	3	2.3	32.6
	skip sidedress 1 and 3	310	5	60	20	14	2	2	2.4	33.4
	skip sidedress 1, 2 and 3	206	1	54	23	17	2	3	2.3	33.9
			ns	ns	ns	ns	ns	ns	ns	ns
Field 2	grower practice	535	2	26	36	29	5	1	1.8	31.8
	skip sidedress 1 and 3	329	5	20	40	27	8	1	1.9	33.8
	skip all sidedress	114	5	21	35	30	8	1	1.8	31.1
			ns	ns	ns	ns	ns	ns	ns	ns

[ns] treatment means not significantly different at p = .10

[z] sized by standard commercial categories, in head count per 60 lb net wt. box

[y] relative leaf color of canopy leaves, as measured by leaf reflectance meter

Field 1. Loam texture, transplanted 7/22/96. Sprinkled in, furrow irrigated. Preplant application of 55 lb N/acre; 42 lb N/acre (AN-20) applied through sprinklers. Four sidedress applications of a total of 420 lb N/acre, of various N sources. Harvested 10/28/96. Soil NO_3-N at first sidedress = 43 ppm.

Field 2. Loam texture, transplanted 7/9/96. Sprinkled in, furrow irrigated. Preplant application of 71 lb N/acre, 42 lb N/acre (AN-20) applied through sprinklers. Four applications of a total of 421 lb N/acre, of various N sources. Harvested 10/15/96. Soil NO_3-N at first sidedressing = 35 ppm.

Table 3. Response of broccoli to varying nitrogen regimes.

	N treatment	Total N (lb/acre)	% of plants Crowns[z]	Bunch[z]	Small	Average head wt. (lb)
Field 1	grower practice	372	14 b[y]	5	81	0.86
	skip sidedress 1	283	24 a	2	74	0.81
	skip sidedress 1 and 2	202	13 b	2	85	0.84
			*	ns	ns	ns
Field 2	grower practice	314	23 a	12	65	1.4 a
	skip sidedress 1	208	20 a	13	67	1.3 a
	skip sidedress 1 and 2	108	15 b	14	71	1.1 b
			*	ns	ns	*

*, ns treatment means significantly different, or not significantly different at p = .10

z 'crowns' and 'bunch' represent different types of commercial packs; cosmetic standards for crowns are higher than for bunch

y mean separation among N treatments by Duncan's Multiple Range Test, p = .10

Field 1. Sandy loam texture, seeded 6/13/96. Germinated with sprinklers, furrow irrigated. Preplant application of 51 lb N/acre; 42 lb N/acre (AN-20) applied through sprinklers. Three sidedress applications of a total of 241 lb N/acre, mostly UN-32. Late season water-run application of AN-20 at 39 lb N/acre. First harvest 8/19/96. Soil NO_3-N at first sidedressing = 36 ppm.

Field 2. Loam texture, seeded 8/15/96. Germinated with sprinklers, furrow irrigated. Preplant application of 68 lb N/acre; 40 lb N/acre (AN-20) applied through sprinklers. Two sidedress applications (UN-32) of a total of 206 lb N/acre. Harvested 11/26/96. Soil NO_3-N at first sidedressing = 47 ppm.

Table 4. Response of cauliflower to varying nitrogen regimes.

	N treatment	Total N (lb/acre)	% of plants[z] 9's	12's	16's	Small	Average head wt. (lb)
Field 1	grower practice	284	9	47	23	22	2.2
	skip sidedress 1	184	9	59	13	19	2.2
	skip sidedress 1 and 2	84	7	52	20	21	2.2
			ns	ns	ns	ns	ns
Field 2	grower practice	405	4	38	39	19	1.8
	skip sidedress 1	333	2	40	31	26	1.6
	skip sidedress 1 and 2	262	1	32	41	27	1.3
			ns	ns	ns	ns	*

[ns] treatment means not significantly different at p = .10

* grower practice and no sidedress treatment means significantly different at p = .10 by orthogonal contrast

[z] sized by standard commercial categories, in head count per 30 lb net wt. box

Field 1. Loam texture, transplanted 7/5/96. Sprinkled in, furrow irrigated. 42 lb N/acre preplant, 42 lb N/acre (AN-20) applied through sprinklers. Two sidedressings of UN-32 at 100 lb N/acre each. First harvest 9/3/96. Soil NO_3-N at first sidedress = 18 ppm.

Field 2. Sandy loam texture, transplanted 5/17/96. Sprinkled in, furrow irrigated. Preplant application of 82 lb N/acre, 42 lb N/acre applied through sprinklers. Three sidedressings of a total of 239 lb N/acre; late season water-run application of AN-20 at 42 lb N/acre. First harvest 7/17/96. Soil NO_3-N at first sidedress = 30 ppm.

Controlled Release Fertilizers in Celery Production

Warren E. Benedixen
University of California, Santa Maria, California

Santa Maria valley has been targeted as a nitrate sensitive area. Celery is a crop with a potential for high nitrate leaching because it requires high N fertilization, frequent irrigations, a shallow root system, and a high cash crop value.

The use of controlled release fertilizers can significantly reduce the nitrogen leaching hazard especially during high rainfall winter months. The advantage of controlled release fertilizers is that the nitrogen release pattern is based on temperature and time. The amount and frequency of water applications has little effect in nitrogen releases.

PROCEDURES:

Two celery fertilizer trials were established in commercial celery fields west of Santa Maria. The fields had been cropped to vegetables for many years.

Each fertilizer treatment was replicated four times in a randomized block design with each plot 50 feet long and four beds wide. The two center beds, 25 feet long, were harvested for yield. Ten plants per plot were collected at random from the harvested boxes to evaluate the nutrients removed by the crop.

Petiole samples were collected during the growing season to compare nitrogen levels between treatments. The trials were harvested, graded for size, and boxed by the commercial harvest crews.

Ranch 2

A celery fertilizer trial was established on January 5, 1996 to compare 7 fertilizer treatments. Three controlled release fertilizers were applied pre-transplant at the rate of 125 and 250 pounds of nitrogen per acre. The plots with 125 pounds of nitrogen received an additional sidedress application of 100 pounds of nitrogen per acre. The standard commercial fertilizer treatment received a pre-transplant application of 30 pounds of nitrogen per acre (6-20-20) and 3 sidedress applications for a total of 260 pounds of nitrogen per acre. All of the plots received a sprinkler application of 40 pounds of nitrogen per acre 14 days prior to harvest.

Prior to the fertilizer trial at the time the beds were established, all of the plots received 30 pounds of nitrogen and 100 pounds of phosphorous and potassium (3-10-10).

The variety, Conquistador, was transplanted on January 8, 1996. The trial was harvested on April 30, 1996.

Ranch 6

The second celery fertilizer trial was established on February 2, 1996 to compare 5 fertilizer treatments. Two controlled release fertilizers were applied pre-transplant at the rate of 80 and 160 pounds of nitrogen per acre. The plots with 80 pounds of nitrogen received an additional sidedress application of 80 pounds of nitrogen per acre. The standard commercial fertilizer treatment received a pre-transplant application of 30 pounds of nitrogen per acre (6-20-20) and sidedress applications of 8-8-8, for a total of 210 pounds of nitrogen per acre. Fertigation applications of 30 pounds of nitrogen per acre were applied on May 1, 14, and 28, through the drip tape on all the plots.

All of the treatments received 2 tons/acre of chicken manure prior to bedding-up. During bedding-up, 21 pounds of nitrogen per acre was applied as 3-10-10. On March 30, 1996, the controlled release fertilizer treatments received a sidedress application of 90 pounds per acre of phosphorus and potassium as 0-8-8.

The variety, Conquistador, was transplanted on February 23, 1996. The trial was harvested on June 11, 1996. The soil type is a Corralitos loamy sand.

RESULTS:

Ranch 2

The celery yields were high, ranging from 77,376 to 96,270 pounds per acre. Celery yields and stalk size is shown in Table 1. The celery yields were not significantly different between the three controlled release fertilizers. The three controlled release fertilizer treatments with 250 pounds of nitrogen produced significantly higher celery yields than the plots with 125 pounds of nitrogen. The standard commercial fertilizer plots produced the lowest yield and the smallest size stalks. During the early growth stages, the celery was smaller and a lighter green color in the commercial fertilizer plots.

The celery stalks were graded as 24, 30, and 36 stalks per box. The celery size distribution was the major factor affecting yields.

Nine nutrients were analyzed on the harvested plants. The analysis showed no statistical difference between treatments in the percent of nutrients. The percent nitrogen ranged from 2.725 in the Duration treatment of 250 pounds of nitrogen, to 2.350 percent for the standard commercial fertilizer.

The nine nutrients reported in pounds per acre removed in the harvested crop are shown in Table 3. The celery crop removed 86 to 124 pounds of nitrogen per acre. The pounds of nutrient removed, was affected more by the yield than the percent nutrients in the plant.

Table 5 shows the celery petiole NO_3-N levels for 4 sample dates. There are no significant differences between the various fertilizer treatments. Additional petiole samples collected near harvest on April 25, 1996 ranged from 6755 to 8218 ppm in NO_3-N with no statistical difference between treatments. The low values near harvest shows the plants are using most of the applied nitrogen.

Soil samples collected at harvest showed no significant difference between treatments in NO_3-N values. The NO_3-N values ranged from 9-17 ppm in the 0"-6" depth, 6-17 ppm in the 6"-12" depth, 6-17 ppm in the 6"-12" depth, 14-20 ppm in the 12"18" depth and 11-21 ppm in the 18"-24" depth.

Ranch 6

The celery yields on ranch 6 were higher than ranch 2. Celery yields and stalk size is shown in table 2. The yields ranged from 104,819 to 115,659 pounds per acre. The celery yields were not significantly different between the two controlled release fertilizers. The two controlled release fertilizers at 160 pounds per acre produced significantly higher celery yields than the plots with 80 pounds of nitrogen. The standard commercial fertilizer produced the lowest yield. During early growth stages the celery was smaller and a lighter green color in the commercial fertilizer plots.

The stalks were graded into 18, 24, and 30 stalks per box. There was a trend for the higher yielding treatments to produce larger stalks.

Nine nutrients were analyzed on the harvested plants. The analysis showed no statistical difference between treatments in the percent of nutrients. The percent nitrogen ranged from 2.625 for Duration at 160 pounds of nitrogen to 2.450 percent for the standard commercial fertilizer.

Table 4 shows the nine nutrients in pounds per acre removed in the harvested crop. The celery crop removed 110-130 pounds of nitrogen per acre. Celery yields account for the major difference in the pounds of nutrients removed.

The celery petiole NO_3-N values for four sample dates is shown in table 6. The NO_3-N levels are low in the first sample date (4/12/96). The low value of 4,808 ppm NO_3-N for the standard fertilizer treatment is below the deficiency level (5,000 ppm). The downward trend of the petioles NO_3-N from 5/3/96 to 5/6/96 shows the celery is utilizing most of the applied nitrogen.

Soil samples were not collected following the celery harvest because the field was being disked as the celery crop was harvested.

TABLE 1. CELERY YIELD AND SIZE DISTRIBUTION

Fertilizer		Nitrogen Lbs/Acre	Yield Lbs/A	Size Distribution		
				24	30	30
				% of Stalks		
Duration	27-9-9	250	96,270 A	50.7 AB	47.9	1.4 B
Scotts 25	25-7-11	250	96,332 A	55.0 A	40.5	4.0 B
Scotts 24	24-7-7	250	95,273 A	53.5 A	41.3	5.3 B
Duration	27-9-9	125	89,323 B	45.9 AB	44.6	9.6 B
Scotts 25	25-7-11	125	88,759 B	45.3 AB	48.4	6.3 B
Scotts 24	24-7-7	125	90,355 B	42.7 AB	47.1	10.2 B
Commercial		300	77,376 C	24.1	52.7	23.2 A
					NS	

Ranch 2

Duncan Multiple Range Test - Data numbers represented by the same letters are not significantly different at the 5% level.

Size Distribution Data on size 30 values are not significantly different at the 5%

TABLE 2. CELERY YIELD AND SIZE DISTRIBUTION

Fertilizer		Nitrogen Lbs/Acre	Yield Lbs/A	Size Distribution		
				18	24	30
				% of Stalks		
Duration	27-9-9	160	115,659 A	41	92	24
Scotts 25	24-7-7	160	114,916 A	36	100	22
Duration	27-9-9	80	108,011 BC	32	98	26
Scotts 24	24-7-7	80	109,049 B	35	87	31
Commercial		300	104,819 C	23	86	45
				NS	NS	NS

Ranch 6

Duncan Multiple Range Test - Data numbers represented by the same letters are not significantly different at the 5% level.

Size Distribution Data values are not significantly different at the 5% level.

TABLE 3. CELERY NUTRIENTS REMOVED IN HARVESTED CROP

Fertilizer		N Lbs/A	Nutrients Pounds/Acre								
			N	P	L	Ca	Mg	Zn	Mn	Fe	Cu
Duration	27-9-9	250	124 A	37.5 A	298 A	72.5 A	16.5	.112	.294 A	.459 A	.018
Scotts 25	25-7-11	250	107 B	33.0 BC	283 AB	64.4 ABC	15.6 AB	.099	.181 B	.460 A	.017
Scotts 24	24-7-7	250	109 B	32.9 BC	282 AB	63.9 BC	15.1A B	.112	.147 C	.455 A	.017
Duration	27-9-9	125	106 B	31.7 BC	255 CD	60.9 BC	14.6 BC	.101	.153 BC	.426 B	.017
Scotts 25	25-7-11	125	102 B	34.1 AB	277 ABC	69.0 AB	15.2 AB	.101	.142 C	.424 B	.018
Scotts 24	24-7-7	125	102 B	32.2 BC	265 BCD	67.0 AB	15.2 AB	.095	.165 BC	.431 B	.016
Commercial		300	86 C	29.3 C	252 D	58.4 C	13.3 C	.100	.017 D	.369 C	.017
								NS			NS

Ranch 2
Duncan multiple Range Test - Data numbers represented by the same letter are not significantly different at the 5% level.
Data values for Zn and Cu are not significantly different at the 5% level.

TABLE 4. CELERY NUTRIENTS REMOVED IN HARVESTED CROP

Fertilizer		N Lbs/A	Nutrients Pounds/Acre								
			N	P	L	Ca	Mg	Zn	Mn	Fe	Cu
Duration	27-9-9	160	130 A	31.1 A	188 A	34.4	11.6	.306	.075 AB	.157 A	.014
Scotts 24	24-7-7	160	128 A	30.3 AB	184 A	35.6	11.8	.288	.082 A	.156 A	.015
Duration	27-9-9	80	121 AB	29.7 ABC	184 A	36.3	11.5	.360	.068 BC	.147 BC	.013
Scotts 24	24-7-7	80	119 AB	28.1 BC	175 AB	32.6	10.7	.371	.062 C	.148 B	.013
Commercial		300	110 B	27.0 C	166 B	31.0	10.7	.357	.052 D	.42 C	.011
						NS	NS	NS			NS

Ranch 6
Duncan Multiple Range Test - Data numbers represented by the same letter are not significantly different at the 5% level.
Data values for Ca, Mg, Zn, Cu are not significantly different at the 5% level.

TABLE 5. CELERY PETIOLE NO_3-N PPM

Fertilizer		Nitrogen Lbs/A	Petiole NO_3-N PPM			
			4/3/96	4/9/96	4/17/96	4/29/96
Duration	27-9-9	250	12,625	13,734	10,374	8,109
Scotts 25	25-7-11	250	10,900	11,550	9,825	7,100
Scotts 24	24-7-7	250	9,338	10,898	9,556	6,925
Duration	27-9-9	125	10,470	11,069	9,140	7,128
Scotts 25	25-7-11	125	12,503	11,790	10,064	7,427
Scotts 24	24-7-7	125	10,125	11,033	9,465	8,275
Commercial		300	13,725	14,249	12,033	7,725
			NS	NS	NS	NS

Ranch 2
Statistical Analysis showed no significant difference between treatments at the 5% level.

TABLE 6. CELERY PETIOLE - NO_3 N PPM

Fertilizer	Nitrogen Lbs/A	Petiole NO_3-N PPM			
		4/3/96	4/9/96	4/17/96	4/29/96
Duration 27-9-9	160	9,465 A	12,115	8,214	5,673
Scotts 24 24-7-7	160	8,495 A	11,878	8,007	5,636
Duration 27-9-9	80	7,268 B	12,356	7,821	5,613
Scotts 24 24-7-7	80	7,652 B	12,738	8,270	5,624
Commercial	300	4,808 C	12,015	7,489	5,673
		NS	NS	NS	NS

Ranch 6
Duncan Multiple Range Test - Data numbers represented by the same letter are not significantly different at the 5% level.
Statistical analysis showed no significant difference between treatments at the 5% level ON 5/6/96, 5/28/96 AND 6/3/96.

DEVELOPING SITE-SPECIFIC INFORMATION FOR CROPPING SYSTEMS IN CALIFORNIA

G. Stuart Pettygrove[1], R.E. Plant[2], R.F. Denison[2], J.A. Young[2], S.K. Upadhyaya[3], M.D. Cahn[4], E.M. Miyao[5], and T.E. Kearney[5]

[1]LAWR, University of California, One Shields Ave, Davis CA 95616-8627, 530-752-2533, gspettygrove@ucdavis.edu; [2]Dept. of Agronomy & Range Science, UC Davis; [3]Dept. of Biological and Agricultural Engineering, UC Davis; [4]UC Cooperative Extension, Sutter Co.; [5]UC Cooperative Extension, Yolo Co.

INTRODUCTION

The potential for site-specific farming (SSF) has not been investigated for irrigated crops in diverse rotations common in California. Our goal is to determine information requirements for SSF. Specific objectives are:

1. In commercial fields, measure the variability of yield of irrigated wheat (1996), processing tomatoes (1997), and other crops grown in the same rotation.
2. Within individual fields, determine the relationship of crop yield to soil and plant characteristics as observed in aerial photographs and plant and soil samples.
3. Assess the potential for site-specific farming in a Sacramento Valley tomato-field crop rotation and communicate with growers and allied businesses.

DESCRIPTION

We are monitoring the performance of crops in three commercial fields of 77, 78, and 108 acres in the lower Sacramento Valley. The soil textures are mainly clay loam, silty clay loam, and silty clay, and the fields generally are difficult to irrigate uniformly. The fields were cropped to wheat ('Express') in 1995-96 and to tomatoes in 1997. Wheat yield was measured continuously with an Ag Leader™ yield monitor/GPS combination retrofitted on the grower's harvester. Tomato yields were measured in July-August 1997 using a prototype load cell/GPS yield monitor mounted on one of the grower's harvesters. Yields were calculated by weighing fruit at frequent time intervals on a section of the conveyor belt that discharges into the trailer. Distance traveled during each interval was determined by GPS. Output from the load cells was calibrated with weigh wagon data collected during the harvest. The tomato yield monitor was developed by S.K. Upadhyaya and M. Pelletier, Dept. of Biological and Agri. Engineering, U.C. Davis, with financial support from the California Tomato Research Institute. Color infrared aerial photographs were taken in each year, once when the soil was bare and three times during the cropping period. Soil and plant samples were collected on a 200 ft x 200 ft grid or approximately one sample per acre. Digitized aerial images, plant tissue and soil data, and yield monitor data from the wheat crop were compiled in an ArcView® file. Tomato yield data analysis is in progress.

RESULTS - WHEAT

Several examples of whole-field variability are presented here. Two are from the 1996 wheat crop, and a third is from one of the 1997 tomato fields.

The first example shows that in one field, wheat grain yield and leaf N content at the early jointing stage were correlated (Fig. 1).

In this field, the grain yield of 2,940 lb/acre was about half the county average; however, some areas of the field yielded above 6,000 lb/acre.

The main reason for low yield was the effect of heavy rains during the 1995-96 winter on the aeration status of the slow-draining Capay silty clay – the predominant soil in the northern two-thirds of the field. In the higher-yielding part of the field, the predominant soils (Brentwood and Yolo) have a similar surface texture but lack the impervious subsoil of the Capay. In the areas with Capay soil, plants were small and poorly tillered.

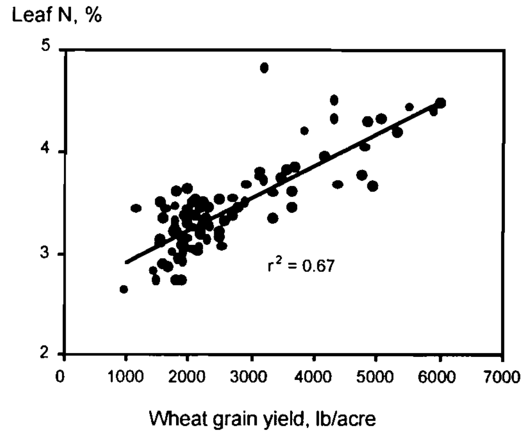


Fig. 1. Wheat leaf total N content versus yield in 77-acre field. Yields are averages for the 25 x 25-ft^2 area nearest each leaf sample location. Various researchers in other states suggest a sufficiency value at early jointing of 3.0-3.5% N.

It is likely that wheat in the areas with saturated soil was not able to obtain sufficient N due to a smaller root system and a greater loss of N from the soil. An aerial application of urea on February 25 resulted in green-up that was visible in a May color infrared aerial photo as streaks running perpendicular to the beds. Initially, we did not observe any pattern in the yield monitor data that corresponded to these streaks. Subsequent analysis did reveal correlation of grain yield spatial patterns to those of the infrared band of the color infrared photo in some areas of the field (Fig. 2). The comparison of yield and color infrared aerial photo patterns was made difficult by GPS error in the yield monitor and the fact that more than one factor (plant tillering, soil color, amount of bare soil exposed) apparently contributed to the photo color values. The yield fluctuations suggest that non-uniform or low N fertilizer topdressing caused a loss of 600-1000 lb/acre grain yield in some areas of the field.

One management scenario would be to use plant N analysis (or chlorophyll meter readings) to identify the most N-deficient areas of the field, then apply a fluid fertilizer such as urea or urea-ammonium nitrate solutions only to the area needing treatment instead of to the entire field. Uniform application of the fertilizer, which would often be applied by airplane in this situation, appears to be important.

RESULTS – TOMATOES

Analysis of tomato yield monitor data is still in progress at this time. Weigh wagon data collected in one field for yield monitor calibration purposes are shown in Figure 3.

The data were collected over a 28-acre area of a 78-acre field. The weigh wagon was pulled along side the grower's harvester and received fruit that had passed through the normal field sorting. In the monitored area, weigh wagon yields averaged 37.67 ton/acre. The grower's average yield for the larger 78-acre field was 34.6 ton/acre. The weigh wagon yields were recorded at 100-ft intervals on parts of 15 beds in an area with 240 beds. Only data from a 700- to 900-ft portion of each row was measured, in part because the weigh wagon capacity was insufficient to receive the fruit from an entire quarter-mile long row. Also, the harvester had to travel at least 100 ft into the field before the flow of tomatoes into the weigh wagon became stable.

There was no obvious spatial dependence in the single-row average yields, shown at the top of figure 3, i.e.; variation in yield appears to be randomly distributed. Within beds, there is also not much obvious spatial structure or dependence. The reasons we do not see much large-scale variability are probably the following:

1. Fruit from high- and low-yielding areas of a bed is intermingled due to the split flow path of fruit in the harvester;
2. "Piling up" of fruit in the harvester tends to smooth yields;
3. Due to variable length of time of fruit in the harvester, difficulty of reading the weigh wagon at night in the field, and limits in the weigh wagon accuracy when it is moving, the yield value and its location on the ground are not known with great precision.

The yield monitor under development does not address the first two problems, but it will provide spatially more frequent and more reliable weight values than the weigh wagon.

The factors that potentially reduce tomato yields within a field probably occur in patches 100-200 feet wide or less or in long, narrow areas. These causes include the following:

1. Furrow irrigation non-uniformity;
2. Cultivation/fertilization practices carried out with three-bed equipment;
3. Pest problems or stand skips that generally occur in small patches.
4. Soil texture variation that occurs in relatively narrow streaks.

The weigh wagon data are too sparse to detect variations caused by these factors. The weigh wagon data show that over a scale of several hundred feet, tomato yields are fairly uniform compared to the 1996 wheat yield from this field (not shown). But more closely spaced yield monitor data are needed to determine if the above-listed causes of variation may have influenced yield.

ACKNOWLEDGEMENTS

Cooperation and assistance of the following individuals is gratefully acknowledged: Tony Turkovich and Martin Medina, Button & Turkovich, Winters), Jiayou Deng, Victor Huey, and the UC DANR Analytical Laboratory. Funding was provided by Calif. Dept. of Food and Agriculture Contract #95-0518.)

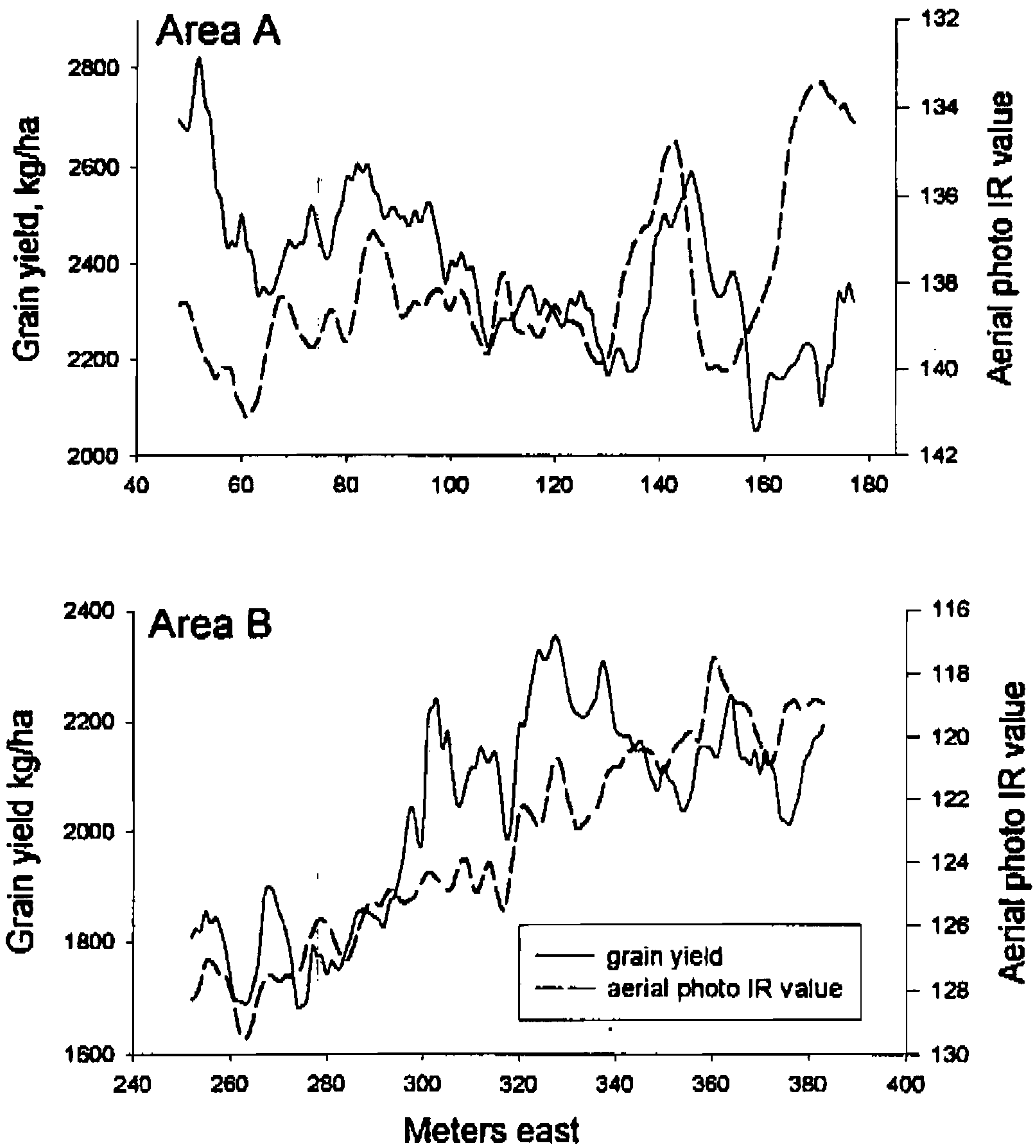


Figure 2. Grain yield and aerial photo IR values during grain fill. Transects are averages of four harvest swaths, each 8 m wide, selected from areas of the field where stripes can be seen in the aerial photo.

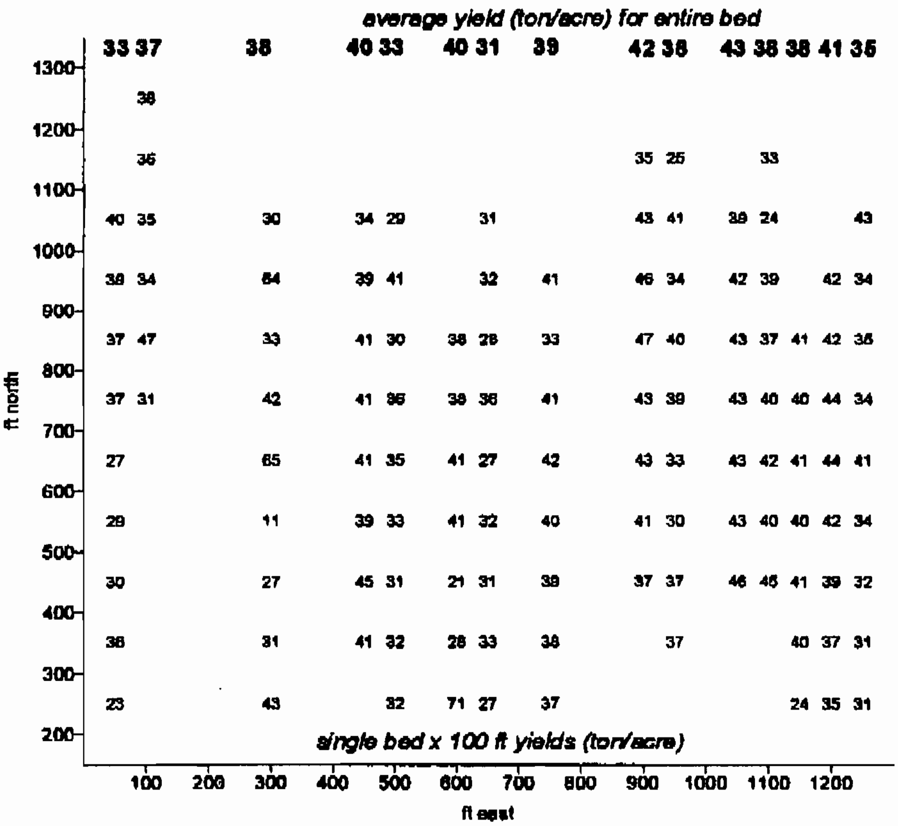


Figure 3. Processing tomato yields (cv. 'Brigade') in a 28-acre area of a larger field. Individual yield points were determined in a one-row x 100 ft area with a weigh wagon receiving fruit from the grower's harvester.

DETERMINING BEST NITROGEN MANAGEMENT FOR BROCCOLI PRODUCTION IN THE SAN JOAQUIN VALLEY

Michelle Le Strange, UC Cooperative Extension, 2500 W. Burrel Ave, Visalia, CA 93291
Phone: (209) 733-6366 E-mail: mlestrange@ucdavis.edu

Jeffrey P. Mitchell, UC Kearney Agricultural Center, 9240 S. Riverbend Ave, Parlier, CA 93648

Louise E. Jackson, University of California, Vegetable Crops, Davis, CA 95616-8746

INTRODUCTION

Broccoli is a crop that can create a high potential for nitrate leaching losses because it requires high N inputs, tends to be irrigated frequently, has a relatively shallow root system, and is a high value crop. There is also a tendency to add excess nitrogen since it is apparently not harmed by excessive nitrogen. Although several broccoli field research projects have been conducted over the years in California to investigate fertilizer timing and amounts, only a few have been grower directed and none have investigated the movement of nitrate from nitrogen fertilizer applications performed under San Joaquin Valley growing conditions.

The objectives of this research are: to determine nitrogen fertilizer best management practices (BMPs) for broccoli production in the San Joaquin Valley; to determine if BMPs change for fall versus spring harvested broccoli; to identify nitrate movement and potential nitrate leaching losses of applied nitrogen fertilizer under furrow irrigation; and to evaluate the effectiveness and utility of the Cardy meter for quick test nitrate values for decision making in broccoli nitrogen management during fall and spring growing seasons.

MATERIALS AND METHODS

Three of four nitrogen fertilizer field tests have been planted and harvested at the UC West Side Research and Extension Center in Five Points, CA. Two plantings were grown for a spring harvest and two are aimed for a fall harvest. Thirteen nitrogen treatments focused on nitrogen need and crop response and investigated nitrate leaching, using preplant, single, and double sidedress applications. Five treatments use low nitrogen levels at preplant and first sidedress with double rates applied as a second sidedress application.

Data measurements include sampling petioles and whole plants at key stages of broccoli production: thinning, rapid vegetative growth, button formation, preharvest, and postharvest. Petiole samples are subject to laboratory analysis and nitrate quick testing. Total nitrogen content is determined from whole plants. Potassium chloride extracts of soil samples collected at five depths down to 150 cm from each plot prior to planting and postharvest were analyzed for nitrate content. Ion exchange resin bags buried at 45 and 90 cm were used to estimate nitrate leaching by collecting nitrate from the soil water solution as it passed through the soil profile. Yield and quality characteristics are also assessed.

PRELIMINARY FINDINGS

New information on nitrogen utilization and fertilization of broccoli in the San Joaquin Valley has been obtained in these field studies. Due to adequate nitrogen depletion in the soil before the trials began, it was possible to observe the effects of a wide range of nitrogen availability to spring and fall harvested broccoli. Overall, the effects of nitrogen stress were: delayed head development, decreased weight per head, but not number of heads per plant, and decreased yield (approximately 30 to 40 percent lower in non-fertilized broccoli). Some yield response differences were noted between spring and fall harvested crops.

In terms of total seasonal nitrogen application, including two sidedress applications, yields were statistically similar at application rates between 180 and 300 lbs N/acre, despite higher values at the highest fertilizer rate. Preplant nitrogen was critical to yield: 45 to 90 lbs/acre applied preplant produced maximum yield; 240 lbs/acre preplant or as an early sidedress reduced yield in the fall crop but not in the spring crop. In all comparisons of the same total nitrogen rate, higher yields or equally high yields were obtained in a single sidedress compared to two sidedress applications.

A useful indicator for sufficient nitrogen application was dry petiole nitrate nitrogen. Higher values were observed in treatments with more than 120 lbs N/acre as were yield averages. Like yield, dry petiole nitrogen showed little response to the higher nitrogen application rates (except when a very large amount was applied as a sidedress). Readings of nitrate concentrations in the fresh petiole sap made with the handheld Cardy meter showed similar trends, but were less indicative of treatment differences.

Postharvest soil samples revealed nitrate nitrogen increased as fertilizer rate increased leaving large deposits of nitrate in the soil profile at the high fertilizer rates. Largest deposits were found below the root zone when 180 to 240 lbs N was applied preplant or as a single sidedress. Some differences between fall and spring crops were observed.

At all but low nitrogen rates, nitrate appears to have been leached below the crop root zone. There was a tendency toward greater leaching below the root zone with higher N application, especially when applied preplant or as a single sidedress. Lesser amounts of nitrate appear to leach below the root zone when comparing one fall field test to one spring field test (results from other studies are still being analyzed).

CONCLUSION

By taking a systems approach to evaluate crop performance as well as soil nitrogen fates and losses, this study is showing that best management practices for fertilizer scheduling must consider the relative benefits of adding excess fertilizer as well as the relative costs of leaching nitrate. The completion of the field studies will clarify these relationships.

ROLE OF NONCROP VEGETATION IN PEST MANAGEMENT

L. E. Ehler
Department of Entomology, University of California,
One Shields Avenue, Davis, CA 95616-8584
530/752-0484, FAX 2-1537, E-mail leehler@ucdavis.edu

INTRODUCTION

Noncrop vegetation can play an important role in management of insect pests of agricultural crops in California. Such vegetation can be either naturally occurring (e.g., riparian habitats, roadside weeds) or deliberately planted by growers (e.g., hedgerows, cover crops). Insects utilize noncrop vegetation primarily for overwintering and for food. As this holds for both pests and their natural enemies, noncrop vegetation can represent a mixed blessing for the grower. It may also require extra maintenance. Thus, it is not surprising that many growers are reluctant to commit resources to maintaining noncrop vegetation on their own property.

In many of our annual crops, noncrop vegetation is the source of the initial colonizing insects whose populations will develop in the agroecosystem during the growing season. This is very different from a perennial crop where insects can overwinter in the target agroecosystem. Other crops can of course be important reservoirs for colonizing insects, and thus are important elements of "farmscape ecology." The literature on the role of noncrop vegetation is too extensive to cover in the limited amount of time available, so I will restrict my remarks to two research projects that illustrate some of the current issues involved.

MANAGEMENT OF STINK BUGS

There are five species of stink bugs (Hemiptera: Pentatomidae) that can be a problem on row crops such as tomato, Bell pepper and bean in the Central Valley. These are consperse stink bug (*Euschistus conspersus* Uhler), red shouldered stink bug (*Thyanta pallidovirens* [Stal]), Uhler's stink bug (*Chlorochroa uhleri* [Stal]), conchuela stink bug (*C. ligata* [Say]), and southern green stink bug (*Nezara viridula* [L.]). Consperse stink bug is usually the most common. All but one (*N. viridula)* are native to California. These bugs overwinter as diapausing adults in protected places, including any noncrop vegetation that provides a suitable refuge. During the growing season, there are at least two generations. The first typically develops on noncrop vegetation following the winter rains; then, as the spring habitat dries up, adults that will initiate the second generation migrate to agricultural crops. Such migration can be devastating to a crop such as tomato grown for fresh market. On the west side of the San Joaquin Valley, for example, sudden influxes of adult *C. uhleri* that developed on nearby Russian thistle (*Salsola australis* R. Brown) have been of serious concern to growers in recent years. Stink bugs are less of a problem in processing tomatoes.

For the past three years, I have investigated the ecology of these stink bugs at a field site near the Sacramento River in Yolo County. This site consists of an agricultural field planted to tomato for processing that is bounded on two sides by riparian vegetation, on one side by a Interstate on/off ramp, and on one side by an Interstate highway. The riparian vegetation is dominated by blackberry (*Rubus* spp.), and is believed to serve as an overwintering refuge for the stink bugs. The first generation, however, develops primarily on weeds growing along the Interstate right-of-way. The most important weedy species are common mallow or cheeseweed (*Malva neglecta* Wallr.), black mustard (*Brassica nigra* [L.] Koch), perennial pepperweed (*Lepidium latifolium* L.) and wild radish (*Raphanus sativus* L.). All five stink-bug species commonly occur in this habitat; however, during the second generation of bugs, the main pest species in adjacent tomato is consperse stink bug. The major natural enemy of stink bugs during the first generation in roadside weeds is the common Argentine ant (*Linepithema humile* [Mayr]), a voracious predator on egg masses of four of the five bugs. Eggs of *N. viridula* are seldom eaten by ants; however, most are eaten instead by the house mouse (*Mus musculus* L.). As a result of egg predation (ants + mice), few stink-bug eggs hatch, and even fewer individuals eventually reach adulthood. Thus, the reservoir of adult stink bugs that can invade the adjacent tomato field is greatly reduced. Ants and mice tend to be active only along edges of the tomato field. Predation by other species in tomato is relatively low, and even though at least ten species of egg parasites occur in the system, they tend to build up later in the season (after most of the stink bug damage is done). As a consequence, survival of stink-bug eggs is much higher in the tomato field compared to the adjacent roadside weeds. The intense predation pressure in the latter habitat is probably responsible for the late build up of egg parasites in the adjacent tomato field. In other words, predation in the spring generation of stink bugs severely limits the supply of eggs available for the parasites to utilize.

This example illustrates how noncrop vegetation can complicate decision making in pest management. For example, should the grower remove the blackberries? While this might reduce the overwintering population of stink bugs, it would also adversely affect predators (e.g., ants) and egg parasites that find refuge there. Should the grower encourage the state to control the weeds along the Interstate right-of-way? This would likely result in a reduction in stink-bug colonizers that initiate the second generation in tomato. However, if there is long-range movement of stink bugs in the area, the grower could experience a false sense of security. The floral resources these weeds provide for the egg parasites that are able to persist must also be taken into account. Perhaps the ants and mice should be controlled so as to allow substantial populations of egg parasites to develop that will then invade the tomato field. With all of these complications and the inherent need for regular monitoring at the farmscape level, it is not surprising that many growers and PCA's simply ignore the ecological interactions in an agroecosystem and opt for a properly timed application of a chemical insecticide. Professional farmscape ecologists might do the same if they were faced with the economic realities of this kind of situation.

SUBSTITUTION OF FOOD SPRAYS

The adults of many predaceous and of most parasitic insects used in biological control utilize floral resources (pollen, nectar) and(or) honeydew. These resources are necessary for increased longevity, fecundity, and other components of fitness in adult insects. In certain predators, the larva is predaceous while the adult is free living (i.e., not predaceous); if the adult female's nutritional needs are not met, she cannot deposit eggs. Examples include certain green lacewings and most syrphid flies. Other species are predaceous in both larval and adult stages (e.g., ladybird beetles, some green lacewings); adults of such species may also require floral resources/honeydew to supplement their diets. Adults of parasitic insects are usually free-living, but commonly require food such as nectar or honeydew to survive and reproduce. In many agroecosystems, floral resources and(or) honeydew are absent at critical points during the growing season, if not absent throughout the season. In such systems, predators and parasites may be relatively ineffective, even in the presence of suitable prey (or pest) species.

The sugarbeet agroecosystem in California is a good example of the problem. Sugarbeet is a biennial plant, normally grown as an annual crop. It is harvested well before flowering, so no pollen is available during the growing season. (The beet plant is wind-pollinated, and while there is abundant pollen, there is little or no nectar in the flowers.) Also, there are no extrafloral nectaries present. There are three aphid species commonly found on sugarbeet--i.e., green peach aphid (*Myzus persicae* [Sulzer]), black bean aphid (*Aphis fabae* Scopoli), and potato aphid (*Macrosiphum euphorbiae* [Thomas]). The former two are important virus vectors and tend to be under chemical control in most fields; the latter species is seldom abundant. Thus, there is little aphid honeydew available during the sugarbeet growing season. No other honeydew producers commonly occur in the system. Chemical and mechanical weed control eliminates any other source of pollen/nectar or honeydew.

In a crop such as sugarbeet, there are two broad approaches to attracting/concentrating natural enemies and increasing their realized fecundity. The first involves planting noncrop vegetation to provide the necessary pollen, nectar, or honeydew. While this approach can be especially useful in orchards and vineyards, it can be problematic in a row crop such as sugarbeet where profit margins are relatively small and there is little incentive for growers to make major economic outlays to maintaining noncrop vegetation in the field. In addition, sugarbeet is very sensitive to interspecific competition, particularly during the early part of the season. An alternative approach involves the use of "artificial" floral resources/honeydews that are placed in the field for natural enemies to exploit. These can be applied as "food sprays" that provide many of the nutritional constituents of pollen, nectar, and honeydew. The conventional food spray was developed by the late Dr. K. S. Hagen at Berkeley and consists of equal parts of sugar (sucrose) and yeast hydrolysate in water. This mixture was designed primarily to attract, arrest, and stimulate egg production in the common green lacewing, *Chrysoperla carnea* (Stephens), a species with free-living adults.

In 1996, we investigated the use of conventional food sprays to enhance *C. carnea* in California sugarbeet. Molasses was added to the mixture to increase attractiveness and persistence in the field. In small plots on the Davis Campus, application of food spray resulted in increased densities of eggs and adults of *C. carnea* in the treated plots. However, due to small plot size, the treatment effect may have been diluted as adult lacewings dispersed out of treated plots and into adjacent nontreated controls. In future experiments, much larger plots are clearly warranted. We also observed that percentage parasitization of lacewing eggs by the native scelionid *Telenomus tridentatus* Johnson & Bin was significantly higher in treated plots in at least one experiment. This raises the possibility that antagonists of biological-control agents may also be enhanced by food sprays (e.g., hyperparasites, parasites of predators). Clearly, an holistic, large-scale field evaluation of conventional food sprays is warranted, for this approach may prove to be an efficacious substitute for the use and manipulation of noncrop vegetation.

FUTURE RESEARCH

Farmscape ecology has the potential for providing both a conceptual basis and practical guidelines for production agriculture. However, before this can be realized, much research will be required. From an entomological standpoint, one of the most critical needs is data on movement of insect pests and their natural enemies. At present, we have very little direct evidence of such movement in the Central Valley. From a crop-production standpoint, IPM researchers must develop management tactics that growers can easily integrate into their operation. Managing noncrop vegetation may be implementable in some farmscapes, but in others, a more simplified substitute may be required.

WILDLIFE AND AGRICULTURE

E. Lee Fitzhugh
Wildlife Extension, Department of Wildlife, Fish, and Conservation Biology
University of California
One Shields Avenue
Davis, CA 95616-8751
Phone (530) 752-1496; E-mail elfitzhugh@ucdavis.edu

INTRODUCTION

Farming faces difficult times because the public and policy-makers do not understand what farmers need and how farming helps the environment. Farmers need to consider how they can educate the public about the benefits they provide to the environment. In the process, they need to do more to benefit the environment. Farming already is important to many species of wildlife. It can be more important if farmers spend a little extra effort. You can provide advice for county bulletins for pesticide use. You can modify equipment and harvesting practices. When you plow fields, maintain some cover. Add biodiversity to your farm planning procedures. Collect and incubate eggs, and stimulate community awareness. If you do even some of these things, you will greatly benefit wildlife and the environment and help voters know how farming helps the environment.

Many kinds of wild animals use cropland. The most successful of these become pests to the farmer, although some parts of our society would protect pests, also. Others are game birds and mammals. Agencies have named some that require special treatment. Many of them are just wildlife. We have not specially prioritized many birds, small and medium-sized mammals, snakes, lizards, and amphibians that live in or use croplands. Although I will use the results from research projects in this presentation, this is not a research report. It is a philosophical presentation. I will try to place agricultural wildlife and farming in perspective and show how you can help maintain farming through wildlife goals. My main emphasis will be on managing farmland to benefit desirable wildlife. However, pests are real, and I will begin with a brief discussion of pest issues on cropland, and farm management that can influence them.

PESTIFEROUS WILDLIFE

It is almost axiomatic that biological controls for vertebrates are: 1) slow-acting, and 2) almost never provide complete protection. Many biological controls involve interrupting prey portions of the food chain or increasing predator portions. The food chain is a useful idea, but using it alone to control vertebrate pests is frequently disappointing. Habitat is another tool used to control pests. If you can remove a pest's habitat, such as a blackbird roost, the problem may disappear. Conversely, creating habitat, such as a windbreak, that will attract raptors, may encourage birds that eat rodents, but may create other problems. Other pests may like the habitat you created for predators. The habitat that replaced that blackbird roost may harbor voles that will migrate to a sugar beet field. Each species has its own kind of habitat. Whenever you change habitat to encourage or discourage one species, be sure to think about what other species may be affected by the change.

Before you change habitats or management to reduce vertebrate pest problems, ask experts with local knowledge what they think the results will be. The county agricultural commissioner or your local pest control operator will either know the answers or know someone who does.

WHAT IS THE ENVIRONMENTAL PROBLEM?

Some environmentalists do not understand that farmers are not the problem. Farmers respond to the same factors that drive urban and industrial expansion, highway construction, etc. Increasing demand from an increasing human population requires many types of development. Farming and other renewable natural resource uses may be the least harmful of all to the environment. Nevertheless, some environmentalists still attack farming as though it were the enemy. They are gaining an increasing urban following because many people today do not understand how plants are grown commercially or how farming benefits wildlife.

At least one reason the environmentalists criticize farmers is that many farmers really have not done what they could have done to benefit the environment, including wildlife. Any farmer will readily admit this if they take time to think about it. The causes -- and solutions-- are a different matter, and therein is the problem between environmentalists and farmers. Farmers can physically do much more for the environment, but often not without incurring financial and legal liabilities that would crush them. Also, there have been a whole array of government incentives and university research and extension programs pushing farmers toward clean, "efficient" farming. Adding to these is the recently increased need for farmers to compete in international markets as government subsidies and tariffs are withdrawn. Whereas "we the people" are responsible for clean farming because of our demands through policy-makers, there still is plenty a farmer can do under present circumstances.

To environmentalists' credit, they have recently worked to remove disincentives in agency programs. They still have a tendency to support legislative requirements for what they see as "necessary" reforms. Only the most enlightened recognize the disincentives such legislation can create for wildlife habitat improvement. Farmers will need to protect themselves politically from such moves, but preventing restrictive legislation will not win the battle. The battle lies in convincing voters, including reasonable people who support environmental organizations, that farmers <u>are</u> doing what they can under the law to benefit the environment. This argument must be convincing, and must include demonstrations that many farmers are using environmentally-friendly methods. Then, you may even gain environmentalists' support for reforms that will protect both farming and the environment.

ENHANCING WILDLIFE

Some kinds of wildlife are desirable around the farm, and many farmers would like to see more of them. The desirable species often are scarce. Some, like ringnecked pheasants, which formerly occurred in great abundance, no longer do so. Why? Often, there are several causes, but usually one operates more strongly than the others. This one is called a limiting factor. I'll discuss a few of the limiting factors that I have noticed.

Bare fields raise few birds. If farmers could arrange their crop rotations on the landscape so that wildlife could always escape from the plow to a vegetated field, farms would have higher populations of beneficial wildlife. Sugar beets and alfalfa are long-rotation crops that help bridge this barren period. A few weeds in the beet field, with their seeds and insects, would make a pheasant happy. Most other recommendations are a variation on this theme.

Vegetating bare working areas will improve farming conditions as well as wildlife habitat. Every farm has non-farmed areas. There are equipment yards, ditchbanks, roadsides, and sometimes a small working space between fields. These areas must be kept free of weeds that otherwise would invade the fields. Instead of discing or using herbicides to keep these areas weed-free, why not plant something, maybe even alfalfa, that would continue to grow, provide habitat, and crowd out weeds with less maintenance than discing and spraying? In some areas, native perennial grasses serve this purpose well, in others broad-leafed legumes such as alfalfa or vetch may be better. None are maintenance-free, but they may require less maintenance than keeping the soil bare. Vegetating bare areas provides benefits not only to wildlife, but also in reduced soil loss and siltation (Anderson, 1996).

Farmers must plan for crop rotations on different soils with different irrigation and fertilizer needs, with weed and pest control complications. Market situations further complicate the process. If you're already doing this complicated planning process, why not just add another line, whether in your head or on a computer, and consider the environment? Irrigation schedules and type of irrigation can be refined and carefully controlled. Most of you may already be doing this. You can do the same with tailwater, and in some areas, return systems. You may be doing this, also. How about interspersing your different crops across the landscape? Distance between fields of the same crop affects equipment travel and efficiency. It also affects wildlife. If you can scatter sugar beets and alfalfa fields among the fields that will be bare, then wildlife will have somewhere to escape during and after the disking. Wildlife will reap great benefits if you include them in your planning.

Water conservation, water quality control, and wildlife goals all share similar procedures. You can return cooler and purer water to natural streams by ponding your tailwater and letting the sediment settle, then running the wastewater into a deep, narrow ditch with vegetated sides and bottom. This will attract insects, keep the water cooler, and prevent bank erosion, reducing maintenance. When you need to clean a ditch, try to do it from one side only, leaving vegetation on the other side. Plant non-weedy vegetation on these areas so you don't have to spray them. Tailwater return ponds and sediment traps can be planted with perennial grasses and non-weedy sedges that compete with weeds.

In Yolo County, John Anderson uses tail-water ponds with silt traps below his fields. Every year, he cleans the silt traps and redistributes the soil on his fields. The ponds, and land around them provide valuable nesting habitat for ducks and pheasants. He added trees between his fields and revegetated a natural waterway with trees and shrubs. Anderson has now attracted deer, wild turkeys, and even a bear, to his farm, which is near the Coast Range foothills (Anderson, 1996).

Channels that carry water are critically important to many wild birds and animals. Wildlife benefit much less if their banks are bare. Natural stream channels, with their meanders, trees, and shrubs, are oases for wildlife, as any farmer knows who has such an area on the farm. Canals and ditches, especially the larger ones, can partially serve a similar function, if properly designed.

Besides modifying habitats, farmers can sometimes help wildlife by changing the way they do things. You can change harvest timing, practices, and machinery. The next paragraphs provide just one example of how the Conaway Ranch is doing this.

Ducks generally begin nesting in the Central Valley in early March, and pheasants slightly later, with later nestings and renestings extending the period into late June. Alfalfa and grain fields are attractive to nesting ducks after the stand reaches about 8 inches height. Because the birds are ready to nest before alfalfa is tall enough, pheasants and ducks probably begin to nest in alfalfa fields at the same time, in mid- to late April. They may nest earlier in grain fields, because grain is taller earlier in the season. Your fields can easily support one nest per acre in May.

Normal harvesting destroys virtually all of the nests and many hens because they fail to flush when the machinery approaches. If better nesting conditions were present in April, with taller vegetation, and near water, some ducks and pheasants probably would nest there instead of in the alfalfa and grain fields. You could provide these conditions in fallow fields vegetated from the previous year, non-farmable areas, or areas reserved for wildlife. If farmers could make the first alfalfa cutting early, while the crop was still short, it might discourage ducks and pheasants from nesting in those fields. A nearby fallow field might then be even more effective. Sometimes, farmers can delay harvesting grain fields until birds finish nesting. The Conaway Ranch is trying all of these ideas, and more. Putting any of these ideas into your farm planning would save some birds.

If birds nest earlier when a tall crop is available, they may be more attracted to grain fields than to alfalfa fields for nesting, because grain would be taller early in the season. Then, if you could harvest the grain somewhat late, the birds may finish nesting before the equipment arrives. Another alternative that would not save as many nests as late harvesting, but would still help, would be to harvest with a tall stubble, as with a stripper-header. You could remove the stubble after nesting was over. Interspersing spring barley or wheat fields with alfalfa fields may save birds. We have not tested this idea, but it is worth trying.

Pheasants are killed when you harvest, even after the nesting season. Sometimes, pheasants will run from the harvesting equipment and hide at the edge of the crop when they reach a bare area. They hide until the equipment reaches them, and kills them. If your operators kill more pheasants on the last swath in the field, try this strategy. Begin harvesting in the center of the field, without first making a swath along the side. Work from the center outward, trying not to leave swaths standing between cut areas. If you have cover along a ditchbank or in an adjacent field, work parallel to those areas, and the pheasants will run into them, avoiding the equipment. Lacking a vegetated edge on the field, leaving an uncut partial swath at the edge will prevent their being killed. This swath can be harvested the next day, after the birds have had time to leave it, or volunteers could drag a rope along it to make the pheasants fly. A 4-H or Future Farmers of America club might be a willing source of volunteers, available on short notice, to save pheasants.

The California Waterfowl Association (CWA), the California Department of Fish and Game, and the University of California, Davis, tested a "flushing bar" designed to flush birds from their nests. The CWA design achieved moderate success at saving the adult hens so they could renest in more suitable habitat.

Even when the flushing bar saves the hens, harvesting removes cover from the nests. Wild hens cannot hatch eggs in a mowed field. If eggs survived the machinery, the eggs and hens would be exposed to serious predation by hawks, foxes, raccoons, skunks, ring-tailed cats, domestic cats and dogs, coyotes, and opossums. Some farmers save the eggs by collecting them and taking them to an incubation facility for later release into the wild. Banded ducklings from these facilities show a good survival rate in the wild (Easter 1995).

WILDLIFE AND PESTICIDES

Another thing you may be able to plan better is pesticide application. Consider using different pesticides, formulations, strengths, or application methods and timing to favor wildlife at critical times for them. Pesticide concerns are specific to localities, but in California, farmers get help and advice on these considerations from their pest control firms, the county Agricultural Commissioner, who has legal authority over pesticide use in each county, from the state Department of Pesticide Regulation, from the University of California Cooperative Extension office, and sometimes from a cooperative local wildlife biologist from the California Department of Fish and Game. You may have to tell your advisors you want to consider toxicity to wildlife, or they may not think of it. All of these considerations should enter into your farm planning. It may cost you a little in short-term efficiency, but in the long run, it may save you from future problems. You will also have the satisfaction of managing your land in the best way you can.

Why should you spend time changing your pesticide practices? Let me try to provide some perspective. Wildlife habitat seems to be more restrictive to hawks than are pesticides, at least in Yolo County, and probably in similar parts of the Central Valley. Still, there are ways farmers could manage pesticides to grow more desirable wildlife. To understand what can be done, and why, it is first necessary to briefly describe the current problems. One involves organophosphate sprays such as diazinon in orchards. When used as a dormant spray in winter, much of it falls on the ground. When it rains, a pulse of diazinon-laden water runs into the rivers. Sacramento and San Joaquin Valley river water obtained during these runoff events contained sufficient pesticide to kill aquatic invertebrates used as food by fish. Organophosphate dormant sprays also affect the nervous systems of birds, causing them to be less fit, and more subject to predation by hawks. The hawks can obtain a great enough dosage from their prey to be lethal, or at least to reduce their ability to kill prey, escape automobiles, etc. This problem is amplified because small birds and rodents absorb the pesticide through their feet and skin, and convert the inactive compounds into active form so that the hawks get even more active ingredient than the prey absorbed. Similar problems exist in row crops when spray drifts onto hedgerows, fallow areas, and ponds.

However, since habitat is more limiting than pesticides, using pesticides should not keep you from creating more habitat where you can do so.

There are some things farmers can do to reduce pesticide problems, and some farmers are already doing them. Anything that reduces runoff from fields into the natural drainages, or slows it down, will reduce damage to aquatic insects by organophosphates. Anywhere water flows from overland into a channel, pesticides may enter stream channels. This happens routinely following irrigation, and more naturally following heavy rainfall. Whenever the overland flow can pass through a vegetated natural area, with its litter and ground cover, some filtering action will occur. If such a "buffer strip" is not feasible, try channeling the water into a settling pond before it enters the outflow. Ponding reduce pesticide and sediment load, especially if the pond is large enough to hold the water for several days before it must pass on. Any of these choices will be beneficial to wildlife. Several native grass, shrub and tree species grow well around ponds and canals, can help reduce weed problems, and will increase wildlife benefits. The same practices that reduce pesticide flow into streams also help desirable terrestrial wildlife.

Another way to reduce pesticide runoff is to reduce the amount wasted on the ground. New methods of delivering dormant sprays will deliver more of the pesticide onto the trees, and less on the ground. This will not only save money, but save wildlife. Once this equipment is ready, the sooner you can modify your spray rigs to use it, the better for everyone. In row crops, the main delivery problem is to avoid overspray beyond the field. The more you can keep spray away from hedgerows, fallow areas, ditches, and ponds, the better for wildlife. New, more precise spray equipment is one answer to reducing pesticide impacts on wildlife -- and it may save money.

New pesticides can have as much as 1,000 times less effect on wildlife as the old ones, and still kill the pest insects. Be aware of these developments. Ask your pesticide dealer about them, and ask your agricultural commissioner or Cooperative Extension advisor to find out about wildlife toxicity of the pesticides that are options for you. You may reduce the impact on wildlife at critical times by reducing the amount of active ingredient, using a different rate of application, presenting it differently, or changing the timing of application. Merced County provided an excellent example of adaptating farming practices to protect the aleutian canada goose. It takes a little thought and effort to discover how to do something better, but it is worth the effort.

HCPs AND ENDANGERED SPECIES ISSUES

Endangered species on your farm can affect your farming activities. Under present law, the only legal way to protect farming from this problem is to develop a Habitat Conservation Plan (HCP) with the U.S. Fish and Wildlife Service and the California Department of Fish and Game. Creating a HCP can be a lengthy and difficult process, and will require "mitigation," even where no change in activities has occurred. There is as yet no alternative, despite concentrated efforts by the California Farm Bureau Federation and California Cattlemen's Association.

RAISE COMMUNITY AWARENESS

Farmers should take active measures to educate local people and those in more distant urban areas about how farming helps the environment. There are several ways in which you can do that. Whenever you make any environmental improvements, including those we have mentioned, call your local print and television reporters. The local Farm Bureau office can help you make these contacts, if you need help. The key is to wait until something is happening (current news). Give the media enough lead time so they can schedule time to photograph the activity. It may be to photograph a nest search conducted by a local 4-H or service club. It could be removing silt from a tailwater pond and returning it to the field, or any other interesting and beneficial operation. The media will be interested if the environmental benefit is obvious.

You can submit news articles to farm journals, and some environmental organizations do read those. However, the public doesn't read those. Try writing a letter to writers who publish in airline in-flight magazines, in hunting or other wildlife magazines, or in other general-interest magazines. Tell them briefly what you are doing. Suggest that you would be willing to talk to them and show them more detail if they want to write about it. Some magazines take stories sent in by writers, and some commission stories on assigned topics from writers they like. In the latter case, a letter to the magazine editor may be more effective. In any event, do a little homework and select a magazine or a writer who has a track record on two accounts. First, that the writer publishes frequently, and second, that the writer has written at least one article neutral or favorable with respect to agriculture. Favorable stories in general-interest publications will give farmers a better environmental image.

Finally, you can stimulate your community service clubs and chamber of commerce to sponsor a community celebration centered on farming or on wildlife, focusing on farming. Such community celebrations are becoming more popular, and they can draw large crowds. In Dixon, California, the Lambtown celebration is a weekend of street vendors, concerts, displays, etc. focusing on the Dixon's agriculture. It is large enough that they close the state highway through town, turn it into a mall, and detour all the traffic onto city streets. Just down the road, the city of Davis hosts a weekend of Davis Duck Days to highlight waterfowl and other wildlife activities throughout the region. They even have helicopter rides and balloon rides to view sites from the air. There are tours, lectures, talks, displays, art exhibits, etc. at these celebrations. Butte County has a self-guided winter waterfowl tour. Alfalfa farmer Jim Kuhn and others organized the Salton Sea International Bird Festival in 1997. Community celebrations attract some media attention, bring tourists to your town, and educate those who come.

HAVE FARMERS SUCCEEDED?

A few farmers are beginning to establish beachheads in the battle for urban understanding. The rice industry in the Sacramento Valley has overcome some serious problems caused by herbicides in water and air pollution from burning stubble. Not only have they resolved the problems, but they greatly improved wildlife habitat in the process, and are now widely recognized as a wildlife-friendly industry. I think there were two keys to their success. First, they made real progress to resolve the issues. Second, the industry organization allowed communicate both to outside interests and to their own growers. They still are under pressure from fisheries interests, but both environmentalists and wildlife agencies admit that it would be a disaster for wildlife should the rice industry leave the Sacramento Valley. Public acceptance of their role in supporting wildlife is helping them overcome the difficulties that remain.

CONCLUSION

Farming is important to the food production systems in the U.S.A. and the rest of the world. A mixture of crops is beneficial to wildlife and long-rotation crops add important long-term cover and nesting areas to farming ecosystems, thus improving biodiversity. Yet, there is room for improvement. Growers can modify equipment and harvesting practices. Most can keep some areas vegetated among bare fields. On larger farms, you can make environmental concerns part of modern budgetary input-output strategies. This will improve biodiversity on farms. You can collect and incubate eggs from destroyed nests. Finally, you can let people in your local communities and in more distant urban areas know about the good things you do. Improving farm practices, then telling the public about what you have done, is your best defense against the environmental and resource challenges that face us all.

ACKNOWLEDGEMENTS:

Dr. Michael Fry contributed ideas and suggestions for the remarks related to pesticides and wildlife. Dr. Terrell Salmon and Dr. Desley Whisson reviewed sections involving vertebrate pest control and made helpful suggestions. Dr. Lee F. Jackson helped me understand wheat and barley growth in California's Central Valley. Many of the ideas were stimulated by Dr. John Anderson. However, I alone am responsible for any errors or foolish ideas. Some of the ideas and examples I used came from a dozen other reports. A list of these reports is available upon request.

ROTATIONAL WETLAND SYSTEMS IN THE KLAMATH BASIN

Harry L. Carlson
Intermountain Research & Extension Center
PO Box 850
Tulelake, CA 96134
Phone (530) 667-2719; E-mail hlcarlson@ucdavis.edu

INTRODUCTION

The Klamath Basin is a high elevation mountain valley located in south central Oregon and northeastern California. The 200,000 acres of the Basin's valley floor are intensively utilized for the production of field and row crops and pasture. Crop agriculture is made possible in the high desert climate because of irrigation water supplied from three reservoirs, along with an extensive system of irrigation delivery ditches and drainage canals. The surrounding hills and mountains are utilized for dryland grazing and timber production.

The Klamath Basin is also home to abundant wildlife. The presence of large populations of migratory waterfowl in the spring and fall is one of the region's hallmarks. Most of the waterfowl in the Pacific Flyway pass through the Klamath Basin in route back and forth from nesting areas in the north and over wintering grounds in the south. The Basin also supports the largest population of wintering Bald Eagles in the United States. Importantly, the Klamath Basin National Wildlife Refuge System, operated by the US Fish and Wildlife Service, provides critical habitat for the visiting waterfowl and for many species of shore birds, pheasants, and raptors.

A principle component of the Klamath Basin Refuge System is the Tule Lake National Wildlife Refuge in California, near the town of Tulelake. The Tule Lake National Wildlife Refuge is somewhat unique in the national wildlife refuge system, in that a large part of the refuge is farmed commercially. Leased farmland on the refuge forms an important part of the field and row crop production in the region. This unique situation resulted because of early conflicts that arose in the reclamation of the area. Most of the farmland, in what is now the 63,000 acre Tulelake Irrigation District, was originally under the waters of historic Tule Lake. Beginning in the early 1900's and continuing into the 1940's, Tule Lake was drained as part of a large, federally funded Klamath Basin Reclamation project. The project was intended to create farmable land and supporting irrigation infrastructure.

In the late stages of reclaiming the lake, land was made available for homesteading by World War II veterans. As the lake shrunk and homesteading advanced, concerns began to be raised about the loss of waterfowl habitat in the region. Political clashes insued between conservation groups and hunting interests on one hand and agriculturists and veterans rights groups on the other. In 1964, a compromise was hammered out and ratified by an agreement between the states of Oregon and California and codified in federal legislation called the Kuchel Act. Basically, this act provided for the establishment of the Tule Lake National Wildlife Refuge with a prescribed amount of permanent wetlands. The act excluded further private ownership (homesteading) of the remaining reclaimed land, but provided for the commercial farming of the reclaimed land for full economic benefit consistent with the wildlife management goals of the refuge. So, a 30,000 acre refuge was established with 13,000 acres of legally mandated permanent wetlands, and 16,000 acres of farmable ground, made available to local producers on a competitive bid basis. Over the years, this arrangement proved generally to be a workable compromise. The ground within the present refuge boundaries was preserved from further development (no private ownership, no houses or farm buildings, no power poles, etc.). The land was available for public hunting as managed by the United States Fish and Wildlife Service and local producers had access to prime agricultural lands which effectively extended the economic viability of their small, privately held homesteads.

ENTER THE 1990'S

Of course, from the beginning of this arrangement there were minor conflicts between wildlife managers and agricultural interests. But in the 1990's things began to rapidly unravel. Drought in the early 1990's led to jurisdictional fights over available water in the Basin. The situation for agriculture was made worse by the declaration of two endangered sucker-fish species in the Basin's main irrigation reservoirs, and by concerns over dwindling salmon runs in the Klamath River downstream from Tule Lake. Efforts to maintain high reservoir levels for sucker fish, and high instream flows for salmon led to the rationing of water in 1992 and producers in some areas were cut off from water supplies. The refuges also experienced water shortages as the refuge system relied heavily on agricultural drain water as a major source of water supply. The shortage of water in the marshes and the low priority of the refuges for water caused some to question continued farming on the refuge property and to even question the allocation of water to growers on surrounding private land. While water allocation priorities continue to be challenged in the courts, the effective priority for allocation of water in the Basin is endangered species needs, domestic use, beneficial agricultural use, power generation and then, waterfowl refuge use.

The pressure against farming extended to the use of pesticides on the refuge. A lawsuit was filed and settled, requiring commercial farmers on refuge land to comply with the very restrictive federal policies governing the use of pesticides on federal land. Federal pesticide use restrictions on federal land are more severe than the already stiff California rules and regulations. Hence, growers in the refuge were prohibited from using many of the crop protectants legally utilized on the neighboring private ground.

It is generally conceded that waterfowl, particularly geese, heavily utilize the feed left after the harvest of commercial crops in the refuge. However, this use became less valued by refuge managers as the waterfowl populations declined in the Pacific Flyway during the drought in the early 1990's. Also, some row crops such as sugarbeets and onions were regarded as having little or no value to wildlife.

MORE TO THE STORY

On the wildlife management side there are serious problems with the condition and utilization of the permanent wetlands. The refuge wetlands consist of largely shallow open water, two to four feet deep, and marsh vegetation dominated by hard-stem bullrush. Under the Kuchel Act these wetlands were designated as permanent. Over the years, these marshes have silted in, becoming shallower each year. Sources of this siltation include silt in agricultural drainage water, soil deposition in the lake from wind erosion on the surrounding fields, and sedimentation from large algal blooms that occur annually in the open water areas. The siltation led to decreased water storage in the wetlands and to the fear of seasonal flooding onto the surrounding agricultural lands during wet years. The development of long-standing, thick dense mats of hard-stem bullrush that choked out other marsh vegetation led to reduced waterfowl usage and to the channelization of water around the marsh instead of through it.

To wildlife managers and hunting enthusiasts the marsh has become decadent, poorly managed, and poorly utilized by waterfowl. Refuge personnel would like to be able to better manage and manipulate marsh water management to encourage habitat diversity and increase the variety of emergent vegetation. Based on successes in other parts of the Klamath Basin Refuge System, managers are confident that if managed appropriately the Tule Lake marsh could and would support greatly increased numbers of waterfowl. Unfortunately, such management is difficult, if not impossible, under the Kuchel Act mandates of permanent water impoundments and confined commercial farming.

A “NEW” CONCEPT

For more than ten years agronomists, wildlife managers, and water managers have been kicking around the concept of *rotational sumps*. In this concept, areas that have been flooded and maintained as marshes would be rotated periodically onto ground that was previously farmed. That is, marsh areas would be drained and reclaimed for farming purposes and a corresponding amount of farm ground would be diked and flooded to produce wetland habitat. There are several very positive potential outcomes of this management strategy: 1) early secessional marshes and/or ephemeral marshes could be created and maintained. Such marshes have been demonstrated to provide valuable waterfowl food and habitat, resulting in heavy bird utilization; 2) these rapidly growing marshes may be very effective in removing nutrients from recycled agricultural drainage water; 3) deep water storage could be created that would be useful for flood control and provide for additional water releases within the refuge; 4) reclaimed land would provide growers with nutrient-rich, fertile ground with little, if any, soil-born pests or diseases (essentially virgin soil); 5) starting with clean soil, sustainable cropping systems could be developed and prescribed that would discourage the introduction and build up of serious soil-born pest and diseases, thereby reducing the need for chemical pesticides; and 6) the concept legitimizes the role of agriculture as an effective tool in refuge management.

SOLUTION CAUSED PROBLEMS

The rotational sump solution is not without problems. The establishment of new dikes, levees, and water delivery systems will be expensive. It is, however, feasible that these costs could be largely off-set by revenues gained from farming leases and federal dollars earmarked for habitat improvement on the refuge. Private groups, such as Ducks Unlimited, have also expressed an interest in funding habitat improvement projects on the refuge. Once these improvements are in place they would be relatively easy to maintain.

Reclaiming and farming ground that has been in long-standing marsh (50 years) will present challenges. Residue management and cultural and disease problems associated with freshly decaying organic matter should be anticipated. Also, there is concern that drainage and reclamation of the old marsh areas will lead to an increase in nutrient loads in the refuge drainage water. One research project is underway and another one is proposed to measure this possible impact on pilot/demonstration projects. As noted above, such nutrient-rich water may be applied to rapidly growing new marsh areas or back onto cropland where the nutrients could be recaptured.

STATUS

Politically, rotational sump appears to be a tough sell. Many environmental groups fail to see the value of any agriculture taking place on a National Wildlife Refuge. The US Fish and Wildlife Service is currently being sued over refuge farming practices. The grower community is skeptical about current farm ground being placed, even temporarily, into wetlands. They worry that future decision makers may declare wetlands cannot revert back to farming when the plan calls for such rotation. On the other hand, a solicitor general opinion has been issued stating that the rotational sump concept is consistent with the statues expressed in the Kuchel Act, and waterfowl managers are convinced that such habitat modification will result in improved waterfowl utilization. Active research and pilot projects are under way to demonstrate the benefit of this approach to waterfowl, and to measure some of the possible negative impacts. University research has been proposed to measure the benefits to the growers of leasing reclaimed land.

Wildlife managers, water managers, local growers, waterfowl enthusiasts all stand to gain by enlightened management of the refuge resources. Hopefully, ongoing and proposed research will provide some of the answers needed to assure constituents that innovative management practices could result in a win-win situation for the majority of those concerned.

ASSESSING THE CHALLENGE FOR WATERFOWL HABITAT IN THE RICE LANDSCAPE OF THE SACRAMENTO VALLEY

REID, FREDERIC A., RICHARD G. KEMPKA and MICHAEL A. BIAS. Ducks Unlimited, 3074 Gold Canal Drive, Rancho Cordova, CA 95670

HILL, JAMES E. and SYLVIE M. BROUDER, Agronomy and Range Science Department, University of California, Davis, CA 95616

WYLIE, GLENN and JOHN H. DAY, Biological Resources Division, USGS, 6924 Tremont Road, Dixon, CA 95620

With more than 95% of historic wetlands destroyed, harvested rice fields in the Sacramento Valley provide critical foraging habitat for waterfowl during wet winters. Concurrently, with the passage of state legislation (AB 1378 in 1991), over concerns related to air quality, it will be necessary for the majority of California rice growers to seek alternative methods to straw burning in the immediate future. As the Central Valley winters some 60% of all waterfowl (excluding sea ducks) in the Pacific Flyway, and up to 20% of those wintering in the entire United States, rice fields play an integral role in the landscape of wintering waterfowl in western North America.

In an effort to better understand the implications of potential conjunctive use of winter flooding for rice straw decomposition and waterfowl habitat, a consortium of research projects were initiated in 1993 under general guidance from the CVHJV. The information gaps and emphasis of work were developed in order of (1) agronomic issues, (2) waterfowl response, (3) water quality and quantity, and (4) other wildlife use.

Agronomic assessment indicated that rolling or chopping of straw followed by shallow flooding is second only to burning in cost effectiveness. Eight treatments involving straw residue management by incorporation, rolling, burning, or removal under winter flood and non-flood conditions were evaluated over three years, under fully replicated sites (70-acre experimental micro-basin site). Saturated flooded sites yielded the greatest decomposition of rice residue.

Diurnal duck use of rice fields was dominated by northern pintail and American wigeon, and to a lesser extent, mallard and northern shoveler. Goose use was dominated by white geese (70%) and white-fronted geese (23%). Flooded burned or rolled fields were selected over non-flooded fields. An analysis of satellite images indicate that over 142,000 of the total 424,811 acres of rice were flooded in winter 1993-94. A variety of field manipulations will result in a mosaic of habitats, necessary to meet the demands of waterfowl, water interests, and endangered species.

CALIFORNIA RANGELANDS: BALANCING LIVESTOCK PRODUCTION AND WATER QUALITY

Kenneth W. Tate; UCCE Rangeland Watershed Specialist; Agronomy and Range Science, Davis, CA 95616-8515
Melvin R. George; UCCE Range and Pasture Specialist; Agronomy and Range Science, Davis, CA 95616-8515
Edward R. Atwill; UCCE Environmental Health Specialist; School of Veterinary Medicine; Veterinary Medicine Teaching and Research Center, 18830 Road 112, Tulare, CA 93274
Sheila Barry; Watershed Management Specialist; Alameda County Resource Conservation District, 1996 Holmes St, Livermore, CA 94550

Rangeland Watersheds

Rangeland is the one of the most extensive landscape types in California, covering more than 40 million acres of the state's 101 million acres. Although the precipitation that falls on California rangeland represents only about 15% of the total surface water source, the location of rangelands between the forested areas and major river systems results in most surface water flowing through rangeland. Eight of California's 12 major drainage basins are located within rangelands, predominately within the 20 million acres of privately owned rangeland. Consequently, the quality of California's surface water is highly dependent on the condition and management of rangelands. Almost all of California's rangelands are grazed.

California Rangeland Water Quality Management Plan

In 1989 the Range Management Advisory Committee to the California State Board of Forestry identified water quality as a high priority rangeland and livestock production issue. As a result UC Cooperative Extension and the Natural Resources Conservation Service have worked closely with the livestock industry and regulatory agencies to develop an awareness of clean water issues among rangeland owners and livestock producers. In late 1990, RMAC approved a two-phased program to address nonpoint source pollution on 20 million acres of privately owned rangeland. *Phase one* was to develop a statewide rangeland water quality management plan and *phase two* is implementation of the plan by cooperating agencies, organizations, groups, and individuals at state, regional, and local levels. Leaders in the livestock industry began working with RMAC and the State Water Resources Control Board to develop a rangeland water quality management plan intended to become an amendment to California's Nonpoint Source Management Plan. This culminated in the State Water Resources Control Board's 1995 approval of the California Rangeland Water Quality Management Plan, an industry supported program of voluntary compliance with clean water regulations. To show that voluntary compliance is a viable alternative to regulation, livestock producers must now assess nonpoint pollution sources on their ranches, and develop ranch water quality management plans that will identify needed changes in practices. The Rangeland Watershed Program, initiated jointly in 1990 by UCCE and NRCS, have begun to conduct ranch water quality planning short courses that will help them complete these plans. During the first year of these short courses more than 100 ranchers representing over 400,000 acres have completed plans.

Cryptosporidium parvum: Outreach and Applied Research

The issue of range cattle, water quality, and human health provides an excellent example of how outreach education and applied research have been employed to address water quality concerns on California rangelands. *Cryptosporidium parvum* (*C. parvum*) is a manure borne protozoal parasite that can be carried by and cause gastrointestinal illness in humans, domestic animals and livestock, and wildlife. This parasite is transmitted through the fecal-oral route by contaminated water and/or food supplies. *C. parvum* oocysts (eggs) shed from one species of mammal appear to be infectious to other species of mammals. In humans, clinical disease appears to occur at all ages, but is most common among children. The predominant clinical sign of the disease is profuse, watery diarrhea lasting up to several weeks in immunocompetent humans. The disease can be prolonged and life-threatening among immunocomprimised humans such as AIDS patients. The lack of an effective treatment and the fact that *C. parvum* was implicated in recent large-scale waterborne outbreaks of gastroenteritis in humans (400,000 cases in Milwaukee, WS, 1993; and 13,000 cases in Carrollton, NC, 1987) make this a critical public health issue. Special concern exists within those water districts which have historically leased rangelands upstream and adjacent to their reservoirs for grazing.

The City and County of San Francisco owns roughly 30,000 acres of the Alameda Creek Watershed in southern Alameda County. The watershed, and the reservoirs contained within it, are a crucial component of the system providing drinking water to over 2 million people. In February 1997, the San Francisco Public Utilities Commission (PUC) proposed a moratorium on grazing within the watershed, citing concerns that grazing livestock in the watershed posed an unacceptable risk to water quality by shedding *C. parvum* in their feces. Since the watershed is dominated by annual grasses, completely eliminating grazing would significantly increase the risk of wild fire, threatening near-by homes and ranchettes. Increased erosion following a wild fire would jeopardize drinking water supplies. A technical team composed of UCCE Advisors, Specialists, RCD personnel, NRCS staff, and SFWD staff was brought together to address this water quality issue. The team first conducted several outreach meetings with the stakeholders to sort fiction from fact, and to insure that all stakeholders had the opportunity to be heard on this issue. Utilizing science-based information from the literature and from the work of team members, a proactive quality control program, and sound range management principles the team developed a management plan to address this issue. The plan allows for grazing within the watershed. Management measures being implemented as a result of developing this plan include managing stocking rates to retain adequate vegetative cover, excluding calves less than 5 months of ages from areas directly adjacent to reservoirs, locating water developments and supplemental feeders away from stream channels, maintaining a general herd health program, and implementing a control program to reduce feral pig populations. The next step in addressing this watershed scale issue is a ranch water quality planning short course for ranchers holding private land within the Alameda Creek Watershed. The course is scheduled for early 1998.

Conclusion

We now have a strong watershed based research and extension continuum that helps rangeland owners and managers voluntarily comply with clean water regulations. The proactive approach of the range livestock industry to water quality issues has played a large role in the development and success of the program. We believe elements of this program provide a model for helping agricultural producers respond to clean water regulations in a positive and proactive manner. This is an opportunity for cooperative extension and the agricultural experiment station to help traditional clientele while solving problems that face all Californians.

FEDERAL PERSPECTIVE ON PESTICIDE DRIFT: BUILDING ON INTEREST

Karen Heisler
Pesticides Program
U.S. EPA, Region 9
75 Hawthorne (CMD-4-3)
San Francisco, CA 94105
Phone (415)744-1100; E-mail heisler.karen@epamail.epa.gov

EPA'S INTEREST IN DRIFT

EPA is concerned about off-target spray drift because of the potential risks to people and the environment. The Agency's concern is validated by some 2000+ annual reports of drift incidents. Spray drift can result in pesticide exposures and public health risks to agricultural workers in neighboring fields or to citizens nearby, including children playing outside their homes or in schoolyards. Spray drift can also result in contamination of another farmer's crops, causing illegal pesticide residues, or causing plant damage. And drift can impact non-target, non-commercial plant life and wildlife downwind of the treatment area.

We know that all pesticide applications by ground or aerial equipment result in some drift, as has been demonstrated by scientific studies and reports. A number of factors influence the degree to which pesticide drift occurs, including the decisions pertaining to application, the immediate physical and meteorological condition of the site, the condition and functioning of equipment.

EPA'S RESPONSE TO DRIFT CONCERNS

As a national program, EPA has limited direct control over the factors that influence drift. The Agency has an opportunity to promote drift mitigation through education and outreach with partners in field implementation of our program and with the grower and applicator communities. The product registration process provides regular interaction with registrants in which drift minimization can be made a high priority in product labeling.

As part of EPA's scientific assessments of pesticides, new or old, we consider all sources of pesticide exposure before we can decide how or even whether a pesticide should be used. Besides relying on scientific studies we are increasing our attention to incidents in the real world--including adverse effects from drift....how many incidents reported, how serious, and for which uses. Product labeling is a fundamental tool to dictate application strategies that reduce drift through buffer zones, lower application rates and frequencies or number of permitted applications per year. When such mitigation measures don't provide adequate protection, EPA may cancel the use or application method altogether.

But label-based conditions cannot adequately address specific and unique local conditions. Regulators and users operating in the field are better equipped to integrate the site-specific circumstances into a reasonable mitigation approach. National regulatory guidelines need to be specific enough to provide consistency across a varied agriculture, and flexible enough to contribute to balanced solutions that work for farmers and applicators and that are adequately protective of human health and the environment.

THE NECESSITY OF PARTNERSHIP

To achieve this goal, it is clear that we must work in consort with our state and tribal regulatory partners and also with the regulated community to minimize the potential for drift to occur. The EPA is actively involved in the national multi-stakeholder Coalition for Drift Minimization, which came into being about 2 years ago, convening for the first time in December of 1995. The Coalition includes applicator advocate organizations, technical experts, pesticide and equipment manufacturers, pesticide educators, agricultural insurers, and other government agencies, both state and federal.

Since its inception, the Coalition has approached its stated goal to minimize drift through three channels; regulatory, educational, and technological. Task forces of Coalition members were established to focus on each of those areas, and the following priorities and activities identified and pursued.

Regulatory Task Force:
Surveying state agencies on drift enforcement to establish a baseline of information about drift regulation nation-wide;
development of definitions that all members can endorse for uniformity in communication;
initiation of partnership with insurance industry with intent to share data between insurers and regulators;
review of regulatory informational language developed by EPA for inclusion on product labels.

Educational Task Force:
Identifying responsible parties and decision-makers who need to be reached through education and outreach - applicators retain position of highest priority for education, followed by growers and farm advisors as contributors to decision-making complex;
identification of expected standards of behavior and professional conduct among decision-makers;
inventory of existing training requirements, programs, and materials;
development of national curriculum and initial associated training materials - for FY98 training season, this includes a video emphasizing drift-table technology, which has been recognized among Coalition participants as powerful graphic teaching tool in principles of drift;
development of measures of success for educational program.

Technology Task Force:
Inventory of technologies relevant to drift minimization;
database and repository of technological information pertaining to drift minimization with broad accessibility;
review of label specification pertaining to equipment developed by EPA articulating preferences relative to nozzle choices, placement, swath adjustment.

The parallel efforts of the three Coalition task forces provide course-correction and validation of approaches for higher quality products and more assurance of success prior to launching new approaches and tools. For example, regulatory priorities and availability and viability of technologies were considered with input from all represented sectors in the development of the national curriculum. Coalition members have repeatedly remarked on spin-off value of improved networks for such validation in the course of members' daily work, and are increasingly able to provide support to other colleagues and constituents with related concerns.

CURRENT AND FUTURE CHALLENGES

Benefits of the Coalition aside, outstanding issues continue to challenge our efforts to minimize drift. The relationship between science upon which risks are assessed and real world of application and its impacts continues to be unclear and calls for further study. Furthermore, the variability of issues associated with drift requires consideration of many different circumstances and mitigation approaches. For instance, issues pertaining to large-acreage monocrop systems are likely to raise different concerns, or 'environmental endpoints', than in cases where many more crops and pesticides are used in close proximity to non-agricultural land uses.

Data on which drift risk assessment and decisions are based have been enhanced by the work of the Spray Drift Task Force, a group of more that 35 registrants that have worked cooperatively to generate data for product registration. The development of the database and associated models are derived from controlled field trials that explored a range of application variables. Generally, the new data corroborate what we have known to be true, that drift is harder to control as conditions are less favorable and less predictable. Still, agencies and industry are collectively short on data that comprehensively reflect real-world circumstances of application, and the variability of behaviors within the industry defies meaningful characterization of average.

The Coalition has noted these intrinsic limitations in the scientific validation of real-world drift and has recognized that a refined regulatory response and effective enforcement must be accompanied by complementary responses: Elevating the mean of professionalism and prudence in the applicator industry; encouraging integration of principles of stewardship among all decision-makers beyond compliance with the law; identifying and encouraging research and extension in specific areas of concern; developing national curricular standards for regulatory applicator educational programs; partnering with agricultural insurers to better assess impacts and communicate concerns to the regulated community. It is likely that the coming years will also provide us with increasing real-time and site-specific monitoring data that will likely motivate scientific developments to extrapolate further refinements in our understanding of drift.

It's very important that applicators, growers, product manufacturers, regulatory agencies, and research communities continue to work together to make improvements and seek solutions. Regulatory agencies can and will take actions as they see necessary to further restrict the use of certain agricultural pesticides in order to assure public health and environmental protection. The reliance on regulatory solutions can be mitigated to the degree that individual applicators and the industry as a whole continue to improve their technical skills and decisions to reduce spray drift.

California's Enforcement Policy on Pesticide Drift

Paul H. Gosselin
Assistant Director of Enforcement, Environmental Monitoring and Data Management
Department of Pesticide Regulation

Pesticide Drift

Pesticides are applied to a particular target, such as a field, orchard, structure, or even an individual plant. When the pesticide moves off, or away from, the application target, it is said to have drifted—hence, the term "pesticide drift." Many factors can result in the movement of pesticides beyond the target area. Although the term "pesticide drift" often encompasses all factors, the regulatory agencies limit the term "pesticide drift" to the off site movement directly caused by the application.

Some pesticides may move away from the application target due to volatilization of the pesticide. Volatilization is a characteristic of the pesticide that cannot be controlled by the applicator. When pesticide drift results from factors other than volatilization, the applicator may have been able to prevent it and may have violated a pesticide law or regulation.

Regulatory Standards

Pesticide labels often direct applicators not to apply products when environmental conditions favor drift. Also, as discussed below, laws and regulations direct pesticide applicators to operate in a manner to prevent substantial drift and not to apply pesticides when there is a reasonable possibility of contamination of persons or damage to nontarget property.

Food and Agricultural Code (FAC) section 12972 requires applicators to use pesticides in a manner that will prevent substantial drift to nontarget areas. The regulations define the term "substantial drift" as meaning that "the quantity of pesticide outside the area treated is greater than that which would have resulted had the applicator used due care."

Also, Title 3, California Code of Regulations (3 CCR) places requirements on pesticide applicators. Section 6614 is entitled "Protection of Persons, Animals and Property." Subsection (b) requires applicators not to make or continue an application when:

(1) There is a reasonable possibility of contamination of the bodies or clothing of persons not involved in the application process;

(2) There is a reasonable possibility of damage to nontarget crops, animals or other public or private property; or

(3) There is a reasonable possibility of contamination of nontarget public or private property, including the creation of a health hazard, preventing normal use of such property...."

Subsection (a) requires applicators to evaluate meteorological conditions, the application equipment they intend to use, and the target and surrounding properties to determine the likelihood of harm or damage from the application. This information aids the applicator in deciding whether to begin or continue an application and how to conduct the application.

Pesticide applicators have a duty to stop or reschedule an application when conditions exist which could reasonably be expected to cause contamination or damage.

Other state regulations prescribe application standards for specific pesticides to minimize pesticide drift. These include Drift Control (section 6460), Propanil (section 6462), Phenoxy and Certain Other Herbicides (section 6464), Paraquat (section 6466) and Cotton Harvest Aids (section 6470). These sections addressed documented impacts from the use of specific pesticides. The restrictions often targeted specific locations.

Investigations

County agricultural commissioners investigate every pesticide drift complaint whether they were made anonymously and/or over the phone. Once initiated, investigations are completed, even if a complainant withdraws its complaint or receives compensation for damages. DPR's Pesticide Investigative Techniques and Sampling Techniques Manuals establish the procedures to follow during an investigation, including sample collection procedures. Investigators collect evidence to determine if an applicator complied with applicable labeling, permit conditions, laws, and regulations.

A determination of compliance or noncompliance often involves evaluating the decisions the applicator made before and during the application. Applicator decisions, such as steps taken to protect nearby sensitive areas, modification of application equipment, or stopping an application because of weather conditions or proximity of workers in nearby fields, are evaluated to determine compliance.

Reviewing readily available information on application standards and guidelines can assist the investigator in evaluating applicators' decisions. The pest control industry publishes information about best management practices for pesticide applicators, and pesticide labels often include advisory language concerning pesticide drift minimization.

Enforcement

While there may be rare exceptions, in most cases the existence of damage or contamination (e.g., fish kills, phytotoxicity, damaged crops, and people sprayed) establishes the fact that the damage or contamination could have reasonably been expected to occur. In those cases, the applicator should not have made (or continued) the application, and the pest control business or the applicator would be cited for violating 3 CCR section 6614(b).

Some pesticide product labels direct applicators not to apply the product when conditions favor drift. If the applicator applied the pesticide under conditions the label directed against, the pest control business or the applicator could be cited for violating FAC section 12973 (using the pesticide in conflict with its registered labeling).

When an investigator determines there is sufficient evidence showing that a law or regulation was violated in a case or complaint involving pesticide drift, the DPR Enforcement Guidelines are used to determine the appropriate action. In most instances, the first violation warrants an Agricultural Civil Penalty or State action. Enforcement actions are undertaken without regard to outside events, such as private legal actions taken by persons alleging pesticide injury or damage. Taking established, consistent enforcement action maintains the integrity of the pesticide regulatory program and provides an even playing field for the regulated community.

Future

Pesticide drift incidents whether involving crops, people or property continue to challenge agriculture, communities and the regulators. To reduce the occurrence of drift incidence, DPR is pursuing the following steps: 1) increase enforcement surveillance; 2) providing clearer guidance to the regulated community on pesticide drift standards; 3) improving the regulations based on science and technology advances and, 4) cooperative partnerships with the agricultural community on voluntary compliance programs.

Pest Management in Urban - Rural Agriculture in the Central Valley and Fresno County

Richard H. Molinar, Farm Advisor
UC Cooperative Extension
1720 S. Maple Ave., Fresno, CA 93702
Phone: (209) 456-7555; FAX: (209) 456-7575
E-mail: rhmolinar@ucdavis.edu

The Players:

"It's a hot summer day in July. Mrs. George looks out the kitchen window of her one-year-old house to see a huge cloud of dust. A 60 hp. John Deere tractor is disking up the eight-acre cherry tomato field only 100 feet from her property line."

"Mr. Thomas is in his backyard barbecuing steaks when he smells a chemical spray. The grower, one block away, is spraying his gailon (sprouting broccoli) for aphids."

"Mr. Thao has been farming the same rented ground for nine years. A grammar school is built only one-fourth mile away this year and the farmer needs to spray his strawberries with a fungicide by helicopter, but the ag commissioner says 'no'."

So sets the scenario for urban-rural conflicts (the names are fictitious but the events are factual).

The Background:
California leads the nation in both agricultural production and numbers of new residents added annually. Urbanization gradually 'chips' away at prime California farmland, creating new urban-rural interfaces. The State experienced a gradual decline of agriculture in Los Angeles and the San Francisco Bay Area as more and more farmland was converted into urban housing. Several hundred thousand acres of rich coastal farmland were lost to urbanization in the two decades after World War II. Most of the lost production was relocated to the Central Valley. Problems arise when farmers on this urban-rural 'fringe' attempt to use pest controls or cultural practices associated with agriculture.

The urbanization continues today in both Los Angeles and Orange Counties. In 1982, Los Angeles County had 317,000 acres in farms, while in 1992, there were only 103,000 farmland acres. Orange County experienced similar reductions, from 155,000 in 1982 to 61,000 in 1992. The situation is quite alarming in light of the fact that in 1996 Fresno County had a 2.1% population increase, while LA had .5% and Orange had 1.3%.

While families in new housing tracts go shopping at a nearby shopping centers, Family Farmers (Small Farms) attempt to make a decent living from their 10-60 acres of 'specialty crops' nearby. Specialty crops are commonly grown because the potential exists to make a living off of a limited number of acres. "Small farms" are defined as: *family-run operations, grossing usually less than*

$100,000 annually. 'Specialty crops" are *unusual or exotic crops, unusual varieties of common crops, and/or miniature or baby vegetables.*

The Central Valley of California is made up of 18 counties, three of which lead the State [and Nation] in value of farm production. The three, Fresno, Tulare, and Kern, are at the southern end of the Valley (100 miles wide by 275 miles long), which, if combined into one country, would rank 5th in agricultural production in the world.. The Central Valley region has also seen a population gain of approximately 50% between 1980 to 1995. Fresno and Tulare Counties make up 25% of the State's total small farm population, which, in 1996, was approximately 78,000 farms in California. About 60% of the small farms raising specialty crops in Fresno County are on the urban-rural fringe. While driving along these fringes it is not unusual to see strawberries, cherry tomatoes, summer squash, peppers, etc. being sold from the many roadside stands; or to see many rows of strange, long, cylindrical, fuzzy vegetables growing on trellises. The specialty crops raised on these farms range from cherry tomatoes to moqua, baby lettuces, bittermelon, herbs, cilantro, summer squash, peppers, eggplant, and ethnic foods. They tend to be grown on small acreages, have a high cash value per acre, and are usually grown very intensively.

SPECIALTY CROPS GROWN ON THE URBAN-RURAL FRINGE
FRESNO COUNTY

	Acres		Acres
long beans	151	lemongrass	40
bittermelon	148	moqua	85
boysenberry	125	okra	20
napa	107	opo	36
cucumber	445	sugar peal	50
daikon	122	sinqua	46
doan gwa	15	zucchini	770
Ch/Jap eggplant	10	strawberries	554
gailon	140	taro	2

Fresno County is somewhat unique in that its farmers represent a very diverse ethnicity. About one-half of the farms in Fresno County are minority operated; 50% are S.E. Asian and 45% are Hispanic. Most of the Asian are Hmong (60%), who were invited to come here after their alliance with the CIA in helping U.S. soldiers during the Vietnam War. To remain in Laos would have meant certain death. The only occupation they knew was farming. So, while they live in the city, they farm on small parcels of rented land nearby.

Thus in Fresno, the problem of agriculture on the urban-rural interface is compounded by an influx of (new) farmers with a limited knowledge of modern agriculture and limited funds to implement the new technologies they learn here.

Pest Management

Many of the specialty crops grown on the fringe have very limited pesticide registrations. Growers sometimes have no choice but to resort to a more highly toxic chemical such as methomyl because that is the only one registered for a particular problem. Using fumigants, such as methyl bromide or metam sodium, is potentially very hazardous near houses and shopping centers. However, for the 1,000 plus acres of strawberries in the Central Valley there is not yet a viable alternative. As new schools, houses, and shopping centers are built on city boundaries, agriculture in that area gradually disappears, or moves further out, creating a new fringe. It is simply too cumbersome for the farmer to raise crops in close proximity to concentrations of people. Will it disappear entirely? Probably not because there are certain advantages for the farmer growing crops on the fringe. It gives them a good, viable roadside market to sell their specialty crops at retail prices, and it puts the farmer closer to wholesale packers/shippers and other marketing outlets such as farmers markets. The farmer will have to be more creative in the agricultural practices he/she uses on the farm. Using some of the alternatives already available for pest management, even though sometimes not as effective, will have to be considered.

Mulches for weed control. Black plastic and organic mulches provide good weed control of most annuals and many perennials. The disadvantage is a higher cost for materials than with preemergent and postemergent herbicides. Many growers are using black polyethylene plastic in eggplants, bittermelon, moqua, sinqua, cherry tomatoes, squash and other crops with very good results. Some strawberry growers are testing the black mulch.

Biological Pest Controls. The use of living organisms has proven effective for many pest problems. Viruses and nematodes for grub control, various strains of the Bacillus bacteria for lepidopterous, mosquito, and beetle insects, and fungi for certain diseases have all proven effective. A rust fungus for certain weeds is being investigated. There are many familiar insects which have been used for many years, e.g. ladybird beetles, lacewings, predatory mites, parasitic wasps and can be purchased, and encouraging native populations of damsel bugs, assassin bugs, big eye bugs, and syrphid flies is helpful. A grower routinely purchases trichogramma wasps to release in his specialty cherry tomato fields and is convinced it is helpful. Several species of predatory mites were released in strawberry fields in Fresno this past year to evaluate their use in a "Biologically Integrated Strawberry Systems" (BISS) program. This concept was totally foreign to the Hmong farmers raising these crops but they watched the practice very carefully.

Botanical Pest Control. The benefits of extracts from certain plants as pest controls are undisputed. Rotenone®, pyrethrin, sabadilla, nicotine, and neem can be used on many crops to control insects and diseases. There are numerous formulations and combinations of botanicals registered for many of the specialty crops discussed. Trilogy®, derived from the neem tree, is very effective against a wide variety of insects and certain fungal diseases. Rotenone®, in combination with pyrethrins or piperonyl butoxide, is effective against many beetles and other insects. One grower in Fresno raises his own tobacco to make his own nicotine extract for insect control.

Natural Earth Products. Diatomaceous earth, sulfur and copper have been used for disease and mite controls. Ultra fine oils and soap sprays are used for many smaller, soft-bodied insects such as aphids, whiteflies, mites etc. Luffa (sinqua), moqua, and opo are plagued every year by the two spot spider mite as are most other members of the cucurbit family. We evaluated several of these natural earth products for the control of this pest. The Trilogy, oil, soaps, and diatomaceous earth all provided fairly effective control in two years of research.

Mechanical. Although quite expensive, some growers are using floating row covers (Reemay®, etc.) to keep insects out by exclusion. It also provides effective control of many viruses which are spread by insect vectors such as aphids. A grower near Kingsburg with four acres of eggplants was advised that he had larvae of the sphinx moth causing considerable damage on the plant leaves. He decided to send his kids into the field to hand-pick the larger caterpillars (the organic spray would not be very effective on the larger instars) and follow that up with two sprays of Dipel®. The practice proved successful. Trapping the sun's heat under clear plastic in the middle of summer for four to six weeks has been used for many years. This practice, known as ***solarization***, has been shown to be effective for many weed seeds, disease problems, insect problems, and suppression of nematodes. Renewed interest in solarization has developed with the possibility of losing methyl bromide in January 2001. Temperatures between 140-150° F. have been recorded in the interior part of California. Solarization is not as effective in the coastal areas with the fog and cooler climate. Solarization research in strawberry fields in the Central Valley was initiated in Fresno and Merced Counties in 1997.

References

Agricultural Crop and Livestock Report. Agricultural Commissioner of Fresno County. 1996.

American Farmland Trust: Policy Statement and Background. 1997. 3 pgs. Internet address: www.farmland.org/farmland

Farmland Policy in California's Central Valley: State, County, and City Roles. Alvin D. Sokolow, October 1997. University of California. 12 pages. Internet address: www.ucop.edu/cps.

Fresno Specialty Crop Report. R. Molinar and M. Yang. University of California Cooperative Extension. 1996. 2 pgs.

Pesticide Use in California: Strategies for Reducing Environmental Health Impacts. William S. Pease, J. Liebman, Dan Landy, and David Albright, March 1996. University of California. 36 pages. Internet address: www.ucop.edu/cps

DEEP RIPPING OF ENVIRONMENTALLY SENSITIVE LANDS FOR TREE & VINE DEVELOPMENT

Michael A. McElhiney
District Conservationist
USDA Natural Resources Conservation Service
711 County Center III, Suite B
Modesto, Ca. 95355
Phone (209) 569-0497; E-mail mcelhine@inreach.com

The purpose of this presentation is one of information sharing based on professional experience in Stanislaus County, California. The subject ties in closely with the conference theme "Agricultural Challenges in an Urbanizing State." Some of our best soils are being consumed by urban development which places more pressure for agricultural development of "marginal soils" on the terraces of the Central Valley and low foothills of the Sierra Nevada.

Deep ripping of soils like the San Joaquin soil series (now California's State Soil) or the Rocklin, Montpellier, Whitney, Pentz, Redding soil series and many more may present some unique opportunities to Agronomists assisting producers with fertility, irrigation, erosion and other management decisions. Man-modified landscapes are usually in great contrast to the published Soil Survey for the area can be a real challenge when making any recommendations.

Deep ripping of these same soils and particularly the intermittent wetlands and vernal pools associated with them have raised some major obstacles for private property owners. Some producers are trying to deal with a maze of federal bureaucracies regarding wetland regulations that may affect their ability to develop all of their property through deep ripping practices.

Recent newspaper headlines declare:

"Deep ripping sets off farming fury" (Stanislaus Farm News 4/4/97)

"Valley developer is suing feds" (Sacramento Bee/Modesto Bee 5/18/97)

"Act supports fairy shrimp and reveals laws' absurdity" (Stanislaus Farm News 8/22/97)

"Farmer struggles against mixed bureaucratic signals" (AG ALERT 9/10/97)

"Wetlands continue to vanish, despite tough federal rules" (New York Times/Modesto Bee 9/18/97)

With the reorganization of the United States Department of Agriculture (USDA) the Natural Resources Conservation Service (NRCS) replaced the Soil Conservation Service (SCS). In 1996, Congress provided NRCS the new responsibility of Lead Agency for conducting wetland determinations and delineations on privately owned agricultural lands when requested by the landowner. Congress provided no additional authority with this new responsibility. Also, the concept of abandonment was dropped and the concept of "Once Prior Converted (PC), Always PC" was introduced.

Federal Agencies with wetland authorities and responsibilities include:

* The Regulatory Branch of the US Army Corps of Engineers who issue Clean Water Act Section 404 Permits for any disturbance or conversion of wetlands;
* The Environmental Protection Agency who have oversight and veto powers over all wetland conversions and permits issued by the Corps of Engineers;

* USDI Fish & Wildlife Service has responsibilities regarding any endangered species habitat that may be converted through deep ripping activities, particularly in regard to federally listed endangered fairy shrimp in vernal pools. Most of these remaining habitats are on private property;

* USDA NRCS assists private property owners comply with various Federal and State laws and assists agricultural producers improve resource conditions on their property through voluntary efforts at their request.

Some Key Federal Legislation and Regulations affecting wetlands include:

1969	National Environmental Protection Act
1972	Clean Water Act
1973	Endangered Species Act
1977	Executive Order 11990 - Required Protection of Wetlands
1980	Section 404 of Clean Water Act Guidelines
1985	Farm Bill - Food Security Act - Swampbuster
1986	Corps of Engineers Wetland Regulations issued
1988	"No-Net-Loss" Policies in place
1990	Farm Bill - Re-affirmed Swampbuster
1996	Farm Bill & USDA Reorganization "Once PC, Always PC"

In 1985, Congress linked agricultural commodity programs with conservation compliance of wetlands and highly erodible lands. This linkage was targeted exclusively at USDA Farm Program Participants. In other words, NRCS/SCS conducted wetland determinations only on farms that were receiving some USDA program benefit. Those wetland determinations will most likely be cancelled by the end of the year and all future wetland determinations will be done using new standards yet to be agreed-to by the Corps of Engineers, EPA and NRCS.

Many agricultural producers on private property in the West with permanent crops (orchards, vineyards, rangeland and pastureland) did NOT participate in USDA agricultural commodity programs and therefore did NOT have a wetland determination done on their property and therefore may NOT be sufficiently informed about wetlands on their property.

In general, regulatory agencies were not funded to conduct information and education programs to private property owners. Although NRCS/SCS was required to inform all USDA program participants of any wetlands found on their property, most of the ongoing wetland conversions are occurring on landscapes that did not require a USDA wetland determination.

With President George Bush's 1988 statement of "no-net-loss" of wetlands, the Corps of Engineers began to focus on all jurisdictional wetlands, including vernal pools. Initially the Corps of Engineers issued permits for the conversion of these wetlands as long as there was "no-net-loss." Most of these permits were related to commercial development for shopping centers, freeways and housing subdivisions. Now the focus includes landscapes that are being actively converted (deep ripped) for orchard and vineyard development.

With endangered species (fairy shrimp) now linked to these landscapes and with 404 permits increasingly harder to obtain, frustrated landowners continue to look to Congress for changes in the Endangered Species Act and Clean Water Act. The result so-far is that NRCS is now the Lead Agency for conducting wetland determinations on agricultural lands. NRCS does not issue 404 permits, and does not regulate endangered species habitat.

NRCS wetland determinations are valid for most agricultural uses. If a 404 permit is required, additional documentation and biological opinions may be required. NRCS Prior Converted Cropland determinations are not always in agreement with Corps of Engineers policies. "Once PC, Always PC" is yet to become a reality.

So what "Service" can NRCS provide to private property owners who wish to go through the process?

* NRCS has offices in most counties and know the land and live in the community;
* NRCS can conduct wetland determinations & delineations or can verify consultants work if hired by the property owner;
* NRCS can assist with planning, alternatives, mitigation and restoration;
* NRCS has local resource data available such as hydric soil lists, aerial photos, soil surveys, wetland inventory maps;
* NRCS has additional wetland designations, such as artificial wetlands (AW) and prior converted cropland (PC);
* NRCS uses the same criteria as the Corps of Engineers;
* NRCS can be the only federal point of contact and can assist property owners understand the rules/laws/procedures;
* NRCS is not regulatory in mission or nature;
* NRCS is USDA, not EPA, not Corps of Engineers, and not Fish & Wildlife Service;
* NRCS is there to help, if property owners want our help;

Recent aerial photos reveal that large areas of these vernal pool landscapes continue to be converted to orchard and vineyard development through deep ripping practices. Regulatory agencies are reviewing aerial photos and are citing property owners for wetland conversions. Increasingly, complaints are filed by individuals and environmental groups who continue to bring this issue to the attention of regulatory agencies.

Soils that were once considered "marginal" or were designated as "poorly suited" for intensive agricultural crop production as noted in many older Soil Surveys, are now out-producing some soils that have been traditionally thought of as "well suited" for deep rooted crops such as almonds and grapes.

Developing these soils into productive cropland requires a lot of horsepower; (D-10 Caterpillars) and deep shanks ripping 6-8 feet through these ancient soil profiles of claypan and duripan (hardpan) and bedrock. At the present time, deep ripping is apparently cost-effective, as long as there are no vernal pools or other wetlands disturbed.

Agricultural producers need to be well informed even if some of their new orchards and vineyards have converted wetlands in violation of the Clean Water Act and possibly the Endangered Species Act. Environmental laws and regulations do not appear to be waning. Sooner or later, there may be regulatory and/or escrow consequences.

As lead agency with the responsibility for wetland determinations on agricultural lands, NRCS will continue to take a balanced, professional approach in this area of our work. NRCS assisted with a number of deep ripping information meetings sponsored by the Corps of Engineers and EPA in 1997. More information and education is essential if we are going to achieve "no-net-loss."

All professionals providing consulting services to private property owners should be aware of the regulations and assist clients avoid the potential consequences of deep ripping on environmentally sensitive lands. Deep ripping of vernal pool habitats is one of many challenges agriculture faces in an urbanizing state.

CONSERVATION FARMING AND ITS POTENTIAL IN CALIFORNIA

Brent Rouppet
Soil and Plant Sciences, Merced College
3600 M Street
Merced, CA 95348
Phone 209/384-6251

Conservation farming and tillage practices are not new. They have been practiced throughout the United States and the world for many years utilizing both a variety of techniques, methods, and procedures, as well as an assortment of farm implements. Research and development of conservation tillage began in the United States as early as the 1930s or before, but did not gain popularity until the mid 1960s. Growers began accepting conservation tillage practices in order to reduce soil erosion and to save fuel, time, and money.

Conservation tillage is a system of management which combines two major objectives:

- To maintain production of profitable, high yielding crops
- To conserve energy, water, soil, and other natural resources

As stewards of the land, the ideal with conservation tillage practices is to assure future production through wise use of resources while still providing food and fiber for the current population.

The most recent incentive or push for conservation farming began when soil conservation was mandated by the 1985 Food Security Act. The Swampbuster and Sodbuster portion of this act required growers farming highly erodible croplands (HEL) to initiate an approved conservation plan by 1990. If the growers farming these highly erodible croplands failed to comply with "Swampbuster" and "Sodbuster", they no longer remained eligible for USDA program benefits (e.g., price supports and disaster payments). The 1990 Food Security Act further strengthened the conservation requirements for all highly erodible cropland. By 1990, 26% of the cropland in the United States used some form of conservation tillage. Best estimates have current conservation tillage acreage above 33% of all cropland being farmed.

It has become the incipient goal for agriculture to develop systems that are permanent or sustainable. In 1987 the World Commission on Environment and Development defined sustainable agriculture as: "meeting the needs and aspirations of the present without compromising the ability of future generations to meet their own needs." Intensive agriculture systems sustainability is now emphasized because of:

1. limiting nonrenewable resources
2. high soil degradation
3. pollution of surface and groundwaters

It is true that agricultural production should be as economical as possible for both producers and consumers. However, at the same time the soil can not be permitted to be degraded or destroyed. Since tillage is mainly a resource consumer and can cause soil degradation when used in excess, adaptation of tillage practices to the above notion of sustainability are being promoted. This includes:

1. reduction in intensity of cultivation
2. reduction of frequency of cultivation

Any adaptation to reduction in tillage must be geared to soil tillage requirements and crop establishment needs. It should also assure that resultant conservation or sustainable tillage practices be both soil and crop specific in nature.

The initial problem occurs where bare soils, associated with conventional tillage, lead to severe soil losses due to erosion by both wind and water. Long-term increases in production costs result when erosion alters the soil's productive capacity. The adverse effects of erosion on rooting zone depth and soil quality are the most pervasive long-term causes of soil productivity losses.

Conservation tillage has two basic advantages for the agricultural producer: (1) conservation of soil, water, and soil organic matter resources; and (2) reduction of costly inputs while maintaining or actually improving crop yields and profits.

1. Soil, Water, and Soil Organic Matter Resources: Improved soil and water conservation through conservation tillage results in preservation of topsoil and soil organic matter. The primary causes of soil erosion are excessive and/or poor tillage practices that leave bare soil exposed to the eroding forces of water and wind. The basic principle of conservation tillage is to keep a soil and water holding cover on the soil surface, whether by residue or vegetative cover.

Under conditions of limited soil water and precipitation, crop yields are equal and often significantly higher with conservation tillage systems than with conventional tillage. The higher yields with conservation tillage systems generally are attributed to increased soil water content resulting from increased infiltration, decreased runoff, and decreased evaporation. Since increased infiltration, decreased runoff, and decreased evaporation often result from conversion to conservation tillage systems, it is possible for growers to change to more intensive crop rotations or to increase crop yields with traditional crop systems.

2. Conservation Tillage and Production Costs: Conservation tillage provides cost savings in three principal areas: (1) energy; (2) time and labor; and (3) machinery costs. Tractor fuel is the single largest use of energy in agriculture. Conservation tillage systems help to reduce fuel use up to 60% with no-till compared to conventional tillage systems (Table 1).

Time and labor are reduced when field trips are eliminated with labor reductions of 50-60% being common while time saved in actual tillage is also greater. Reduction in machinery costs vary depending upon the conservation tillage system selected. With a straight no-till farming system, only four basic pieces of equipment are required: a tractor, a planter, an herbicide sprayer, and a harvester.

Table 1. Comparison of Fuel Requirements for Field Operation in Conventional, Chisel, and No-Till Systems for Corn on Loam Soils.

Tillage System and Field Operation	Fuel Requirement (gal/ac)
Conventional System	
Disking corn stalks	0.45
Moldboard plowing	1.85
Disking	0.55
Field Cultivation	0.60
Fertilizer Injection (NH_3)	0.70
Planting	0.50
Cultivation	0.35
	5.00
Chisel Plow System	
Chisel Plowing	1.25
Disking	0.55
Field Cultivation	0.60
Fertilizer Injection (NH_3)	0.70
Planting	0.50
Cultivation	0.35
	3.95
No-Tillage System	
Shred Corn Stalks	0.75
Liquid Fertilizer Application	0.20
No-Till Planting	0.50
	1.45

Source: Rouppet, 1995

When compared to a conventional tillage system which requires an assortment of plows, disks, cultivating equipment, etc., it is easy to evaluate differences in equipment costs.

In a sprinkler-irrigated wheat study in the Clovis, New Mexico area, irrigated cost and return estimates showed large differences between conventional and conservation tillage systems. while yields and purchased inputs were similar, the conservation tillage system saved $27.71/acre in irrigation fuel and oil savings. The difference was caused by reducing the number of irrigations from seven to five, showing less loss of water due to evapotranspiration. Also, conservation tillage operating expenses for the wheat were $35.24/acre less that the conventional tillage system. Together, there was a total savings of $62.95/acre with the conservation tillage system when compared to the conventional tillage system (Jones et al., 1994). This illustrates that, not only can yields be maintained with conservation tillage systems, operating costs and water inputs can also be reduced.

The challenge for California's continued adaptation of conservation tillage for the 21st century is simple: maintain production of profitable, high yielding crops while simultaneously conserving energy, water, soil, and other natural resources. We must integrate all available information on conservation farming and tillage so California's farming community can utilize it while being confident in the facts for their decision making processes. We can indeed then meet this challenge which can satisfy not only the grower, but all societal and environmental needs and concerns. The potential for more conservation tillage to be adopted in California is immense.

Literature Cited:

Jones, J. M, J. D. Libbin, N. B. Christensen, and J. Schroeder. 1994. Economic Comparison of Conventional and Conservation Tillage in Eastern New Mexico. Research Report 687. New Mexico State University; Agric. Ext. Sta., Las Cruces, NM.

Rouppet, B. 1995. Conservation Farming in New Mexico. Cooperative Extension Service, New Mexico State University, Las Cruces, NM.

CULTURE, CAPITAL, AND CONTOURS:
A Socio-Economic Approach to Managing Marginal Agricultural Lands

Daniel C. Mountjoy, Ph.D.
USDA - Natural Resources Conservation Service
635 Sanborn Place, Suite 7
Salinas, CA 93901
Phone (408) 424-1036; Fax (408) 424-1027; E-mail Dmountjoy@aol.com

BACKGROUND

Land use changes in California history have led to increasing reliance on marginal lands for the production of agricultural commodities. The management of these lands involves increased costs to producers and to society at-large through off-farm environmental impacts. A case study of hillside farming decisions in the 70 square mile Elkhorn Slough watershed in northern Monterey County identifies the varied human causes of marginal soil use and degradation, and illustrates strategies to conserve soil resources.

European settlers began to shape the California landscape more than 200 years ago for the production of introduced crops and livestock. They sensibly established their farms and communities on the most productive land along rivers in the state's fertile valleys. As population pressures and the demand for agricultural produce grew, the need for arable land led to the draining and diking of wetlands and terracing of hills. Over the next 150 years, new technologies such as large earth moving equipment, water pumps, new cultivars, and sprinkler and drip irrigation were essential to the expansion of agriculture onto marginal soils. Specialty crops suited to marginal soils have led the charge on outlying marginal soils. Wine grapes, strawberries, avocados, and almonds have all proven profitable on less than prime soils. Income from these high value crops can offset the initial costs of investment.

The most recent pressure towards cultivation of marginal soils has been the inexorable spread of urban development outward from the original valley bottom agricultural communities onto surrounding prime farmland. The resulting demand for productive land has increased the attractiveness of breaking hilly range land for irrigated crops.

CASE STUDY OF STRAWBERRY PRODUCTION IN MONTEREY COUNTY

Cultural History: The history of farming in Monterey County (as in most of California) is a product of ethnic immigration patterns. Each group of people that has become strawberry producers has transformed the area's natural resources. Strawberries were first grown in the region in the late 1800's by Northern European immigrants ('Anglos'). These early berry farms were concentrated in the Pajaro Valley while the surrounding sandy uplands were used primarily for dairying by Portuguese immigrants.

A major expansion of strawberry production onto hilly slopes occurred following the repeal of the Alien Land Laws in 1952 when Japanese farmers were able to acquire land of their own. Rather than sharecropping on Anglo farms, the Japanese farmers began to acquire small acreages in the available lower-priced coastal bluffs and consolidated sand dunes around Elkhorn Slough. This new form of intensive hillside strawberry production required careful management of the erodible soils but yielded high returns to hard-working family farmers.

Beginning in the 1950s new strawberry varieties and production methods produced higher yields but demanded more labor than the farm family could provide. This labor shortfall led to the introduction of a third ethnic group in strawberry production. Seasonal Mexican migrants were able to meet the new labor demands. These workers soon learned the process of strawberry production from their Anglo and Japanese employers and became independent sharecroppers beginning in the 1960s. In the 1970s publicly-sponsored co-ops created opportunities for other Mexican laborers to become independent producers. During this period new strawberry cultivation was initiated on undeveloped property in northern Monterey County with slopes of 15 to 35%.

Strawberry land management today reflects this ethnic history of its farmers. The historical opportunities of each group can still be seen with Anglos farming the most fertile valley bottom land, Mexicans farming the steepest, most erodible marginal soils, and the Japanese cultivating less erodible hill land and some valley-bottom land.

The Role of Capital in Financing Hillside Management: Economic theory predicts that marginal lands will be cultivated as the demand for prime land pushes up values and rents and makes the lower costs of marginal land more attractive. An examination of the development of hilly lands in the Elkhorn Slough watershed of Monterey County reveals that indeed the land rents are cheaper than in the surrounding valleys. However, many of the farmers in the hills are farming there because they could not gain access to leases on flatter more productive ground. Even if they could afford it, many Mexican immigrants lack the social networks to secure a lease on prime farmland. As latecomers to the industry they must content themselves with the land that is available.

Land ownership has long been considered a prerequisite to investment in conservation practices on marginal land. This theory is based on the assumption that the benefits of conserving natural resources will not be realized in the short term and tenants are unlikely to farm a piece of land long enough to realize the long-term benefits. In the highly erodible loamy sands of Monterey County this assumption does not hold up since conservation investments yield immediate benefits in the form of preventing gully erosion and direct crop damage. As a result, every farmer invests in some form of erosion control. There is no significant difference in the management of lands by owners or tenants in the project area.

A much more important factor in explaining variation in the management of steep marginal lands lies in the type of financing that the grower is able to tap into. Long established Anglo and Japanese growers have access to commercial lending institutions that provide resources to cover all aspects of production. In contrast, most of the more recent Mexican immigrant farmers depend on their shippers for production loans. Most of these loans cover only direct production costs and rarely support investments in long-term conservation practices.

These contractual lending-marketing relationships also lock the growers into a single marketing outlet and lead to a situation of price taking. As a result, Mexican growers have lower earnings than other strawberry farmers. Lower returns lead these farmers to continuously crop their hillside farms in order to pay off their loans. So while historic opportunities have led Mexican farmers to farm the most marginal lands, they also have the least financial ability to invest in these lands. Investments in soil quality or conservation remain a low priority and the result is accelerated erosion and degradation of these fragile lands.

Strategies for Managing the Contours: The social and economic opportunities for hillside farmers have resulted in the rational selection of short-term damage reduction strategies. A farmer faced with limited financing and an uncertain future would be taking a large risk to invest in cover crops or terraces. Instead, the preferred strategy is to place the strawberry furrows across the slope and protect the access roads from gully erosion with plastic lined ditches. Unfortunately, this solution tends to effectively control only about 50% of the potential erosion problem. Even at an annual cost of $261 per acre these management strategies still allow an annual erosion rate of 33 tons per acre.

More effective hillslope management techniques have been developed by innovative farmers together with the Natural Resources Conservation Service. Underground drainage conduits cost considerably more to initially install but can eliminate 95% of the erosion problem at an annualized cost of $256 per acre spread over 15 years. Unfortunately, up front costs usually exceed the cash flow abilities of most farmers.

Since most farmers have either been unable to afford or have been unaware of these alternative management strategies, erosion control efforts have been only partially successful. Rill erosion of strawberry beds reduces the rooting area of the crop and gully erosion on field roads buries the crop further down the hill and prevents access to the fields in the spring. The gradual downhill movement of soil through annual cultivation and erosion processes has reduced the topsoil depth by as much as three feet over 20 years on some farms.

Most farmers have been able to compensate for eroded clay and silt fractions, and reduced organic matter with increased inputs of soil amendments and fertilizers. Increases in strawberry cultivar productivity has outpaced the extra cost of production inputs so most farmers do not consider soil degradation to be a pressing problem except on the field roads. However, average soil losses exceed soil genesis by a factor of six. At this rate 15% of the 3,600 acres of strawberries in the Elkhorn Slough watershed are expected to go out of production in the next ten years.

The cultivation of marginal lands not only poses a threat to the sustained productivity of the farmland but also damages resources downstream. When steep erodible hillsides are farmed, the transport of soluble and soil-borne agrochemicals into water bodies is accelerated. On-farm soil erosion transports sediment onto adjoining private property, county roads, and riparian and wetland habitats. These external costs of farming marginal lands are rarely shouldered by the farmers but are paid by taxpayers and the public at large.

THE ELKHORN SLOUGH WATERSHED PROJECT

In 1994 the Elkhorn Slough Watershed Project was initiated by the USDA Natural Resources Conservation Service in partnership with the Resource Conservation District of Monterey County. The eight year project was planned to address the social and economic causes of soil degradation on private farmlands within the watershed. The project was initiated with the recognition that technical solutions alone will not solve the problem. The project also was based on the assumption that marginal land could be farmed if appropriate measures were taken to protect the resources. Project implementation has focused on overcoming information, financial, and technical barriers to improved land management.

Information Barriers: The interdisciplinary project team has targeted outreach and information programs to distinct sub-populations within the watershed. Due to the ethnically and economically distinct experiences of local farming groups, information does not flow freely among all farmers. Mexican farmers tend to learn about agricultural innovations from family members and marketing representatives while Anglos tend to rely more on Cooperative Extension advisors and their own proprietary research. The Japanese farmers tend to rely more on other members of their marketing cooperatives or private advisors. NRCS promotion of conservation practices have tapped into these varied networks to more effectively reach the desired audiences. Bilingual events have encouraged greater participation by Spanish-speaking farmers. Neighboring farmers are invited to meet together to discuss common resource issues and develop mutually compatible plans for addressing the problems. This approach utilizes peer pressure to increase participation but also facilitates discussion of innovative local solutions to the problems.

Financial Barriers: Since cash flow limitations prevent investment in costly land conservation practices, NRCS has encouraged farmer participation in financial cost-share programs. Many farmers were unaware of these programs or felt the amount of funding scarcely compensated for the time-consuming application paperwork. The project team has sought ways to streamline the bureaucratic process by delivering documents to the farmer for signatures. These issues have not been fully resolved but unprecedented numbers of farmers have signed up for program benefits in the last two years due to a proactive strategy for advertising the program to needy individuals. In some cases, the existing cropping or marketing system will never remunerate the farmer sufficiently to justify an investment in sustained resource management. In these situations the farmers are encouraged to consider crop diversification to lessen marketing dependence and risk, increase revenues, and reduce the impact on the land.

Technical Barriers: Technical solutions must be tailored to the management abilities of the farmer. Some farmers want an erosion control system that they can ignore for an entire month during the winter and are willing to pay for this designed security. Others want to minimize cost but can provide hourly maintenance during storms. For a resource conservation technology to be accepted and maintained it must be affordable, understandable, and manageable with available skills, equipment, and time. The watershed project team has been conducting trials on a number of practices that meet these criteria for farmers who can not invest in underground outlet systems. For instance, annual grasses are being sown in the ends of furrows to trap sediment and slow runoff; vegetated roadways and field border plantings are being studied for their potential to attract beneficial insects and reduce the cost of spraying insecticides; and low cost techniques for laying out furrows to minimize erosion are being taught.

CONCLUSIONS

The case study of the Elkhorn Slough watershed illustrates the need to understand the social and economic factors that lead to the development of farming on marginal lands. The Watershed Project has also tested effective strategies to encourage voluntary management of difficult terrain. There is no single technical recommendation that is appropriate for all hillside farmers. Without understanding the interests and abilities of each farming community we can not prescribe how best to manage those lands. The cost of delivering an effective technical outreach program is high but the social and environmental cost of doing nothing is even greater.

Expanded cultivation of marginal lands in California is generally viewed as an inefficient use of land resources when compared with the prime agricultural soils of the level valleys. However, many social and economic pressures have already driven farmers to utilize these marginal resources. Unfortunately, a lack of experience, financial resources, and acceptable management technologies have often resulted in severe resource degradation in many locations.

Local reaction to erosion and water quality problems has led to ordinances that restrict hillside farming in many counties. Yet in some cases marginal lands can be farmed sustainably and profitably with specialty crops. If, as a society, we are consciously making the decision to pave over our fertile valley cropland then we need to also take on the responsibility of promoting sound management of the marginal lands that will next be farmed. Perhaps the appropriate mitigation for urban development of prime farmland may be to require the developer to invest in the training and infrastructure needed to sustain hillside farming. This approach internalizes the true cost of shifting production from prime to marginal farmland and allows us to evaluate the full consequences of our choices.

Scholarship Essay

How can you, in your agricultural career, help to resolve the conflict between the need for natural resources required by production agriculture and the rapidly growing urbanizing society in California?

Joel G. Canestrino
Student, Agricultural Systems in the Environment
University of California, Davis
Hometown: Lodi

The current conflict between the agricultural and urban sector over the use of California's finite natural resources will evade simple solutions. Farmers in the state can not expect help from the government in the form of subsidy programs which are designed to maintain the state's agriculture base nor can they expect to be able to outbid urban populations for land or water resources. The best way to minimize the current conflict is to invest heavily in agricultural research and development with the primary goal being to produce a high quality crop, with sustainable, high yields.

Investment in agricultural research and development has historically, had a fifteen to twenty percent return rate for every dollar invested and relies mostly on intellect, which is a renewable resource. Research and development improves production efficiency in many ways. Each time efficiency increases, yields increase or the use of non-renewable resources for the same yield decreases. Either way, resources are conserved and there is less pressure to put marginal land into production.

My ideal agricultural career would be to spend the next fifteen to twenty years as a Production Specialist for the seed industry and then farm with my family. In the seed industry, I would like to work in a position which focuses on applied research. I want to work closely with plant breeders to improve crop resistance to plant pathogens and I would like to establish recommended cultural practices for specific varieties. Improved genetic resistance will result in the use of less pesticides, the conservation of natural resources and reduce the exposure of the urban population to potential toxins. Establishing recommended cultural practices will improve production efficiency resulting in reduced fertilizer use, better irrigation practices which will make more water available for urban or environmental uses and, hopefully, higher yields. As a farmer I hope to apply my knowledge and experience to produce vegetable or specialty crops for local markets and restaurants. Regardless of my future career, I look forward to promoting and improving California's role as the world's leader in agriculture.

Scholarship Essay

How can you, in your agricultural career, help to resolve the conflict between the need for natural resources required by production agriculture and the rapidly growing urbanizing society in California?

Allison M. Bettencourt
Student, Soils/Irrigation Production Management
Fresno State University
Hometown: Visalia

A career as a soil conservationist, with Natural Resources Conservation Service, allows me to address issues dealing with our natural resources on a day to day basis. Through my education, work experience, and my determination to make a difference, I believe that I can help bridge the gap to a better understanding of agriculture. I feel that people need to be more informed about our natural resources so they can appreciate the value of prime agricultural land.

Through NRCS, I have the ability to work with various agencies, organizations, groups, growers and landowners on alternative methods for protecting and preserving agriculture's prime farmland. There are many different aspects of my career, present and in the future, that give me the opportunity to make an impact on educating people on awareness of our natural resources.

One of my career goals is to contribute to making a difference in agriculture. I can accomplish this through educational outreach opportunities that are available to me. I am able to inform people who make crucial decisions dealing with urbanization using information in the advance draft of the Western Tulare County Soil Survey. The survey is also a great educational tool to help address more effectively, the current issues we are facing,. The survey helps show that soils have different limitations or uses which help identify the location for urban areas on our less desirable ag lands. The survey also contains the information that I need to work closely with planning departments and supervisors that make these crucial land use decisions.

In my career, I will also assist with the implementation of programs that target funding for research and development into new hybrid seeds and other genetic improvements. This leads to producing higher net yields per acre, thus helping offset prime farmland loss caused by urban expansion. I also helps land users plan and apply integrated resource management systems that are economically and environmentally sustainable. In addition there are other activities, that I am involved in, that help lead people to a greater understanding of the area around them which includes the physical and biological process that shape it and the activities that effect it.

Since there is a clear difference in the value of the land in ag production versus urban development, I want to help show that ag land is valuable enough to preserve. People need to remember that the Central Valley is the nation's most important agricultural resource that produces two hundred and fifty commodities which are worth more than thirteen billion dollars a year. I feel that is the best reason for preserving what we have. We need to work together to encourage more compact urban growth and wiser use of our natural resources in the valley.

Scholarship Essay

How can you, in your agricultural career, help to resolve the conflict between the need for natural resources required by production agriculture and the rapidly growing urbanizing society in California?

Jennifer Campos
Student, Crop Science Department
Cal Poly, San Luis Obispo
Hometown: Woodland

According to the UC Sustainable Agriculture Research and Education Program at UCD, agriculture has changed dramatically since World War II. The research program has stated that these changes have allowed farmers to produce the majority of our food with reduced labor demands, but not without a significant cost to our environment. The significant costs of our farming methods that the Sustainable Agriculture Research and Education Program have recognized include topsoil depletion, groundwater contamination, the decline of family farms, continued neglect of the living and working conditions for farm laborers, increasing costs of production, and the disintegration of economic and social conditions in rural communities. By the year 2025, it is predicted that eight billion people will be living on the planet. It cannot be denied that these people will need land, energy, water and food whether they live in cities or in rural settings. The depletion of natural resources required for production agriculture is inevitable. A suggestion I can offer to help resolve the conflict between the need for natural resources required by production agriculture and the rapidly growing urbanizing society in California is compromise; compromise between agriculturists and urban city dwellers.

We cannot determine or control how long our resources will last. But we can, as many agriculturists are already doing, implement sustainable agriculture practices. The UC Sustainable Agriculture Research and Education Program says that the best approaches to agriculture are those that are the least toxic and least energy intensive and yet maintain productivity and profitability. In order for production agriculturists and urban city dwellers to compromise they need to be educated. Misconceptions about agriculture exist among urban city dwellers. Production agriculturists, often set in the way things have always been done, may not see the opportunities for protecting the environment that cities desire. In my career in agriculture I would like to work toward bridging the gap between production agriculturists and urban city dwellers by interacting with the community through educational workshops, seminars and campaigns. I think a program similar to the Farm Bureau's Ag in the Classroom, which aims to expose students to agriculture in their general curriculum, would be beneficial in teaching both urban city dwellers and productions agriculturists the overall impact of farming practices on the members of the community and the environment.

Poster Presentations

Root Distribution of Cotton Under Drip Irrigation.

R.B. HUTMACHER, K.R. DAVIS, S.S. VAIL, M.S. PETERS, J. COVARRUBIAS, USDA-ARS and Univ. of CA.

Numerous studies have described wetted patterns characterizing water distribution under subsurface drip irrigation, but few have identified root distribution under these conditions. A study was conducted under field conditions for three years in a clay loam soil in the western San Joaquin Valley of California. Primary objectives of the study were to evaluate root distribution of cotton under subsurface drip irrigation at water application rates ranging from 50 to 100 percent of estimated crop evaportranspiration. Emitter spacing was 0.91 m along laterals that were spaced 1.52 m apart. Root length density and root weights were determined as a function of distance from emitter and depth in the profile. The depth and root length density for root distribution were significantly affected by water application amount and horizontal distance from emitters. The influence of growth stage on root distribution will also be discussed.

R.B. Hutmacher, (805)746-80220, rbhutmacher@ucdavis.edu

Comparison of Nitrate Uptake and N-use Efficiency of Acala and Pima Cotton.

D. W. RAINES*, R. TRAVIS and M. ASLAM, Univ. of California, Davis.

Field trials evaluating the response of cotton to nitrogen indicate that recommendations for fertilizing cotton may not be appropriate for the newer varieties and management practices. In addition, greenhouse studies in which these varieties were grown under controlled conditions showed that accumulation of NO_3-N by Pima (*Gossypium barbadense)* is significantly greater than the Acala (*Gossypium hirsutum*) types. However, this is accompanied by a greater biomass accumulation. In an attempt to better define the processes regulating nitrogen utilization by these two species nitrate uptake by 10-day-old seedlings of three Pima and four Acala varieties was examined. Uptake by Pima cotton varieties was ~ 50% higher at 0.05 mM nitrate as compared to Acala varieties. The differences in uptake rates decreased as nitrate concentrations increased. In contrast, nitrate efflux from Pima roots was about 2-fold higher at all nitrate levels. The relationship between transport of nitrate by roots and N-use efficiency of Pima and Acala cotton will be discussed.

D.W. Raines, (916) 752-1711, derains@ucdavis.edu

Comparative Uptake and Assimilation of Nitrate in Intact Seedlings of C_3 (barley and C_4 (corn) Plants Effect of Light and Exogenously Supplied Sucrose. S.S. GOYAL* and H.L. SEHTIYA, University of California at Davis.

The controversy regarding the role of light in nitrate uptake and its assimilation continues to exist. In the present study with 9-day-old seedlings, one percent sucrose in the medium increased nitrate uptake by 31% in barley and 70% in corn, during light. The corresponding increase during darkness was 38% in both barley and corn. Darkness during the assay period decreased the *in vivo* nitrate reduction by 88% in barley and 49% in corn, as compared to light. Inclusion of sucrose in the medium during light increased the *in vivo* reduction of nitrate by 89% and 77% in Barley and corn, respectively. The corresponding increase during darkness was 967% in barley and only 51% in corn. Comparative uptake and assimilation of nitrate in green and etiolated seedlings of barley and corn will be discussed from standpoint of whether light is obligatory for nitrate uptake or its reduction.

Sham S. Goyal 916 752-2472 ssgoyal@ucdavis.edu

The Contribution of Low Molecular Weight Organic Acids from Decomposing Rye to Reductions in Rook-Knot Nematode Populations. R.G. MCBRIDE, R.L. MIKKELSEN, and K.R.BARKER, N.C. State Univ.

Plant-parasitic nematodes are invertebrate worm-like animals that require a susceptible hose plant to complete their life cycle. Nematode control includes the use of resistant cultivars, cultural practices, and chemical control. An alternative method of control is the addition of organic materials to the soil. It has been suggested that the organic acids associated with the degrading organic materials may be directly toxic to the nematodes. In this study rye was incorporated into nematode-infested soil at different rates. The soil solution was analyzed to determine the presence and concentration of five low molecular weight organic acids by means of ion exclusion chromatography. The acids recovered were minimal, and were only present for a short time, suggesting that these acids do not play a substantial role in the control of plant-parasitic nematodes. However, a bioassay where tomatoes were grown in rye-amended soil showed a significant reduction in nematode infection compared with the non-amended soil.

Robert Graber McBride 919 515-2388 Robert_Mikkelsen@ncsu.edu

Effect of 15 Years of Biosolids Application on Crops and Soil Phosphorus. A.E. PETERSON*, R.P. WOLKOWSKI, P.E. SPETH, TH WRIGHT, and P.L. SCHLECHT, Univ. of Wisconsin-Madison and Milwaukee Metropolitan Sewerage District.

Since biosolids contain considerable amounts of plant nutrients, recycling of these nutrients may benefit agricultural crops and be environmentally safe. Experiments to study these effects were established in 1979 on the Walworth County Farm, Elkhorn, WI on Plano silt loam (prairie) soil. Corn is grown as the indicator crop. Twenty-two groundwater wells were installed to depths of 8 to 10 m and are sampled bimonthly. Treatments are untreated, fertilizer, 6.6 (the normal rate) or 13.3 T ha^{-1}. Corn yields and tissue analysis have indicated no toxic effect from any biosolid application. No heavy metal movement has been found below the tilled soil. Nitrate concentrations have increased has been found below the tilled soil. Nitrate concentrations have increased in the heavy biosolids treatment. After 15 years of biosolids application, no detrimental effect on plant growth or Zn uptake is shown, regardless of the soil P of the plow layer which now measures 52,220, 340, and 183 mg kg^{-1}, respectively, for the check, 6.6, 13.3 T ha^{-1}, and the fertilizer treatment. There seems to be no reason to limit biosolids P application to that removed by the crop from the effect on the environment. Also the comparative risk assessments for methods of biosolids disposal show land application to have the least risk.

A.E. Peterson, (608) 262-6844, shabman@vt.edu

Nonpoint Source Risk Assessment using BASINS; Case study of Yolo County, CA. R. FAVREAU, M.ZHANG AND S. GENG*, Univ. of California, Davis.

The EPA recently distributed DASINS a multi-purpose environmental analysis system which runs on a PC equipped with ArcView 2.1 GIS system. We have two objectives: to determine if BASINS is an efficient system for performing water quality risk assessment, and to determine if BASINS provides sufficient information for a course in environmental risk assessment. To evaluate these objectives, we used data from Yolo county. CA. BASINS has six major elements: three are data analysis tools designed to identify pollution problems in the study area, and three are modeling tools to study pollution concentrations. This study applied each of these tools to the watersheds in Yolo county. We found that BASINS is indeed a very efficient water quality assessment system and is an excellent resource for education.

S. Geng, (916)752-6939, sgeng@ucdavis.edu

Genetic Analysis of Root Architecture in Lettuce. L.E. JACKSON, D.A. ST. CLAIR, R.W. MICHELMORE, L.J. WYLAND, and O. OCHOA, Univ. of California, Davis.
Large root systems that efficiently obtain nutrients and water from deep and surface soil layers would be advantageous in cultivated lettuce, *Lactuca sativa*. A shallow-rooted crop that requires high fertilizer and irrigation inputs. Its wild relative, *L. serriola*, has a deep root system. Accessions from the two taxa were crossed, and F_3 and F_4 families were produced. In the greenhouse, 70 F_3 and F_4 families were grown for 3 to 4 weeks in sand in large pots. Roots were assessed for dry weight, taproot length, and number of lateral branches along the taproot in 5-cm increments. Large variation for some traits was observed, *e.g.*, among F_3 families, mean taproot length was 19 to 33 cm, and mean number of laterals emerging from the lowest 5 cm of the taproot was 0.2 to 9. Parent offspring regressions between F_3 and F_4 families are underway. AFLP markers were used to develop a genetic map using the same population. The genotypic and phenotypic data will be analyzed using both single factor ANOVA and interval mapping to detect marker-QTL associations.

L.E. Jackson, (916) 754-9116, lejackson@ucdavis.edu

Morphology ;and Pedologic Processes in Weathered Granitic Bedrock, Southern California. C.S. FRAZIER* AND R.C. GRAHAM, Univ. of California Riverside.
Joint fractures in granitic bedrock can facilitate the ingress of water, roots, and other weathering agents. This study was undertaken to characterize the morphology and select physical and chemical properties of weathered granitic bedrock in southern California, with an emphasis placed on describing and investigating the morphologies and pedalogic processes that occur along the periphery of joint fractures. Pedalogic processes acting inward form fracture margins have resulted in the formation of a lateral sequence of for morphologic zones within each weathered bedrock horizon; the matrix, fracture rind, fracture coating, and fracture fill. Micromorphological observations, pH, and distributions of pedogenic clay and Fe-oxides indicated that chemical weathering increases upwards in the weathered bedrock profile and laterally towards joint fracture margins. Localized hydration-induced shrink-swell activity of illuvial clay deposited within planar voids appears to be influential in mineral grain comminution and overall disruption of rock-controlled structure and fabric. When manifested on a larger scale, shrink-swell activity appears to cause a convergence of juxtaposed fracture walls and a concurrent reorganization of rock fabric along joint fracture margins. In general, shrink-swell processes appear to play a critical role in the transformation of bedrock to soil.

R.C. Graham, (909) 787-3711, graham@citrus.ucr.edu

Assessing the Fertility Status of Long-Term No-Tillage Cottyon Soils; In-Row versus Between-Row Sampling. D.D. Howard*, M.E. Essington, and D. D. Tayler, Univ. of Tennessee.
Information regarding nutrient stratification of long-term no-tillage (NT) crops is limited. This study was conducted to evaluate nutrient stratification relative to the planted row and soil depth on three soils having broadcast K applied for six years to NT cotton. Rows were planted within a few cm of the previous year's row. The selected soils were Memphis silt loam, Lexington silt loam and Loring silt loam. Potassium rates of j0, 28, 56, and 112 kg/ha broadcast annually. Experimental design was a RCB with five replications. Sub-samples were collected from the row *IR) and between rows (BR) to ta depth of 30 cm. Sub-samples was divided into 0-8, 8-15, and 15-30 cm depths. Soil pH and Mehlichj-I extractable P (EP) and K)EK) were evaluated. Solil pH varied between the IR and BR positions and among depths; however, variation was small to insignificant. EP{ varied with soil, sampling position and soil depth. Differences in EP due to sampling position would not affect soil test ratings; therefore sampling position would not affect fertilizer recommendations. EK was greater in the IR position than the RB position of the 0-8 cm sampling depth for the three soils. Sampling only the BR position may in some instances give a lower soil test value, resulting in a higher fertilizer recommendation. These differences varied with soil–applied K rates.

D.D. Howard, (901) 425-4748

Effect of Seeding Date on Male Sterility and Agronomic Traits of Rice Mutants. X. LEI* and D.J. MACKILL, Univ. of California, Davis and USDA-ARS.
Male sterility is an important trait for population improvement and hybrid seed production of rice (*Oryza sativa* L.). We studied the effect of seeding date on male sterility and agronomic traits in a collection of 72 rice mutants showing various degrees of sterility at Davis, CA. In 1997, the study included three seeding dates at 20-d intervals: April 27(A), May 16 (B), and June 5 (C). Male sterility increased, and plant height and tiller number decreased at seeding date C compared to A and B, and days to heading and total grain number decreased progressively from A to C. Most mutants performed poorly at seeding date C. Some sterile types appeared to show the characteristics of photoperiod-sensitive genetic male sterility (PGMS), which is useful for hybrid rice seed production. In one line, sterility was nearly 100% at dates A and B but decreased markedly at date C. These mutants are being evaluated further for their stability under sterility-inducing and fertility-inducing conditions.

David J Mackill 916 752-5966 djmackill@ucdavis.edu

Environmentally-Influenced Male Sterility in Rice. S. HAN* and D.J. MACKILL, Univ. of California, Davis and USDA-ARS.
Production of hybrid rice seed requires male sterility in the female parent. Male steriles influenced by environmental factors, such as photoperiod-sensitive genetic male sterility (PGMS), are easier to use than the conventional cytoplasmic male sterility systems. They do not require restorer genes and can be propagated by growing plants in fertility-inducing conditions. Useful PGMS rices are currently available only in China. In an attempt to isolate new PGMS mutants we collected 615 putative spontaneous male steriles from a farmer's field and transferred them to a greenhouse. In 1995, seed was collected on the putative steriles was planted in the field at Davis. Of 547 progeny rows, 140 were segregating for sterility and 116

were uniformly sterile, indicating that these mutants may not have been completely male sterile. Mutants which were confirmed to be sterile were evaluated under different daylengths in the greenhouse, growth chamber and in the field (long day at Davis, CA; short day in a winter nursery in Hawaii). Several mutants show PGMS behavior, and their stability is now being evaluated.

David J Mackill 916 752-5966 djmackill@ucdavis.edu

Seed yield of Easy Tripping Alfalfa Under Honey Bee Pollination. K.L. TAGGARD*, E.E. KNAPP, L.K. GIBBS, S.C. MUELLER, and L.R. TEUBER, Univ. of California, Davis and University of California Cooperative Extension, Fresno County.

California is a major alfalfa (*Medicago sativa* L.) seed producing state in the USA. Most pollination is by honey bees (*Apis mellifera* L.). Unfortunately, most honey bee visits are from bees foraging for nectar. These bees learn to avoid tripping the flower, and as a result pollination is notoriously inefficient. We previously demonstrated that outcrossing rate is not altered by selection for easy floret tripping. The objective of this research was to determine seed production on populations selected for easy floret tripping. Populations derived from 'CUF 101' by selection for easy floret tripping were evaluated along with the parental source at three California locations for three years. At all locations and across all years easy tripping populations produced 30 percent more ($P \leq 0.05$) seed than CUF 101. Selection for easy tripping florets is an effective indirect method of increasing alfalfa seed yield.

K.L. Taggard, (916) 752-9629, kltaggard@ucdavis.edu

Allocation of Test Locations and Years for Alfalfa Seed Yield Trials. L.R. TEUBER*, K.L. TAGGARD, L.K. GIBBS, AND S.C. MUELLER, Univ. of California, Davis and University of California Cooperative Extension, Fresno County.

Small plot trials to assess alfalfa)*Medicago sativa* L.) seed yield are associated with very high coefficients of variability and limited utility. We recently determined a small plot design that reduces the coefficient of variability from upwards of 50% to 15 to 20%. The objective of this study was to determine the optimum allocation of test environments for alfalfa seed yield trials. A randomly chosen set of nine nondormant cultivars and germplasm pools were grown at three California locations and harvested for three years. The study was replicated four times at each location. Plots were two rows wide (1.5 m) by 13.7 m long and planted with an alternate check cultivar to be used as a covariate. Differences ($P<0.01$) in seed yield existed among the entries and only the genotype x location interaction was significant ($P<0.01$). Optimum allocation of test environment was 4 replicates, 2 years, and 2 locations. Similar data quality can be obtained by substitution of locations for years.

L.R. Teuber, (916) 752-2461, lrteuber@ucdavis.edu

Screening Eucalyptus Clones for Salt Tolerance. C.M. GRIEVE*, M.C. SHANNON AND J.A. POSS, USDA-ARS, U.S. Salinity Laboratory, Riverside, CA.

Selection of trees that may be suitable for use in drainage water reuse systems requires screening candidate species under saline conditions. Four clones fo *Eucalyptus camaldulensis* (4543,4544,4573, and 4590) and one clone of *E. nudis* (4501 were transplanted into greenhouse sand cultures. Eight salinity treatments with 3 replications were imposed; targeted electrical conductivities of the irrigation waters (EC_i) were 2, 4, 8, 12, 16, 20, 24 and 28 dS/m. Solutions were prepared to simulate ion composition frequently present in the Na- and SO_4-dominated saline drainage waters of the San Joaquin Valley of California. Shoot extension and trunk diameter were measured weekly. Saplings were harvested after 7 weeks of treatment. Relative salt tolerance of the clones, based on shoot biomass production, was evaluated. Leaf-ion analyses for three treatments (EC_I = 2, 16 and 28 dS/m) showed that the clones differed significantly in ion uptake and partitioning within various levels of the canopy. Clonal differences in coppicing response to salinity were also observed.

C.M. Grieve (909) 369-4836, cgrieve@ussl.ars.usda.gov

Can Lengthening the Harvest Interval Improve Alfalfa Hay Quality During ther Summer. R.L. KALLENBACH* and D.W. CUDNEY, Univ. of California.

The intrusion of summer weeds into alfalfa (*Medicago sativa* L.) hay fields can affect forage quality as much as or more than crop maturity. Our objectives were to assess the impact of harvest interval on weed growth and hay quality in the Desert Southwest. There were three treatments: 28, 35 and 42 d between harvests. At each of three harvests we measured the % weeds and acid detergent fiber (ADF). Plots on a 28 d harvest interval contained 12% more weeds than plots on a 35 d harvest interval and 16% more than on a 42 d interval. Acid detergent fiber was 285 g per kg on a 35 d harvest interval which was 3 g per kg less than hay from a 28 d interval and 29g per kg less than a 42 d interval. We believe that the lower forage quality from the 28 d compared to the 35 d harvest interval is due to the greater percentage of weeds in the 28 d treatment. The higher ADF from hay on a 42 d harvest interval was because weed composition did decrease enough to offset the greater maturity of the alfalfa. Our data suggest a 35 d harvest interval maximizes hay quality b reducing weed competition while considering forage maturity.

R.L. Kallenbach 760 921-7884 cepaloverde@ucdavis.edu

Fatty Acid Analysis of Soil Microbial Communities A Comparison of Two Methods. K.J. GRAHAM* and K.M. SCOW, University of California, Davis.

Fatty acid analysis has proven to be a valuable tool for the study of soil microbial communities and offers many advantages over traditional microbiological techniques. Soil fatty acid methyl ester (SFAME) analysis quantifies all fatty acids present. Phospholipid fatty acid (PLFA) analysis uses only the polar fraction of the lipid extract. Both SFAME and PLFA were measured for soil samples form California's San Joaquin Valley. Data analyzed by several multivariate techniques showed similar classification patterns for the two methods. There were differences in the amounts and proportions of fatty acids extracted. Though a smaller sample size can be analyzed by SFAME than PLFA, many fatty acid peaks can not be reliably indentified by SFAME. Interpretation of microbial community structure and status based on PLFA profiles shows promise, whereas use of SFAME profiles for such purposes is less reliable.

Ken Graham 916 752-0146 kjgraham@ucdavis.edu

Modeling of Water Flow and Fertilizer Movement through the Root Zone to Minimize Leaching.

F. Somma, and J.W. Hopmans*, University of California, Davis, CA.

Growth of barley roots was simulated using two different nitrogen application scenarios, with the objective to study the influence of fertilization timing and rate on root growth and leaching losses to the ground water. Simulation were carried out using a recently developed three-dimensional transient modes for simultaneous, dynamic simulation of soil water movement, solute transport and plant root growth, which incorporates sink terms for water and nutrient uptake. The simulation model includes six different levels of complexity, depending on how much information is available, with the most comprehensive option including the simulation of root and shoot growth as influenced by soil water and nutrient availability, temperature and assimilate partitioning between root and shoot.

J.W. Hopmans, (916) 752-3060, jwhopmans@ucdavis.edu

Differences in Microbial Communities Due to Soiil Depth and C Inputs in California Agricultural Soils. E.J. LUNDQUIST*, S. UESUGI, K.J. GRAHAM, L.E. JACKSON and K.M. SCOW, Univ. of CA, Davis.

Soil microbial communities may be affected by agricultural practices, such as addition of organic materials, and by environmental conditions, such as frequency and degree of soil drying. We measured changes in microbial biomass C, dissolved organic C, respiration, and phospholipid ester-linked fatty acid (PLFA) profiles following re-wetting of air-dry soil. We compared soils from three farming systems receiving different levels of organic inputs, and from two depths; 0-3 cm, which dries severely between irrigations, and 3-15 cm which experiences smaller fluctuations in soil moisture. Microbial biomass C increased more following soil re-wetting, and respiration kinetics indicated increasing C availability in farming system soils which had received higher organic inputs. PLFA profiles differed between farming system soils or soil depths. The response of MBC, respiration, and PLFA composition following soil re-wetting suggested greater adaptation to soil wet/dry cycles in the surface than deeper layer.

Erica J. Lundquist 916 752-0146 ejlundquist@ucdavis.edu

GIS-BASED ANALISES OF SOIL QUALITY PARAMETERS FROM A WETLAND/CROPLAND ROTATION SYSTEM. 1F. COSTA, 2C. BODE, 3W. JARREL, and 1C. SHENNAN. 1Univ. of California-Santa Cruz, 2Univ. of California-Berkeley and 3Oregon Graduate Institute.

Soil quality parameters have been postulated to be highly affected by spatial distribution and temporal events. The integration of geostatistics and geographical information systems (GIS) was used to investigate the spatial variability of basic soil properties and soil quality parameters from one pilot site in a wetland/cropland rotation study. The contour line maps are good for initial visual assessment of the data sets. Normalized addition analysis is useful for non-threshold indices, but poor for showing the relationships between parameters. Overlay analysis is excellent for characterizing parameter relationships. Overlay analysis showed that the microbial activity parameter was not affected by the total C and N pools.

Francisco Costa (408) 469-9523 costa@vegmail.ucdavis.edu